ETMobile

Instruction Manual

MANUAL VERSION 1.5

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1 Introduction and General System Description

The *ETMobile* (ETM) is designed specifically for applications in which lightweight, completely un-tethered eye gaze tracking is required. The spectacle mounted unit (SMU), which includes an eye and scene camera mounted to a safety glasses style assembly, and the small display/transmit unit (DTU) are the only components required for recording in the field. An additional computer (ETM PC) is necessary for processing the camera data to compute gaze and for data analysis, but is not essential for the data collection processes.

The eye camera records the eye being tracked while the scene camera records the environment being observed by the user. The eye camera views the reflection of eye from a hot mirror (reflective in the near IR spectrum, but transparent in the visible spectrum) so that nothing need obscure any of the subject's normal field of view. The scene camera is aimed directly forward.

The eye and scene camera video can be simultaneously recorded on an SD card, by the small DTU, or transmitted directly to the ETM PC via LAN cable or WLAN (wireless) connection, or both. Eye and scene data are updated at either 30 Hz or 60 Hz. The ETM PC, running an application called ETMobile, processes the eye and scene camera video to compute point of gaze on the scene image, 30 or 60 times/sec. It can do this in real time if connected to the DTU by LAN cable or WLAN, or can do the same processing off-line from data recorded on an SD card by the DTU.

The ETM PC displays point of gaze as a cursor, superimposed on the scene image, records that image as a 30 Hz or 60 Hz video "avi" file, and can also record a digital "csv" file containing a record of pupil diameter and gaze coordinates with respect to the scene camera field of view.

The *ETMobile* program can be installed on multiple PCs (that meet the minimum required specifications) but can only be run if a hardware license dongle is connected to a USB port.

The *ETMobile* system is designed to be durable under a variety of active applications including vehicle operation and athletics. However, the components should not be handled harshly outside of normal use.

There are no user serviceable parts within any components. Opening any unit may void the warranty.

The most recent ETM systems are shipped with Windows 10 installed on the ETMobile PC and are configured to use a wireless connection called Wi-Fi Direct for point-to-point communication between the PC and DTU. Older systems were shipped with PCs running Windows 7 and used a connection type called Ad Hoc for point-to-point wireless communication between the PC and DTU. For some tasks described in this manual there are small differences in required settings depending on which type of wireless point-to-point communication is configured. In these cases the manual gives separate instructions for "Win 10" and "Win 7" systems. There may be some systems that were shipped as "Win 7 systems" and were later upgraded to "Win 10", and which are still configured for "Ad Hoc" wireless connection. In these cases the "Win 7 system" instruction for "Ad Hoc" communication settings should be followed. See section 11.9, or consult Argus Science if unsure which connection type is being used by a particular system.

2 Environmental and Safety Considerations

2.1 Statement on Safety Levels of Infrared Illumination

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

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 ETMobile Optics Modules operate at least an order of magnitude below this level. The power of the LED's used varies somewhat from sample to sample. The largest irradiance value that will be produced with the Argus ETMobile Optics is 0.50 - 0.60 mW/cm² (@ 880nm Wavelength), at the plane of the eye.

The ETMobile uses non-coherent illumination. There are no lasers in the system

2.2 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 ETMobile 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

ETMobile Spectacle Mounted Unit (SMU)-- including eye camera, scene camera, and adjustable hot mirror, mounted on safety glasses style assembly.

Display/Transmit Unit (DTU)

ETMobile PC (ETM PC). (shown with DTU)

CAT 5 cable (for connecting ETM PC and DTU).

DTU Battery

DTU power supply.
This power supply is only for connection to the DTU. <u>DO NOT</u> CONNECT THIS POWER SUPPLY TO THE BATTERY CHARGER.

DTU battery charger, and battery charger power supply.
This power supply is only for connection to the battery charger. <u>DO NOT</u> CONNECT THIS POWER SUPPLY TO THE DTU.

Software License Dongle – This USB Hardware key allows the ETMobile software to be installed and run on multiple computers. The dongle key must be connected to run the ETMobile program.

SD card.

DTU carrying case. The DTU fits inside the DTU carrying case which can then be worn either as a backpack, or can be fastened to the subject's belt.

ETMobile system carrying case.

The lower photo shows foam cutouts for the head gear, DTU, charger unit, power supplies and batteries. The case includes a separate zipper compartment for the laptop PC.

DTU Stand

An optional Stand Adapter has been supplied with your ETMobile system that can be used as either a desktop stand or may be utilized to hold the SMU Optics set when creating an Environment Map in Gazemap. Instructions for installing the DTU Stand can be found in Section 11.5 Appendix E.

4 Interconnections

ETMobile PC
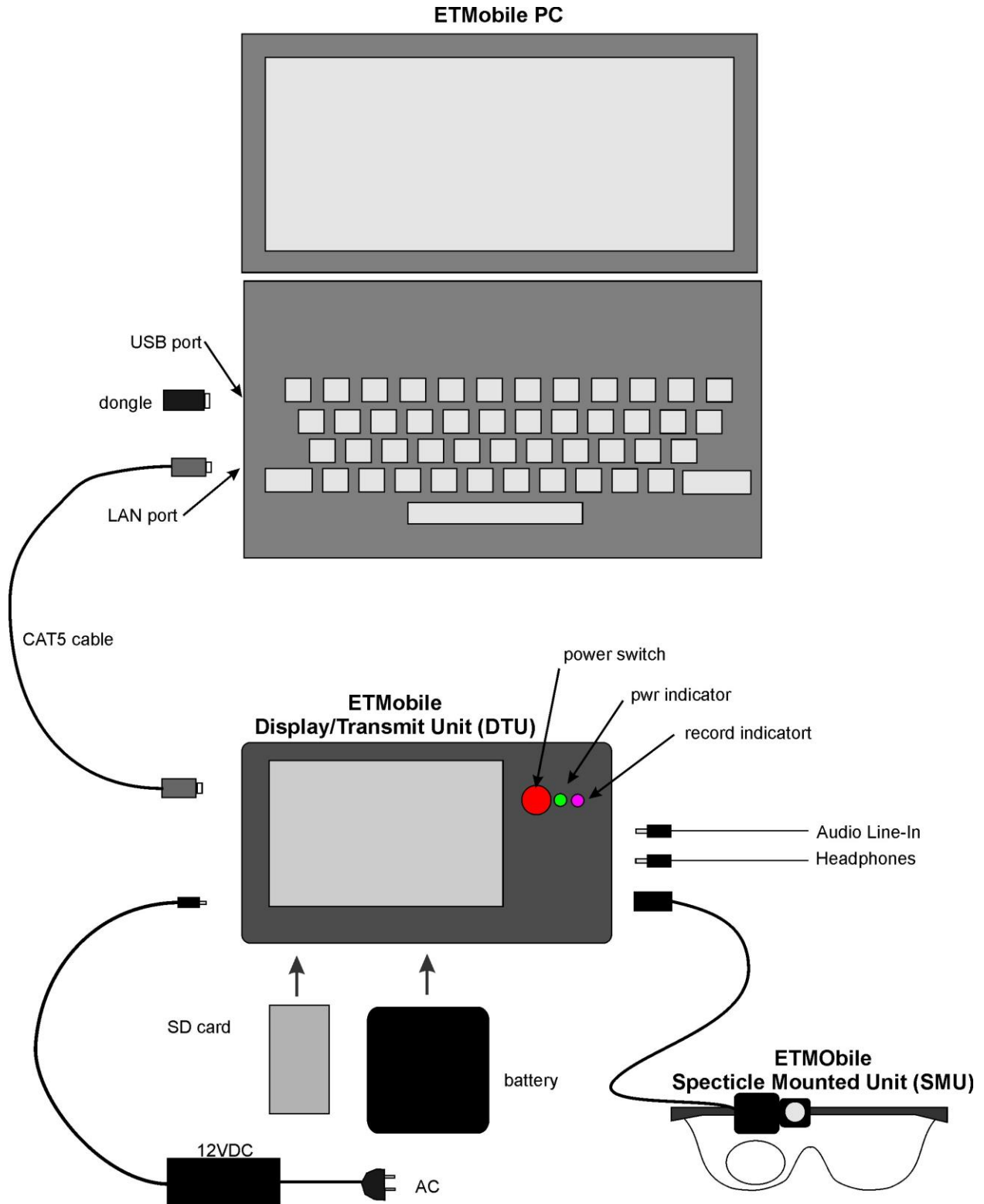
5 Eye Tracking Basics

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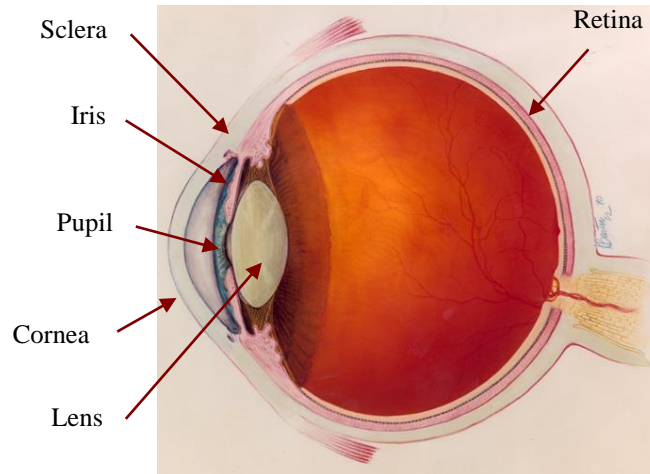
The *sclera* is the white part of the eye.

The MobileEye 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.

A set of three harmless near infra-red (IR) lights is projected on the eye by a set of LEDs in the SMU. The near IR light is not visible to the user so it does not cause a distraction, however it is visible to the eye camera on the SMU. The mirror reflection of these three lights from the front surface of the cornea appears in the camera image as a triangle of three dots, at a fixed distance from each other, called the *Spot Cluster*.
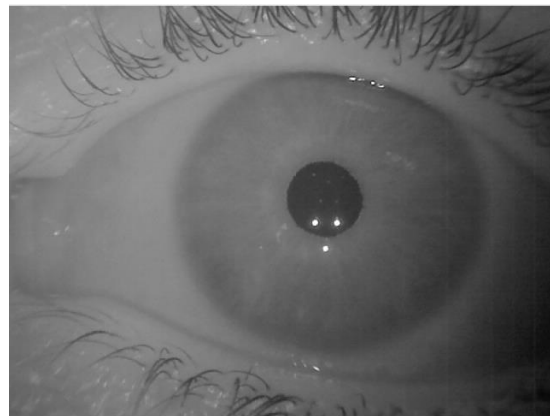
When the eye rotates in its socket, the center of the pupil moves relative to the spot cluster. By comparing the vector (angle and distance) between the pupil and one of the CRs in the spot cluster, the eye tracking system can compute the pointing direction of the eye.

By teaching the system how these angles relate to an image on a second camera that is viewing the environment, the Scene Camera, the eye tracker can compute point of gaze with respect to the scene camera field of view.

6 Display/Transmit Unit (DTU) operation

6.1 ETMobile DTU (Display Transmit Unit) power up

Be sure the ETMobile DTU (Display Transmit Unit) is loaded with a charged battery or connected to an AC source with the 13.5 VDC power supply; and be sure that the ETMobile optics unit is connected.

Press the power switch. After boot-up, the startup screen should appear almost immediately.

- After several seconds, the start up screen in the display area will be replaced with the image from either the eye or scene camera on the ETM optics unit. The Eye/Scene button can be used to switch the display between eye or scene image.
- The data field located to the right of the word "Subject" is used when recording .avm files on the SD card of the DTU. A QWERTY keyboard will pop up when you touch the field area and you can type the name of the subject in that space.
- The "Wireless Indicator" and the "Network Cable Connection Indicator" are located in the bottom left corner of the display. When the DTU is connected to a WLAN connection the lines around the "Wireless Indicator" light up green. When the DTU is connected to a LAN connection, the "Network Cable Connection Indicator" lights up blue.
- Directly to the right of the internet indicator icons are icons that indicate power adapter presence, battery life, and SD card memory usage. When using the AC power supply adapter, the icon shaped like the adapter plug lights up. If using a DTU battery, the icon shaped like a battery will light up and indicate the battery life that remains. If there is no battery being used

in the DTU, the battery icon is filled with a red exclamation point. Directly below the battery icon is an icon shaped like an SD card. If an SD card is present, this icon will indicate the amount of space available on the card.

- The touch screen is used for direct Interaction with the DTU. To use the touch screen press a finger firmly against a button.
- When the DTU is in "live" mode (red dot on the Live/Playback mode button), the Eye/Scene button can be used to switch the display between the eye and scene image.
- To shut down the unit, hold down the red power switch button for 4 seconds.

6.2 ETMobile DTU screens

All screens appear with a row of 5 buttons along the right side, information icons at the lower left, and either camera images or special controls in the central area.

6.2.1 Eye and Scene image screen

Touch the Eye/Scene display button to switch the display between eye and scene images.

6.2.2 Playback screen

Touch the "playback" button (right arrow on the "live/playback" button) to enter play back mode. The camera image will be replaced with a place holder screen and the "file" button will appear in place of the "record" button.

Touch the record button to begin recording an .avm file. When the record button is selected, the file icon will change to a black square. Touch the black square to stop the recording. See section 11.6 for .avm naming conventions and instructions.

Assuming the SD card is inserted, touching the file button will bring up a file list of previously recorded data files. In order to play a desired file, touch the file to select it, and touch the play icon, located in the upper left hand side of the screen, to play it. The red "X" in the upper left hand side deletes the selected file. Touch the black X at the top right hand side of the screen to close the file window. Then, touch the "live" button (the red dot on the "live/playback" button) to return to the camera view.

If the number of files on the SD card exceeds the display space, navigate up/down the list of files with the up/down arrows located in the middle of the top row of icons on the display pictured below.
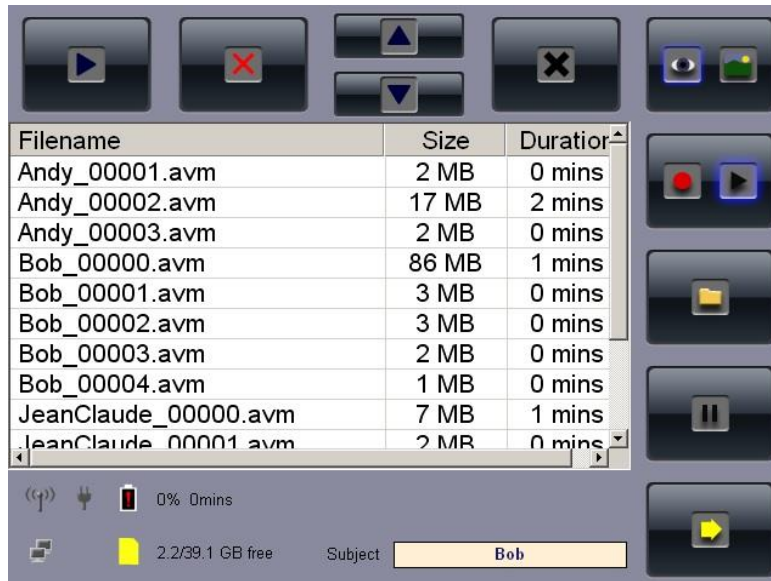
6.2.3 Switch Screen mode and DTU Settings display

Touching the "switch screen" button (bottom, yellow arrow button on the right) causes the column of buttons to change to the icons shown below. The second button from the top changes to a "wrench" icon and the fourth button from the top changes to a "Lock" symbol. The third button from the top is used to bring up additional playback controls. Touching the new "switch screen" button (button with yellow curved arrow symbol at bottom right) returns to the main screen.

Touching the Lock button will cause the DTU to enter "lock mode". The screen will go blank and no settings or modes can be changed without first exiting "lock mode". To exit "lock mode" drag one finger on the screen from bottom left to top right and the "unlock" screen will appear. On this screen press the "unlock" button to unlock the device or the "lock" button to keep the device locked. Not pressing either button will cause the screen to remain locked.

The "double-arrow" button (third from the top) will cause playback options to be enabled when in playback mode. Thus, allowing playback control when playing a file on the device.

Touching the "wrench" icon button will bring up the "DTU settings" screen.
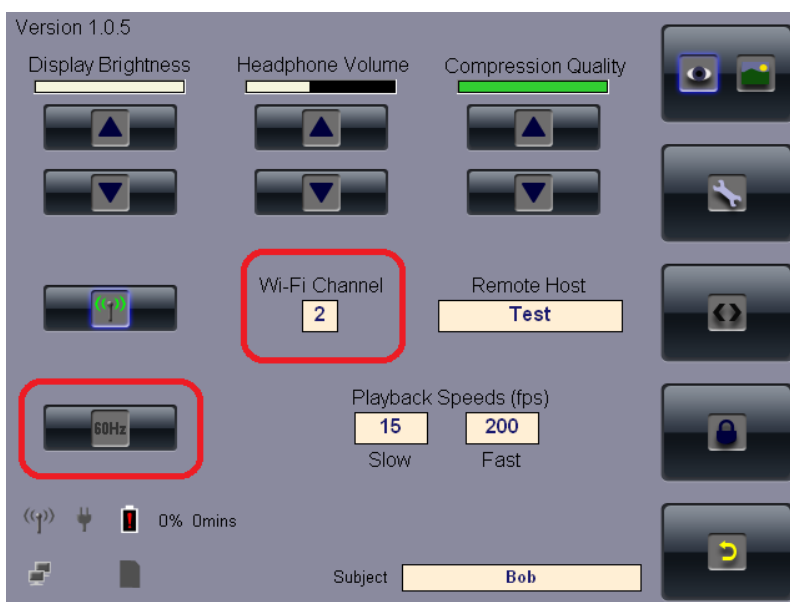
Note that in the case of "Win 10 systems" (ETM systems shipped with Windows 10 on the ETM PC), the "Wi-Fi Channel" item, shown in the screen shot above, is not needed and will <u>not</u> appear on the "DTU settings" screen. The "Wi-Fi Channel" item will appear only on "Win 7 systems".

6.2.3.1 Display Brightness

Touch the arrow buttons under the "Display Brightness" bar to adjust the brightness of the display screen.

6.2.3.2 Wi-Fi

The button with Wi-Fi symbol, near the center left, shows green emission lines when the DTU wireless card is ON. The symbol on the button is all gray when the Wi-Fi card is turned off. Touching this Wi-Fi button toggles the DTU Wi-Fi capability on and off.

Note that Wi-Fi communication may not be active even when the Wi-Fi capability is on. The Wi-Fi symbol that is at the bottom left of all DTU screens shows green when Wi-Fi communication is active between DTU and the *ETMobile*.

Win 7 Systems only:

> The Configuration dialog also allows selection of a Wi-Fi Channel. The default will be Channel 1; however, if multiple systems are to be operated within the same operation environment using Wi-Fi, then each individual DTU should be set to a different Wi-Fi Channel. Available Channels are 1 through 11.

> **Suggested Use:**
> One System: Channel 1
> Two Systems: Cannel 1 and Channel 11
> Three Systems: Channel 1, 6 and 11

> Contact Argus for information about configuring more than three systems.

Win 10 systems only:

> Wi-Fi channel selection is not necessary even when multiple systems operate in near proximity. It is only necessary that the "Remote Host" name match the *ETMobile* Computer name.

6.2.3.3 Compression Quality

The "Compression Quality" bar sets the recorded image quality and .avm file size. Reducing compression quality will reduce file size but will also reduce image quality. If very long recordings are required, compression quality may be reduced to reduce the file size. The default setting is maximum compression quality. The user may also adjust the head phone volume on this screen. The headphone volume can be set for the output volume of the headphone jack of the DTU. This will not affect the volume of the recorded .avm file.

6.2.3.4 Remote Host

The "Remote Host" name shown on the DTU Settings screen and the *ETMobile* Computer name MUST be identical for TCP/IP communication (LAN and WLAN). The convention is that this name is the same as the serial number found on back of DTU. This is normally factory set on both the DTU and *ETMobile* PC, and should not be adjusted. If the name on the DTU Settings screen does need to be modified, touch the "Remote Host" box to bring up keypad display. Type in a name, and touch the <Enter> key to clear the keypad display.

6.2.3.5 Real Time update rate

Real time recording speed can be set to either 60 or 30 Hz. The "60Hz" icon will be highlighted in green when configured for 60 Hz, while a "grayed" out "60Hz" icon will indicate that the system is running at 30Hz. Touching this Icon will toggle between the two modes. NOTE: You cannot change the update rate if in DTU Record mode (recording to SD Card). First stop recording, change the update rate, and then begin a new recording.

6.2.3.6 Playback Speeds

Playback Speed is configurable ("real-time" speed is either 60 or 30). Touching one of the playback speed boxes brings up a keypad display, but only numbers are available for input.

6.2.3.7 Subject

The subject field appears on all screens and its use is described in section 11.6.

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7 Typical Operation Sequences

7.1 Record eye & scene image on DTU for later playback to ETM laptop

- Be sure DTU battery is charged and installed in the unit.
- Be sure SD card is installed in DTU.
- Connect ETM optics to DTU.
- If necessary for the sake of mobility, disconnect the CAT5 cable connection between the DTU and ETM PC.
- Power up DTU and wait for main screen.
- Enter the subject name into the "Subject Field." See Appendix H for instruction if necessary.
- If necessary, touch the "live" icon (red dot on the "live/playback" button) to display a camera image.
- Use eye/scene display button to display the eye camera image.
- Adjust the eye camera and monocle to obtain a proper eye image (see "Adjusting ETMobile Optics").
- Use eye/scene display button to display the scene camera image.
- Adjust the scene camera to obtain the desired scene image (see "Adjusting ETMobile Optics").
- Touch the record button (button with large red dot) to begin recording an eye and scene image file. Upon recording, the record button icon will change to a stop icon (black square).
- Toggle the display to show the scene image, and have the subject look at several points which span the scene camera field of view, are easily identified in the scene image, and can be used for calibration during playback (see "Scene Calibration").
- Switch to lock mode. This is optional, but strongly suggested in order to minimize power usage and maximize the time that the battery charge will last.
- Have the subject begin the experiment task.
- When the run is complete, exit lock mode (run finger from bottom left to top right of touch screen), and touch the stop button (black square) to end the recording.

7.2 Playback pre-recorded eye & scene video to ETM PC for gaze computation

- Connect the DTU to the ETM PC using the CAT5 cable (see interconnection diagram); or set the ETM PC for Wi-Fi operation (Enable the wireless function on the ETM PC, usually slider switch at front of laptop case, and be sure that the wireless N adapter is plugged into a USB port on the ETM PC.) Also be sure the ETM dongle is inserted in a USB port on the ETM PC.
- Run the *ETMobile* program, on the ETM PC.
- If using Wi-Fi, use the "switch screens" button if necessary to get the wrench icon. Touch the wrench icon button on the *ETMobile* DTU screen to bring up the "DTU settings" screen, and

enable Wi-Fi on the DTU (see section 6.2.3). After several seconds, the wireless indicator, near the bottom left of the DTU screen, should show green.

- If using the cable (CAT5) network connection, the network cable connection indicator, near the bottom left of the DTU screen, should show blue.
- Use the "switch screens" button, and if necessary, the "playback" icon on the "live/playback" mode button, to display the "file" icon button. Touch the file icon to bring up the "File" display screen. Select the desired file by touching the file name, and touch the "play" button, located on the upper left of the screen, to begin playing the video file. The Eye and Scene video images should appear on the ETMobile program just as they do when ETMobile is receiving live video.
- Be sure the *ETMobile* program, on the ETM PC, is set to "Live Mode" (button at bottom left of *ETMobile* screen toggles between Live and Playback modes). The ETM PC will "think" it is getting live data from the DTU. Use the *ETMobile* program to properly recognize the corneal reflections and the pupil, and, using the section of the video during which the subject was looking at known points on the scene image, perform the *ETMobile* program calibration procedure. (See sections 9.4.4, through 9.4.7).
- Unlike truly live video, feel free to use the DTU screen pause button (second button from the bottom, on the right column of buttons) to pause the eye and scene video at any time. It will probably be most convenient to pause while adjusting CR and pupil parameters on *ETMobile*, and while clicking on scene points during the calibration procedure. Touch the pause button a second time to resume playing. If needed, use the "double-arrow" button to display rewind and fast forward controls.
- To return to the beginning of the video, either use the rewind control, or touch the "file" button to bring back the file selection screen, reselect the file name, and touch the play button.
- If desired, record digital and video gaze data on the *ETMobile* program (see "Data Collection").

7.3 Copy recorded eye & scene video files to ETM PC

There are two ways to copy recorded video files into the ETM PC. One option, and possibly the easiest way, is to insert the SD card directly into the computer via an SD card slot. Access the contents of the SD card via the *ETMobile* software by setting the *ETMobile* program to "Playback Mode" (button at top right of *ETMobile* screen toggles between Live and Playback modes) and selecting the file you wish to copy from the dialog opened with the "Load" button at bottom right .
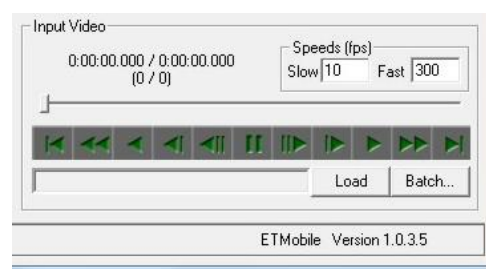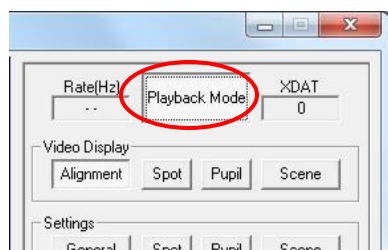
Files can also be copied directly from the SD card as you would with any removable storage system.

Yet another option is to record the eye and scene video files directly on the ETM PC using the *ETMobile* program. Connect the DTU to the ETM PC, via Wi-Fi or CAT5 cable, run the *ETMobile*

program in "Live Mode", and view the eye/scene display on the ETM PC. Then, digital and video gaze data can be recorded directly. The following two sections describe the required steps.

7.4 Real time gaze computation with a cable connection between DTU unit and ETM PC

- Connect the DTU to the ETM PC using the CAT5 cable (see interconnection diagram). If necessary, touch the "live" icon on the "Live/Playback" button to set the DTU to live mode. The live eye or scene video should appear on the DTU's screen. The network cable connection indicator, near the bottom left of the DTU screen, should show blue.
- Be sure the Argus dongle is inserted in a USB port on the ETM PC, and run the *ETMobile* program on the ETM PC. Be sure the *ETMobile* program is also set to "Live Mode" (button at top right of *ETMobile* screen toggles between Live and Playback modes).

- Use the *ETMobile* program to properly recognize the corneal reflections and the pupil, and to calibrate the subject. (See sections 9.4.4, through 9.4.7).
- If desired, record digital and video gaze data on the *ETMobile* program (see section 9.4.12).

7.5 Real time gaze computation with Wi-Fi connection between DTU unit and ETM PC

- Be sure that wireless function is enabled on the ETM PC (usually slider switch at front of laptop case), and be sure that the wireless N adapter is plugged into a USB port on the ETM PC. Also, be sure the ETM dongle is inserted in a USB port on the ETMobile PC, and that the *ETMobile* program is running on the *ETMobile* PC.
- On the DTU, use the "switch screens" button if necessary to get the wrench icon, touch the wrench icon button on the DTU's screen to bring up the "settings" screen, and enable Wi-Fi on the DTU (see section 6.2.3). After several seconds, the wireless indicator, near the bottom left of the DTU screen, should show green.
- Touch the "switch screens" button (bottom right), and if necessary touch the "live" icon on the "live/playback" button to put the DTU in live video mode. Be sure the *ETMobile* program is also set to "Live Mode" (button at bottom left of *ETMobile* screen toggles between Live and Playback modes).
- Use the Eye Video program to properly recognize the corneal reflections, and the pupil, and to calibrate the subject. (See sections 9.4.4, through 9.4.7).
- If desired, record digital and video gaze data on the *ETMobile* program (see section 9.4.12).

- It is recommended that a test subject be used first to establish the wireless range. The Compression Quality will automatically adjust depending on the subject's distance and the Wi-Fi signal in order to allow the subject to reach a farther range without loosing connection to the ETM PC. Thus, when the subject begins to go out of range, the video image on the ETM PC will begin to loose resolution, and will freeze when completely out of range. When the subject returns to a position within range, the live signal will resume; but sometimes this may not happen immediately.

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8 Adjusting ETMobile Optics

Fit to the user
- Put the Spectacles on the user. Adjust the tension of the headband so that the Spectacles are stable and comfortable.

    o A loose fit will allow Spectacle movements that will degrade tracking accuracy and precision.

    o A fit that is too tight will lead to user discomfort and fatigue.

    o View the eye and scene image on the DTU screen or on the ETMobile Program screen if the DTU is connected to the ETM PC.

Adjust the scene Image
- Adjust the pitch of the Scene Camera mount to suit the task.

    o For many tasks, having the Scene Camera centered on the user's midline point of view (eyes looking straight ahead) is appropriate.

    o However, for tasks in which peripheral activity is common, a skewed Scene Camera angle may be desirable.

- Check the focus of the scene image. If necessary, slacken the clamp screw, rotate the scene lens to get sharpest focus possible and retighten the clamp screw gently. Do not over-tighten

Align the eye image on the monitor
- Slide the SMU along the mounting frame until the eye camera is directly above the eye.

- Pitch the Monocle gently to move the eye vertically in the image until the eye image is centered vertically. You can also slightly adjust the pitch adjustment of the camera mount.

- Twist the monocle gently to move the eye horizontally until the eye is reasonably central in the image.
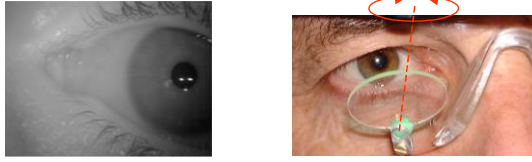
- Rock the monocle until all three reflex spots are visible. Ask the user to make some large eye movements to check that the pupil and spots stay within the image.
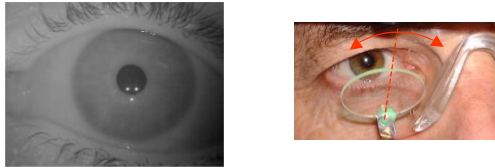
- Check the focus of the eye image. If necessary, rotate the eye camera lens to get sharpest focus on the pupil and spots.

9 ETMobile Data Processing Software

9.1 ETMobile program Overview

ETMobile software comes preinstalled on the Control Computer (ETM PC). It is located in the directory "C:\Program Files (x86)\ArgusScience\ ETMobile\ETMobile.exe"

Shortcuts to this program can be found on the Windows Desktop or under the *Start Menu* in the "All Programs->ArgusScience->ETMobile" folder.

9.2 ETMobile File Types

5 File Types

- **User Profile** (*.evi*) - System and calibration data for each user. These files save a specific calibration for possible future use, as well as eye feature detection settings, and current data (eyd) and video (avi) file names.
- **Data Files** (*.eyd*) - Eye and scene data generated by the Track Record tool in *ETMobile*.
- **Eye and Scene Video data** (.avm) – Original eye and scene video data recorded by the DTU on an SD card.
- **Video File** (.avi) - Video and audio recording with point of gaze, generated by the Video Record tool in *ETMobile*.
- **Configuration** (.xml) - Network comm configuration settings; and optional Head Tracker, and *ET3Space* configuration settings. (*ET3Space* and Head Tracker option described in separate *ET3Space* manual).

Default User File (Profile)

The directory *C:\Users\Public\Documents\ArgusScience \ETMobile* contains a start-up user file, *default.evi*, which contains a default set of system and calibration data. During operation, a unique user file (Profile) can be created for any subject and saved as an .evi file.

Data File

ETMobile automatically generates data filenames based on the user filename (assigned by the experimenter to the .evi file) by appending a 5-digit number. Thus the first data file for a user file *Subject1.evi* would be *Subject1_00000.eyd*, the second would be *Subject1_00001.eyd*, etc. Data files are never overwritten by the system, so if *ETMobile* finds data files for the *.evi file* already existing in the directory, it creates a file with the next sequential number.

In order to delete .eyd files, the user must delete the file within the Microsoft Windows environment.

Video File   *ETMobile* automatically generates video file names based on the user filename by appending a 5-digit number (in conjunction with the .csv data file). Thus the first logged data file for a user file *Subject1.evi* would be *Subject1_00000.avi*, the second would be *Subject1_00001.avi*, etc. Similarly to Data Files, Video files are never overwritten. Therefore, if *ETMobile* finds video files for the *.evi* file already existing in the directory, it creates a file with the next free number.

9.3 ETMobile User Interface Layout
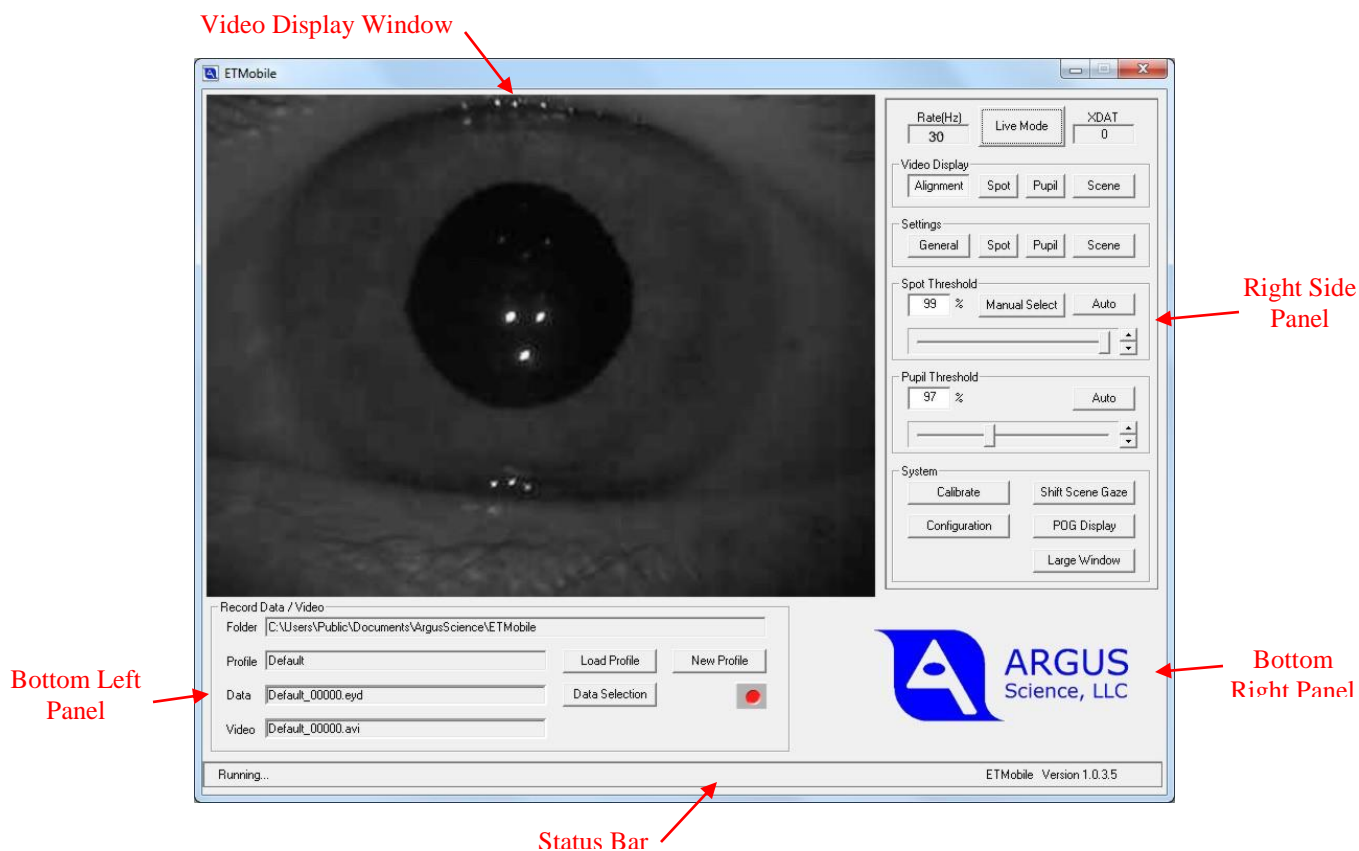
The *ETMobile* program main window has five main components: Video Display Window, Bottom Left Panel, Bottom Right Panel, Right Side Panel, Status Bar.

Video Display Window		This component takes up the majority of the screen space on the ETMobile application. It shows either the eye or scene video image being received from the DTU, or the playback image from a video file being played from the computer.

The actual contents are selected via the other panels in the interface. |
Bottom Left Panel	**Subject Profile**	Create, Load, and Save user profile and calibration Data in ".evi" files as described in Section 9.4.2
	Video Recording	Create a digital recording of a session directly on the Control Computer.
Bottom Right Panel	**Video Playback**	When in "Playback" mode (mode controlled by "Live Mode"/"Playback Mode" button at top right of screen), Argus Logo at bottom right is replaced by video playback controls.
Right Side Panel	**Rate; XDAT; Mode**	Rate and XDAT are displays of current system update rate and current external data value being received. The Mode switch toggles between "Live Mode" and "Playback Mode".
	Video Display	The "Video Display" buttons are used to select the type of image being displayed in the Recorder Image Window. Only one can be selected at a time, under Video Display.
	Alignment	Shows only the eye camera image.
	Spot	Shows the eye image with the spot overlay box.
	Pupil	Shows the eye image with the pupil overlay box.
	Scene	Shows only the Scene frames of the interleaved video feed.
	Settings	Each button opens a dialog for setting parameters related to Spot or Pupil recognition, Scene image appearance, or General system functions
	Spot Threshold	Adjust the threshold setting for recognition of the 3 corneal reflections ("Spots"), and select the spot that will be the "primary" corneal reflection used for gaze computations.
	Pupil Threshold	Adjust the threshold setting for recognition of pupil

System		Buttons to launch the subject calibration procedure ("Calibrate"); add a manual offset to the gaze position computation ("Shift Scene Gaze");
	Calibrate	Launch subject calibration procedure
	Shift Scene Gaze	Add a manual offset to the gaze position computation
	Configuration	Bring up a System Configuration dialog
	POG Display	Open a *Data Display Screen* window to display digital data and plot gaze on a blank background. (Note that this is in addition to the *Video Display Window*, which shows eye or scene video images.)
	Large Window	Show the *Video Display Window* contents in a separate large window.
Status Bar		The Status Bar at the bottom of the window gives information about the current status of the program as well as the version number being used.

9.4 Program Use

A session with the *ETMobile* program usually involves some or all of the following procedures:

- Start *ETMobile*
- Establish the user profile and data file name
- Position the eye image
- Adjust the spot (CR) detection
- Adjust the pupil detection
- Calibrate subject
- View / Record data
- Playback recorded data

The system may also be set up to send and/or receive data from external devices. The following subsections include instructions for these functions and descriptions of the various displays available for monitoring system performance.

9.4.1 Starting ETMobile

Make sure that the License Dongle is connected to the computer. If the ETMobile PC will be receiving live data from the DTU (as described in section 7.2, 7.4, or 7.5) be sure that the DTU is powered up and is either connected to the ETM PC with a network cable, or set for WiFi communication.

Select the *ETMobile* program icon, on the Control Computer desktop, to open the *ETMobile* program with the Video Display Window and other panels previously described.

If the *ETMobile* application will be receiving live data from the DTU (as opposed to playing back an avm data file), be sure the "LiveMode"/"PlaybackMode" button, at the top right of the *ETMobile* window, is set to "Live Mode". Note that the "Rate" box, to the left of the "Live Mode" button shows the update rate (either 30 Hz or 60Hz) that has been set on the DTU (see section 6.2.3.5).

Use of the *ETMobile* program to playback avm video files does not require connection to the DTU and is described in Section 9.4.15 .
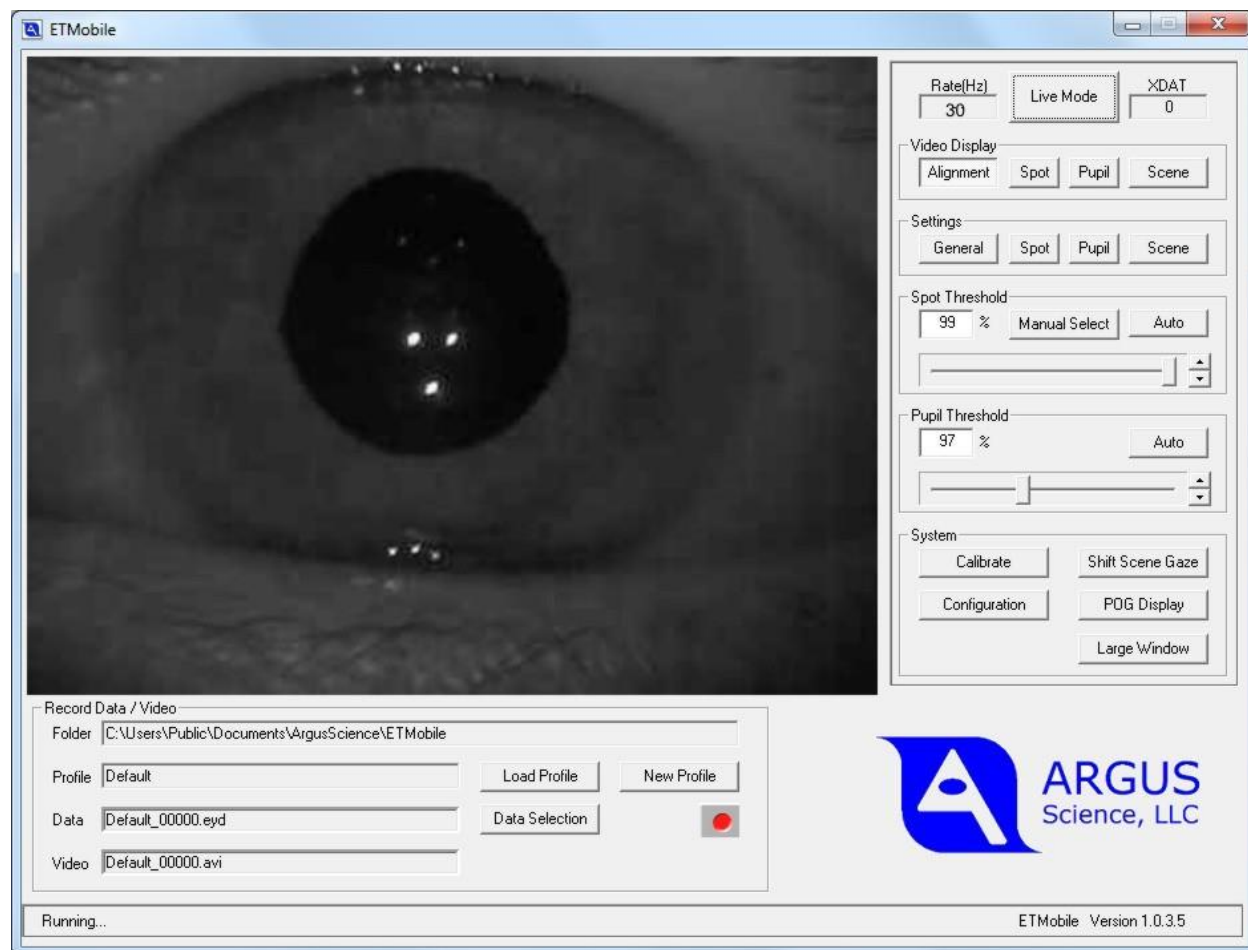
9.4.2 User Profiles and file names

The user "Profile" is stored in a file with a ".evi" extension containing a data and video file name information, feature recognition parameters, and calibration information. Whenever a change is made to any of these items, the .evi file is automatically saved with the new information.

Data (.eyd or .ehd) and video (.avi) file names always consist of the profile name with a 5 digit integer suffix. When a new Profile is created, the suffix starts at 00000. The *ETMobile* screen always shows the files that will be opened and recorded when the user clicks the record button. Everytime data recording is paused, the data and video files are closed, the integer suffix is incremented, and new data

and video files names are displayed with the profile name and new suffix. The evi file is also automatically saved with the new suffix information.

When *ETMobile* is started, it loads the most recent Subject Profile used. If this is the first time running *ETMobile*, it will create a file called "default.evi".

To create a new User Profile, press the "New Profile" button. A *Save As* dialog will appear. Choose a directory (folder) and type in a file name in the usual way. When "Save" is clicked on the dialog, a new evi file will be saved with the specified name, a 00000 suffix, and current Calibration and feature recognition parameters. Data and video file names will be displayed with the newly specified Profile name and 00000 suffix. Calibration and feature recognition parameters remain unchanged, until explicitly changed by the user, in which case the evi file is automatically saved with the modified parameters.

To load a previously saved Profile, click the "Load Profile" button. An *Open* dialog will appear. Browse to the previously saved evi file, and click "Open". The specified evi file will be loaded and data files names will be displayed with the profile name and current suffix specified on the evi file.

When Launching *ETMobile,* if the previously used Subject Profile name or path is not found, the program will set all parameters to "Default" values and will create a new "default.evi" file.

9.4.3 Position the Eye Image

If the *ETMobile* DTU is connected to the *ETMobile* PC during the participant set-up procedure (either with the LAN cable or wireless connection), the *ETMobile* display can be used to position the eye image. Furthermore, the system can be calibrated prior to the task to ensure a good calibration before any activity is started. The resulting calibration will be saved in the user (.evi) file as described in Section 9.4.2.

Be sure the *ETMobile* program is set to "Live Mode" (button at top right of *ETMobile* screen toggles between "Live" and "Playback" modes). Select the "Alignment" button, under the "Video Display" heading, at the top right of the *ETMobile* screen. The display should show the eye image. Have the subject look "straight ahead", and position the image within the *Video Display Window* as described in section 8 ("Align the eye image on the monitor"). Note the black pupil disk, and the three bright corneal reflection (CR) spots. It is important that all three CR spots be visible and either within, or close to the pupil image.

All subsequent steps require that the image of the Eye be reasonably centered in the Display Window.

If the DTU is connected to the *ETMobile* PC, and the *ETMobile* program is being used in real time, have the subject look "straight ahead". If playing a video file play a section (preferably at the beginning of the file) during which the subject was looking "straight ahead".

9.4.4 Check Spot Settings

Click the **Spot** button, under the **Settings** group label to bring up the *Spot Settings* dialog. For best performance under normal conditions, verify that the "Spot Area Limits" are set to 10 and 250. Verify that Spot Search Window is set to Left=50, Top=50, Right=590, and Bottom=430.
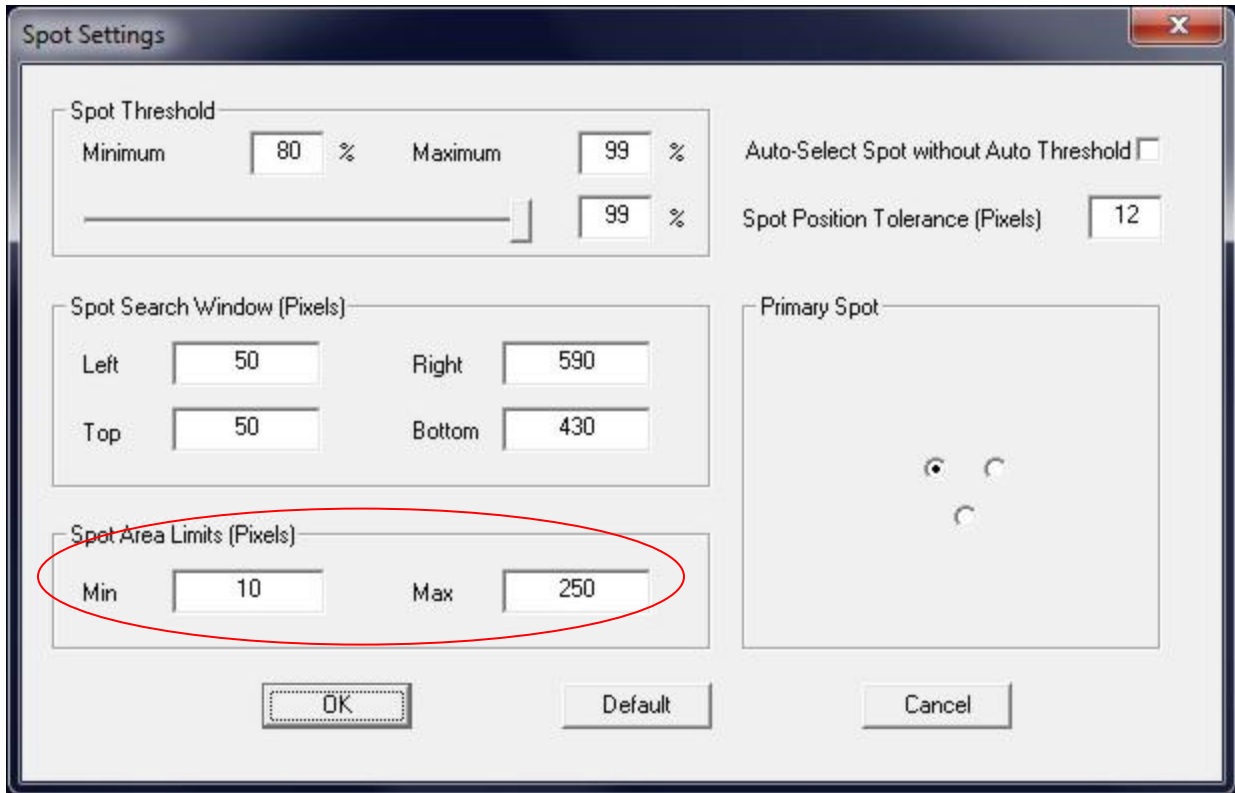
9.4.5 Corneal Reflection (CR) Spot recognition

Select the **Spot** button, under the Video Display heading, at the top right of the *ETMobile* screen.

Click **Auto**, under the **Spot Threshold** heading.   The three CR spots should be visible on an otherwise mostly black background. Purple circles should designate two of the spots and cross should indicate the third. The spot with the cross is the "Master" or "Primary" spot".

*It is important to ensure that the spot selected as the "Master" is the least likely to be obscured during the user's ac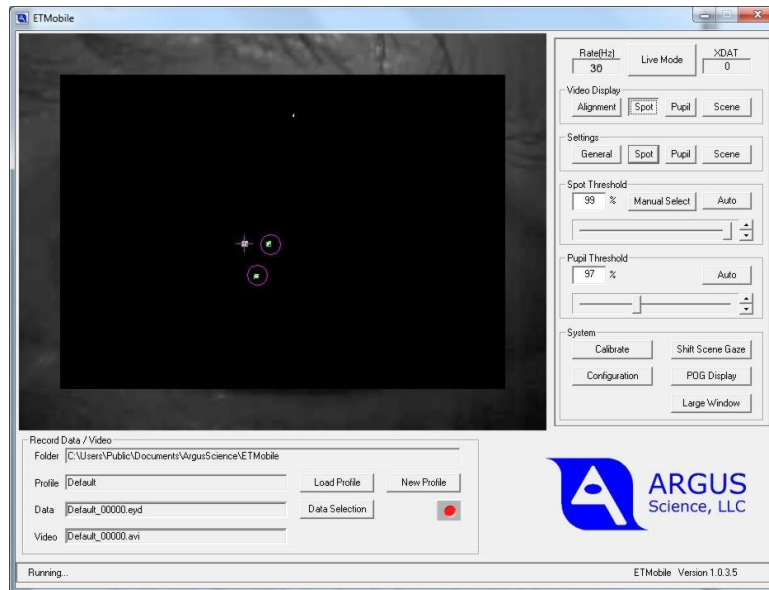tivit*y. The most likely causes of spot loss from normal operation are the eye turning so that the spots fall over the sclera (white portion of the eye) or the eyelids narrow so that they occlude the eye. The Master spot selection can be changed on the *Spot Settings* dialog, Click **Spot**, under the **Settings** group label to bring up the dialog. Select the **Primary Spot** radio button for the desired spot. After clicking OK to close the Settings dialog, the spot chosen as "Primary" should be covered by the cross indicator.
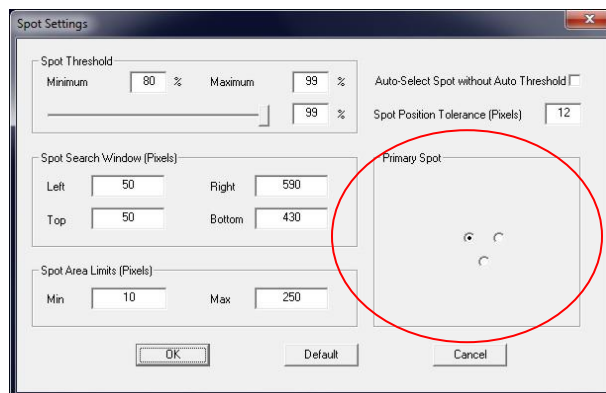
There are also manual adjustments and an alternate manual procedure to achieve proper spot recognition. These are described in section 9.7.1, and can be used if **Auto**, under **Spot Threshold**, does not achieve the desired result. Other settings are described in section 9.5.

9.4.6 Pupil Recognition

Select the **Pupil** button, under the "Video Display" heading, at the top right of the ETMobile screen.
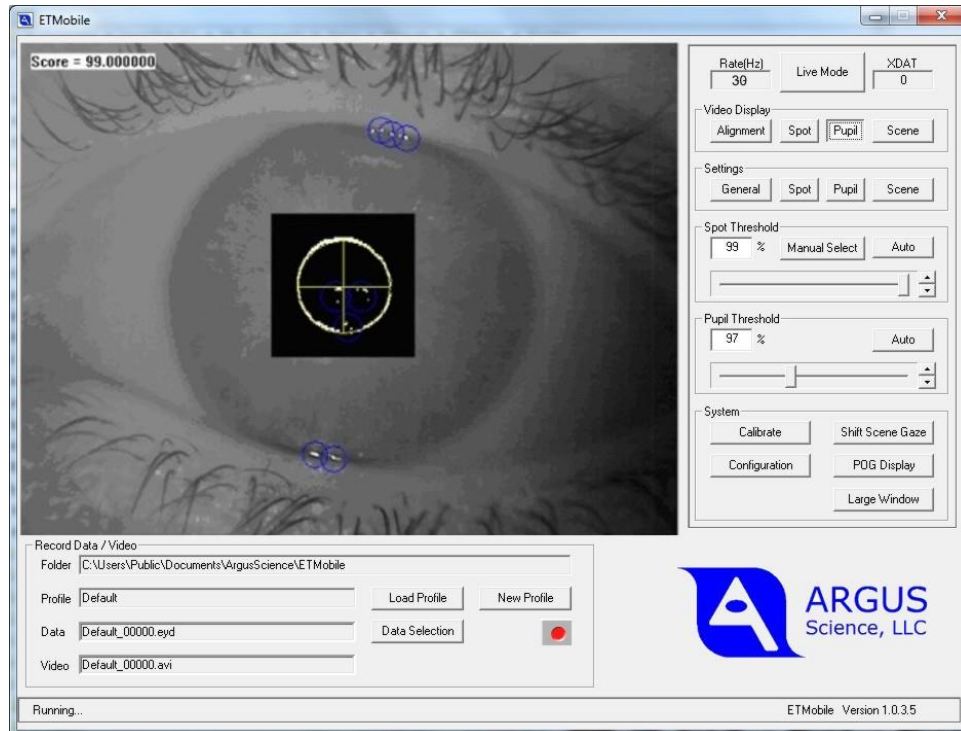
Click **Auto**, under the **Pupil Threshold** heading. The pupil edge should be indicated by a white outline. The outline is formed by multiple white dots and may have varying thickness. If the outlined object is recognized as the pupil, it will be indicated by a yellow circle, approximately corresponding to the white outline, with a yellow cross indicating its center.

The Score in the top left corner of the Eye Display is a measure of the reliability of the calculated pupil position. If it drops below a set limit (available on the **Pupil Settings** dialog, brought up by clicking **Pupil**, under the **Settings** heading), the pupil position for that frame is discarded. If "Auto Threshold" does not produce the desired result there are manual setting adjustments that are described in section 9.7.2. Other advanced settings are described in section 9.5.

9.4.7 Subject Calibration

The Calibration function maps point of gaze onto scene data by relating the positions of eye features (the pupil and CR cluster) to known positions within the scene image. The following instructions

assume that the optional *ET3Space* feature is NOT being used. See the separate *ET3Space* manual for subject calibration instructions if using *ET3Space*.

Before proceeding with calibration be sure the eye image is properly positioned and focused, and feature recognition properly adjusted as described in the preceding sections. Also be sure that the scene camera image is properly aimed and focused, as explained in section 8.

In the "System" group box (bottom of right side panel), click the "Configuration" button to open the *System Configuration Table* dialog. Select the *Subject Calibration* tab. The item labeled "Total Number of Calibration Points" specifies the maximum number of calibration points that will be used. The recommended value for this maximum (and the default value) is 9. Note that it will be OK to use fewer points than the value specified, just not more points. After verifying that the "Total Number of Calibration Points" item is specified correctly, the *System Configuration Table* dialog can be closed (white X in red box at upper right corner).

Select the **Scene** button**,** under the **Video Display** heading, at the top right of the *ETMobile* screen. The Video Display on the main *ETMobile* window will show the image from the head mounted scene camera.
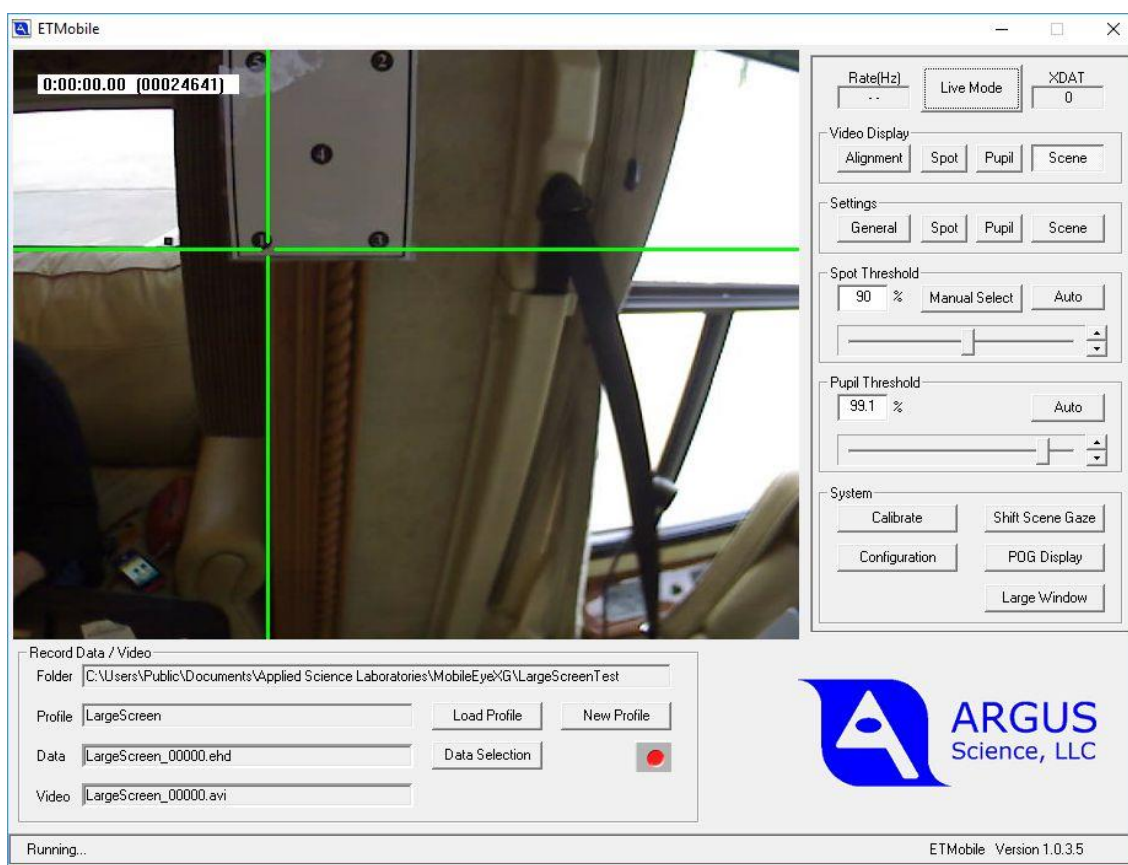
If the eye tracker is being used in real time, rather than from a video file, check the focus and direction of the scene camera as described in Section 8 ("Adjust the Scene Image").

Select **Pupil Overlay** in the **Scene Settings** dialog to overlay the positions of the eye features on the scene image (click **Scene** under the **Configuration** heading, to bring up **Scene Settings** dialog). This will display:

- A purple circle marking the pupil position;
- A purple cross over the master spot;
- A purple vector joining the spot center to the pupil center

The display of these features can later be turned off for an un-obscured viewing of the scene without negative effect on the eye tracking routines.

This Point of Gaze Calibration procedure allows the system to compute the relation between eye feature (pupil and "master spot") position and gaze direction within the scene camera field of view. The software needs at least three valid calibration points in conjunction with reliable eye feature positions to yield a valid calibration.

This procedure can be performed with either live feed from the DTU, while the user is wearing the *ETMobile* optics, or with recorded data being played back from the DTU.

If using pre-recorded data, perform this task in the same way while playing the recorded video in ETMobile. The video will be shown in the Video Display Window. The Audio recording can often be used as the cue to where the participant is looking.

Select the **Calibrate** button in the **System** Group box. The button label will change to **Finish**.

Ask the user to look at an object in the real world, visible in the scene image, and use the purple pupil overlay vector to check that both the spot and pupil are being found reliably. While the user is looking at the real object, use the mouse to left click on the corresponding object in the scene image. If feature recognition is acceptable, a green cross will appear in the scene image at the point clicked.

If feature recognition is not acceptable to the program, usually either because one of the features (pupil or spot) was not recognized or because feature positions were not stable, then a yellow cross will appear. If necessary, ask the user to move their head slightly so that the eye features are tracked more reliably before trying again, or try a spot at a slightly different position in the scene image. Note that by observing the pupil and spot overlay (purple circle and cross previously discussed) it is usually possible to tell whether there is stable pupil and spot recognition.

Repeat this process for a number of calibration points spread over the scene. The minimum number of points is three, but using more points will improve tracking accuracy (Argus recommends using 5-9). The green crosses from successful calibration points remain on the screen until the calibration is finished. The number of valid calibration points (green crosses) should not exceed the maximum value specified on the *System Configuration Table* dialog, as described at the beginning of this section.

It is important that the green calibration points be distributed across the scene camera field of view, and that they do not all fall on a single straight line in the scene camera image.

Finish the calibration by selecting the **Finish** button. A point-of-gaze (POG) cursor in the scene image should now show real-time gaze position. (The appearance of the POG cursor can be adjusted as described in section 9.4.9)

Be aware that a right click in the scene image area, during calibration, will cause a red cross to appear and will decrement the maximum number of valid calibration points (green crosses) accepted. This feature is needed only for calibration when using *ET3Space*, as described in the *ET3Space* manual. There is no need to right click (skip a calibration point) when not using ET3Space. No harm is done by a right click as long as the total number of red and green crosses does not exceed the "Total Number of Calibration Points" value specified on the *System Configuration Table*.

If it is not possible to get acceptable feature recognition (green crosses during the calibration procedure) at points spaced over a reasonable section of the scene camera field of view, it may be necessary to abort the calibration and attempt to improve feature recognition before repeating the procedure. In this case, click "Finish" to abort the current calibration, and follow the directions in previous sections to position and focus the eye image, and to adjust the Pupil and Spot threshold settings.

9.4.8 Offset Correction

If, 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 entire calibration process. Click the "Shift Scene Gaze" button, in the "System" group box. The button label will change to "Finish". Have the subject look at a recognizable target in the scene and click on the target in the scene image. The point-of-gaze cursor should jump to the spot clicked. If necessary, repeat with the subject looking at the same point in the scene or a different point. When satisfied with the result, click "Finish".

9.4.9 Point-Of-Gaze Cursor

The Gaze Crosshair type can be changed in the *Scene Settings* dialog, accessed by clicking "Scene" under the "Settings" group heading. The three cursor choices (circle, crosshair, and large crosshair) are shown below. Also available is "None" which will display the scene image without an overlaid POG crosshair. Cursor color and size can also be selected from the same dialog.

9.4.10   Large Video Display Window

Left click the "Large Window" button, in the "System" group box to open a large window version of the "Video Display Window". Left click the red box with white cross at the upper right to close the large window.

9.4.11   POG Display Screen

A *POG Display Screen* showing digital data computed by the system as well as a two dimensional plot of gaze position data and calibration point position can be opened by clicking the button labeled "POG Display", in the "System" group box.
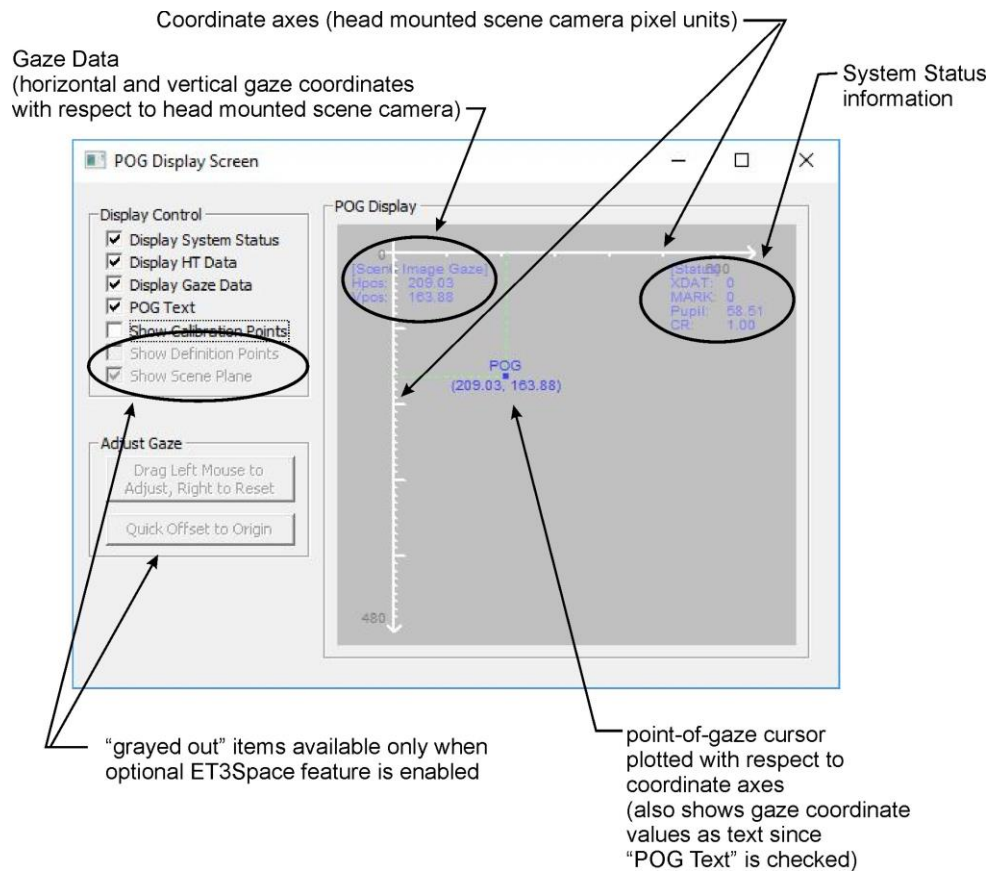
The gaze position data and plot shows gaze with respect to the scene camera field of view. Horizontal position values increase from 0 to 640 from the left to the right edge of the scene camera field. Vertical values increase from 0 to 480 from the top to the bottom of the camera field. In other words, both horizontal and vertical position equal zero in the upper left corner of the scene camera field; horizontal position is 640 and vertical position is 480 in the lower right corner.

The "Display Control" check boxes allow the various displays within the *POG Display Screen* to be enabled or turned off.

9.4.12   Data Collection

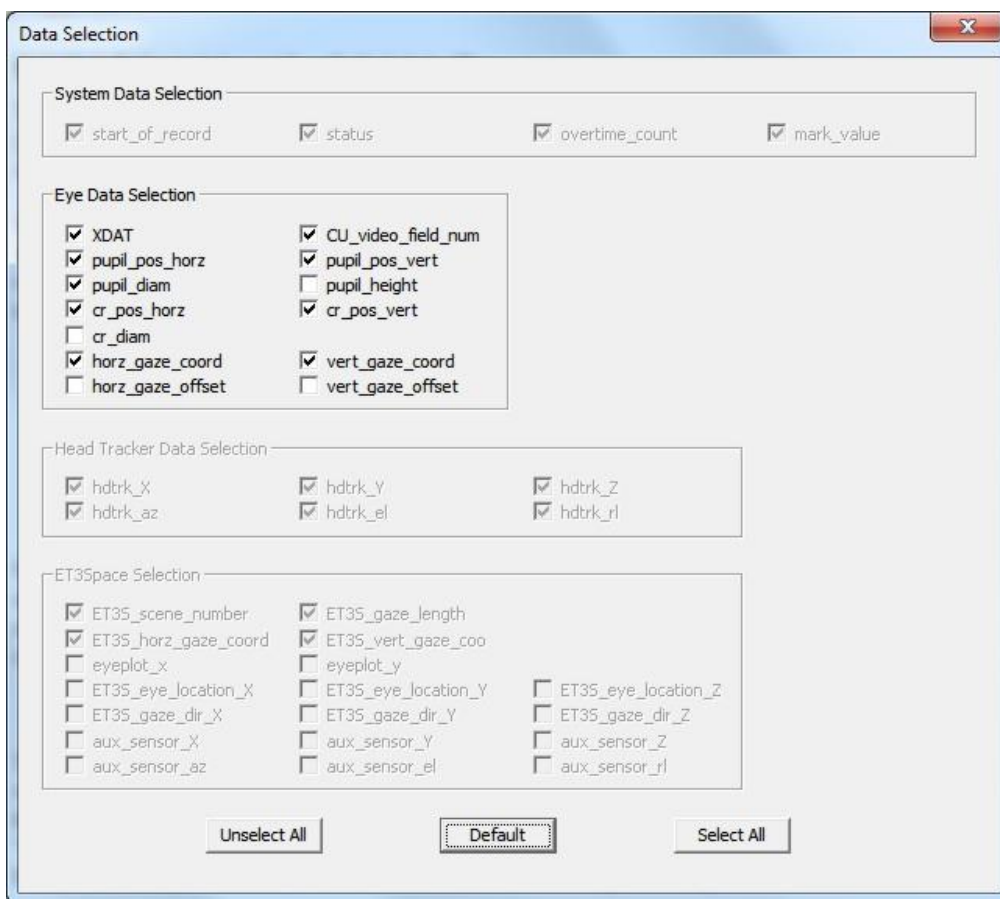Once the system is set up and calibrated, *ETMobile* processes the eye image and calculates gaze position relative to the corresponding field of scene data. Eye and scene data can be input to the system either in real time (direct mode) or from a recorded video file. As previously described, the gaze direction is displayed as a Point of Gaze marker superimposed on the scene video image on the large Video Display Window, and as digital data and a plot point on the *POG Display Screen*. The digital data corresponding to gaze direction, pupil and primary spot position, and pupil diameter can also be recorded on a binary (*.eyd) file; and the Display Window video can be recorded as a video (*.avi) file.

9.4.12.1 Select data set for digital data file

To see the data available for digital recording on a ".eyd" file, open the *System Configuration Table* ("Configuration" button in "System" group box on main program Window), and select the *Data Configuration* tab. In the "Record" group box, left click the "Data Selection" button.

Information about the system configuration and the most recent subject calibration are always stored in the file header. Status, Mark flag value, and record of any missed data fields are always included on every data record, and cannot be un-checked. Other data content can be selected, by checking or un-checking available data items (unavailable items will be grayed out). The following are the default items.

- XDAT (external data values)
- Pupil position coordinates (eye camera pixel coordinates)
- Pupil diameter (eye camera pixel coordinates)
- CR (corneal reflection) position coordinates (eye camera pixel coordinates)
- Gaze Coordinates (scene camera pixel coordinates)

Note that pupil height, CR diameter, and gaze offset values apply to other system types, and are not available for ETMobile systems. Head Tracker data is available only if a head tracker has been connected to the *ETMobile*, and enabled. *ET3Space* data is available only when the optional *ET3Space* feature is enabled. Use of external head trackers and use of the *ET3Space* feature are described in a separate *ET3Space* manual.

9.4.12.2 Select the Codec for video file recording

The video file compression type (Codec) can be selected in the *General Settings* dialog, "Video Compression" group heading (click **General**, under the **Configuration** heading to bring up the **General Settings** dialog). The selected compression format will determine file size and quality. Argus recommends using the default "ETMobile MJPEC Encoder" as shown below.
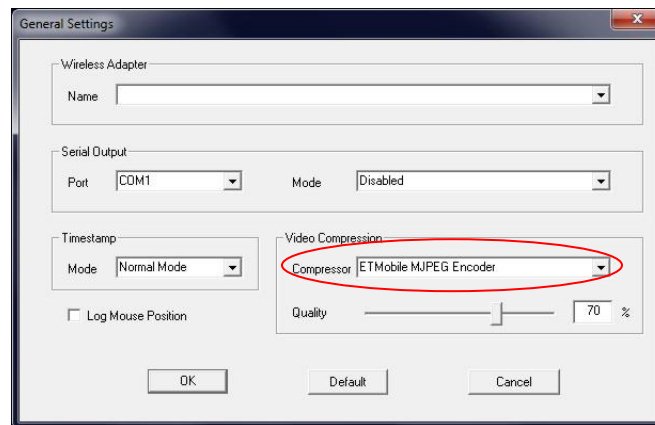
A variety of encoders, including the "ETMobile MJPEG Encoder", can be chosen from the pull down menu under the "Video Compression" heading, on the General Settings dialog. The **Quality** slider will vary compression quality from lowest, at the left of the slider range, to highest, at the right. Lowering quality will reduce file size at the expense of image quality.

9.4.12.3 Start Stop Recording data and video files

Select the **Scene** button, under the "Video Display" heading. This will display the scene image overlaid with a green cursor (either circle, small cross hair or large cross hair) showing the gaze position within the scene. Record both video and a digital data file by clicking the record button (red circle) in the "Record Data/Video" group box on the bottom left panel. The record button will change to a Pause button (two vertical red lines). Click the "Pause" button to stop recording.

The video file name will be the Profile name with a sequential number appended to the end, and an *avi* extension. The binary data file name will be the Profile name with the same sequential number appended, and a *eyd* extension. Each time recording is stopped with the Pause button, the sequential number appended to both file names automatically advances.

Before recording data, the eye feature position display can be switched on or off using the **Pupil Overlay** button in the *Scene Settings* dialog.

As previously described, the Gaze Crosshair type, size and color can be changed in the *Scene Settings* dialog accessed by clicking **Scene** under the **Configuration** group heading.

9.4.12.4 Recording Manual Event Marks

While a data file is recording, it is possible to manually enter a mark value of from 0 to 255 on the file.

Left click the "Configuration" button on the "System" group box to open the *System Configuration Table.* Select the *Data Configuration* tab.
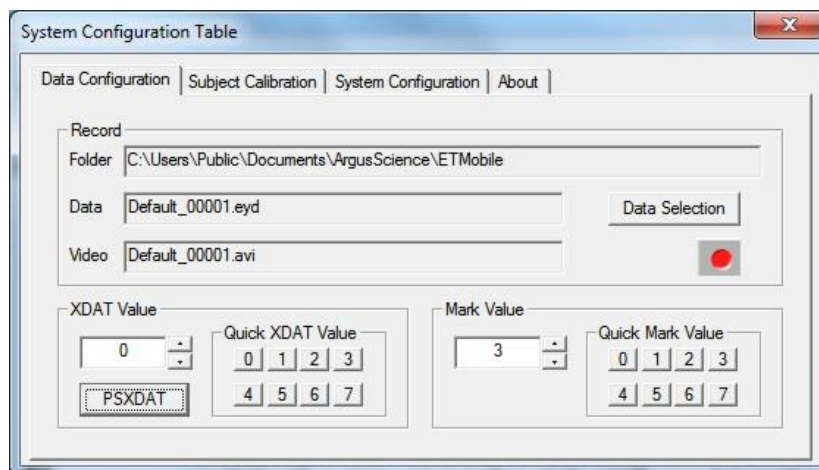
The current file "Mark Value" is shown in the "Mark Value" group box. The value can be changed in three ways.

8 different event marks (numbered 0-7) 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 .

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.

Alternately a value can be typed into the "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 current Mark value is also displayed on the *POG Display Screen* (see section 9.4.11).

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

The *ETMobile* program keeps track of a 16 bit integer data value labeled "XDAT" (short for "external data") which is displayed on the *POG Display Screen*, recorded along with gaze data, and which can be controlled by an external device via a LAN connection. It is most often used for marking events. For example the XDAT channel might be used by an external device to mark the onset of a particular stimulus, etc.

ETMobile will also accept commands from the external device to open data files and to start and stop recording via the same LAN connection. Section has instructions for setting up a LAN connection and communicating with an Argus Science application called *ETRemote*. The protocols for sending and receiving data with a user application are specified in a separate manual, titled *NetworkComWithETMobile*. More detailed instructions for using *ETRemote* are also provided in a separate manual (*ETRemote_with_ETM*).

It is also possible to control the XDAT value from a TTL level parallel digital input or from a serial input. These options require additional hardware not provided with the standard *ETMobile* system. Consult Argus Science for details.

Although XDAT was intended primarily as input from an external device, XDAT values can also be changed manually, in much the same way as the manual Mark values described in the previous section. Open the *System Configuration Table*, *Data Configuration* tab as described in the previous section. Use the controls in the "XDAT Value" group box in the same way as the "Mark Value" controls. The XDAT value shown on the dialog will reflect XDAT value changes made by external devices as well those made using the dialog controls. The current XDAT value will be the most recent value set by either means. (The button labeled "PSXDAT" in the "XDAT Value" group box opens a dialog for enabling the parallel or serial data input features mentioned in the previous paragraph).

9.4.12.6 Viewing recorded data

The *ETAnalysis* program, available from Argus Science, can be used to view, process and analyze data recorded with *ETMobile*. *ETAnalysis* can also be used to make an XML file version of the data for import to *Microsoft Excel*, and a text version of digital data files for import to other applications or processing by user created applications. A separate instruction manual is provided for *ETAnalysis*.

The video (*.avi) files can also be viewed with most video player applications.

9.4.13   Real Time Serial Data Output

Real time communication with *ETMobile* is usually done via a network connection as described in the next section; however, if a USB to serial converter is installed on the ETM PC, the same data recorded on ".eyd" files can be output in real time, as serial RS232 data. Select the COM port and serial output type in the "Serial Output" group box, on the *General Settings* dialog. The "simple" ASCII output includes only the pupil diameter and gaze coordinate data fields. The "advanced" ASCII output includes all available data fields. Consult Argus Science for further details. Real Time Network Communication

9.4.14   Real-Time Network Communication with External Devices

A network connection can be used for TCP/IP communication with an external device.

The external device can send commands to start and stop data recording on the ETM PC, send an external data value (XDAT) to be recorded on an *ETMobile* data file, and can receive real time gaze and pupil diameter data via the same TCP/IP link. The protocols for TCP/IP communication are explained in a separate manual (*NetworkComWithETMobile*).

To enable or disable the TCP/IP communication feature, open the *System Control Table* ("Configuration" button in the "System" group box) and select the *System Configuration* tab. At the bottom of the dialog, in the "Real-Time Input/Output" group box, left click the "Configuration" button to bring up the *Network Configuration* dialog.
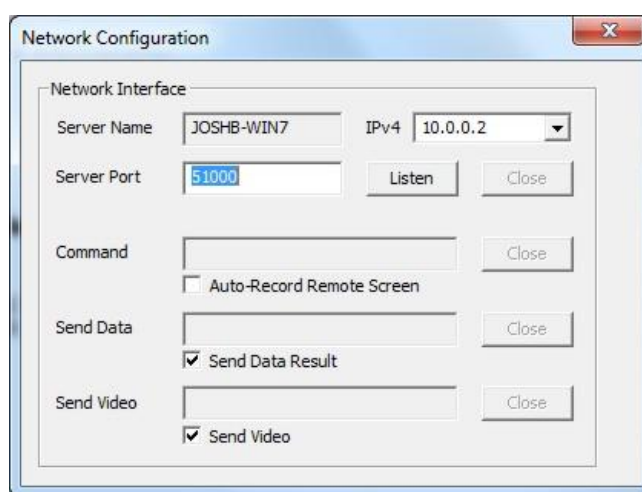
The ETM IPv4 address (or addresses if more than network is available) are shown on the dialog at the upper right. This address will be needed by the external device application that will communicate with *ETMobile*. Either a LAN cable or Wi-Fi may be used, but cannot be the same LAN or Wi-Fi network being used to communicate between the ETM PC and DTU.

The network to be used for external communication must be set, on the ETM PC, to "Obtain IP address automatically".

If Wi-Fi connection will be used between the *ETMobile* PC and DTU, then the built-in LAN port can be used for external comm. In this case use the *ETMobile Network Config* tool, provided on the *ETMobile* PC, to set "LAN to Internet" and "WLAN (Ad Hoc) to DTU" (if Win 7 system) or "Wi-Fi Direct to DTU" (if Win 10 system).

If the built in LAN port, on the *ETMobile* PC is being used to connect to the DTU, then the built in Wi-Fi on the *ETMobile* PC can be used for external comm. In this case use the *ETMobile Network Config* tool, to set "LAN to DTU" and "WLAN to Internet". Alternately a USB to Network adapter can be used to create a second LAN on the *ETMobile* PC for external comm. This second network must be set, on the *ETMobile* PC, to "Obtain IP address automatically". In this case it will need to be

done with Win7 or Win10 "Network and Internet" dialogs (the *ETMobile Network Config* tool will only configure the built in LAN port).

If digital data is to be sent to an external device, enable this feature by checking the box labeled "Send Data Result". <u>The data items sent will be the list of items selected on the *Data Selection* dialog described in section 9.4.12.1.</u> If the video image from the *ETMobile* Video Display is to be sent to an external device check the box labeled "Send Video".

Click the "Listen" button before the external device tries to establish a communication link with *ETMobile*.

Instructions for programming an external application to communicate with ETMobile are found in a separate manual (*NetworkComWithETMobile*). Argus Science provides a program called *ETRemote* which can communicate with *ETMobile* from an external Win7 or Win10 PC via LAN connection. Instructions for using *ETRemote* are also provided in a separate manual (*ETRemote_with_ETM*).

9.4.15   Playback Mode

ETMobile is designed to either receive a stream of eye and scene video data from the DTU ("Live Mode") or to playback previously recorded eye/scene. ".avm", video files ("Playback Mode"). A button near the top right of *ETMobile* screen toggles between Live and Playback modes.

The *ETMobile* program allows full seek commands for .avm playback. This allows the operator to run a specific .avm file at Fast Forward, Slow Forward, Slow Reverse, Fast Reverse and single frame advance or rewind (with the speed of fast and slow being user defined). In addition, the playback features allow the user to advance to a specific frame and begin recording to create the final avi/csv pair for data analysis.

The left image, above, shows the bottom of the ETMobile screen when set to "Playback Mode", while the right image shows the same portion of the screen when set to "Live Mode".

When in "Playback Mode", and a single file playback is desired, select the "Load" button to bring up a browse dialogue. Browse to the desired .avm file. The selected .avm file will appear and the first frame will display in the ETMobile video display Window.

After loading the file, the operator may control the video in several ways:

1. **Progress Bar with time and frame number display**
   The progress bar slider may be used to move the video to any desired time or frame number. The digital values just above the left half of the progress bar show :

   Current Time / Total Time
   (Current Frame / Total no. of Frames)

2. **Seek Commands**
   The individual commands may be invoked to control playback of the avi.
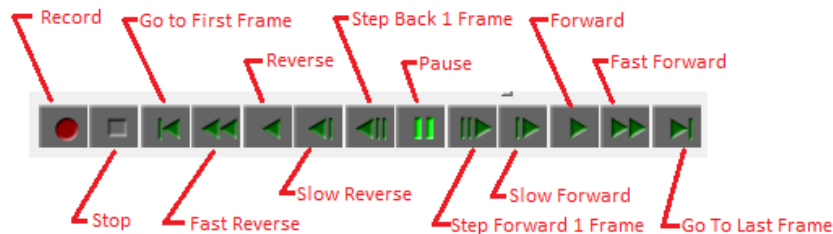
3. **Seek Speed**
   Fast Forward/Fast Reverse and Slow Forward/Slow Reverse can be se to desired speed with the playback speed settings. If Real Time Speed was 30fps, a 3X desired speed would be 90fps while a 1/3 speed would be set for 10fps. (These are the defaults). If Faster or slower speeds are desired, simply enter the desired frame rate for Slow or Fast.
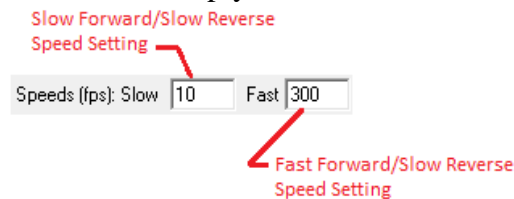
<u>Some Points about Seek Commands</u>:
- When Record is invoked, the speed is set to the original speed of the avm file (30 or 60fps).
- When in any mode except standard play, the audio is muted. Please note that if, for example, Fast Forward was used and then Pause was selected and then Play was then invoked, that the audio and video will still be in sync.
- It is possible to calibrate in Play, Slow Forward, Fast Forward, or even slow reverse or fast reverse if desired.
- When Record is invoked, all other seek commands are disabled except for the "Stop" record (Green square Shown below). The Stop Command can be selected at any time to Stop a recording.

When Record is invoked, the program will use the .avm file, beginning at the selected place, to generate a final set of .avi/.csv files. The avi files contain the scene video with superimposed point-of-gaze cursor, and the csv file contains the digital gaze position data.

The "Fast record from AVM file" feature (check box at lower right "Record Data/Video" group box when in "Playback Mode") allows for conversion of AVM files to AVI/CSV pairs as fast as the PC can process the data (rather than at the recording rate). Typically, 90 frames per second will be converted when this feature is used. Please note that the resulting files retain their original update rate property (30 Hz or 60 Hz) regardless of the speed of the conversion process. If the "Fast record from AVM file" box is not checked, the conversion process proceeds at approximately the original frame rate of the avm file.
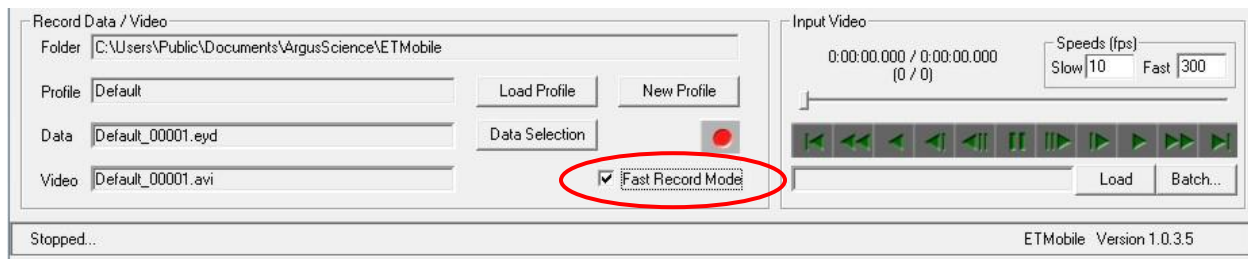
Batch:
If multiple avm files are prepared to run through *ETMobile* to generate the final .avi/.csv files, the operator may invoke the "Batch" command. Left click the "Batch…" button. A *Batch Process Subject Files* dialogue will appear, and the operator is prompted to load both the .avm files and the corresponding .evi files.
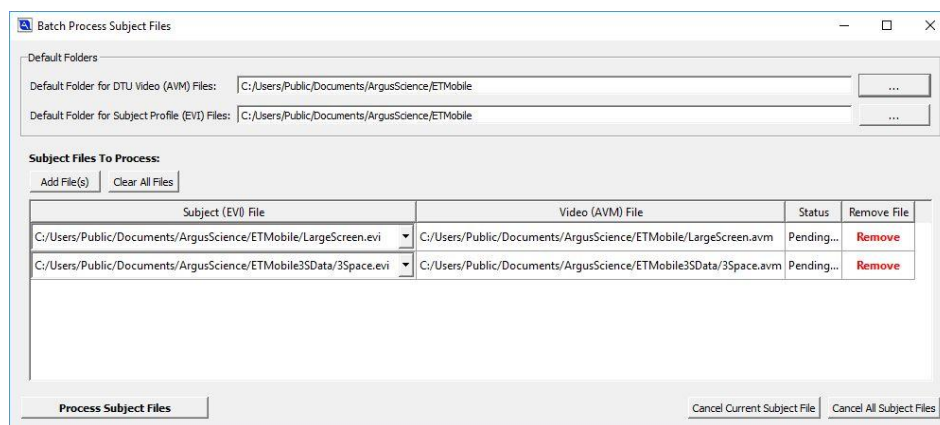
Once all desired files are selected, left click "Process Subject Files" and each file set will process in sequence. "Status" will give an indication of which file is currently being processed and which are pending or complete.

9.5 ETMobile Settings

ETMobile "Settings" dialogs are accessed by clicking one of the buttons in the group labeled "Configuration", near the top right of the *ETMobile* application window.

There are 4 buttons ("General", "Spot", "Pupil", and "Scene") that bring up 4 different dialogs to define default settings or global parameters related to those operations within *ETMobile*.

9.5.1 General Settings
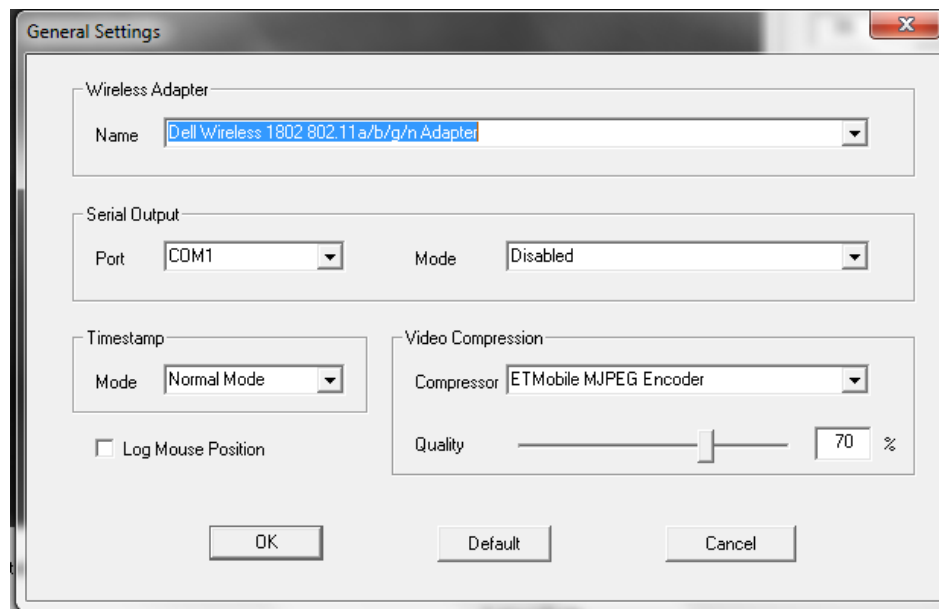
Configuration, General Settings dialog

Subject Profile   Sets the default profile that *ETMobile* will open on start.

Wireless Adapter   The **Name** pull down menu lists any wireless adapters detected
                        by the system. An appropriate wireless network adapter is
                        installed on the ETM PC laptop that comes with the system,
                        and is the one that should be used by the ETM program. This
                        will be the only one listed in the pull down menu unless a USB
                        wireless adapter is added. For other PCs, consult Argus
                        Science to be sure an appropriate device is being used.

Serial Output   Sets serial output Mode and specifies the COM Port to be used.
                        If Mode is set to Disabled, no serial data is output. Other
                        modes are described in appendix C

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Time Stamp   Select Normal, System Time, or Fixed Interval Mode

Compression   Select the video compression codec with which *ETMobile* will record. Argus recommends "ETMobile MJPEG Encoder", which is the default. The codec chosen will determine the quality of your video recording and the size of the file. Additional Codecs may be installed if desired.

                               The Compression Quality percent value sets the video quality that will be recorded. Higher video qualities will result in larger file sizes.

Log Mouse Position   If this box is checked, mouse position coordinates are included on recorded data (csv) files.

9.5.2 Spot Settings
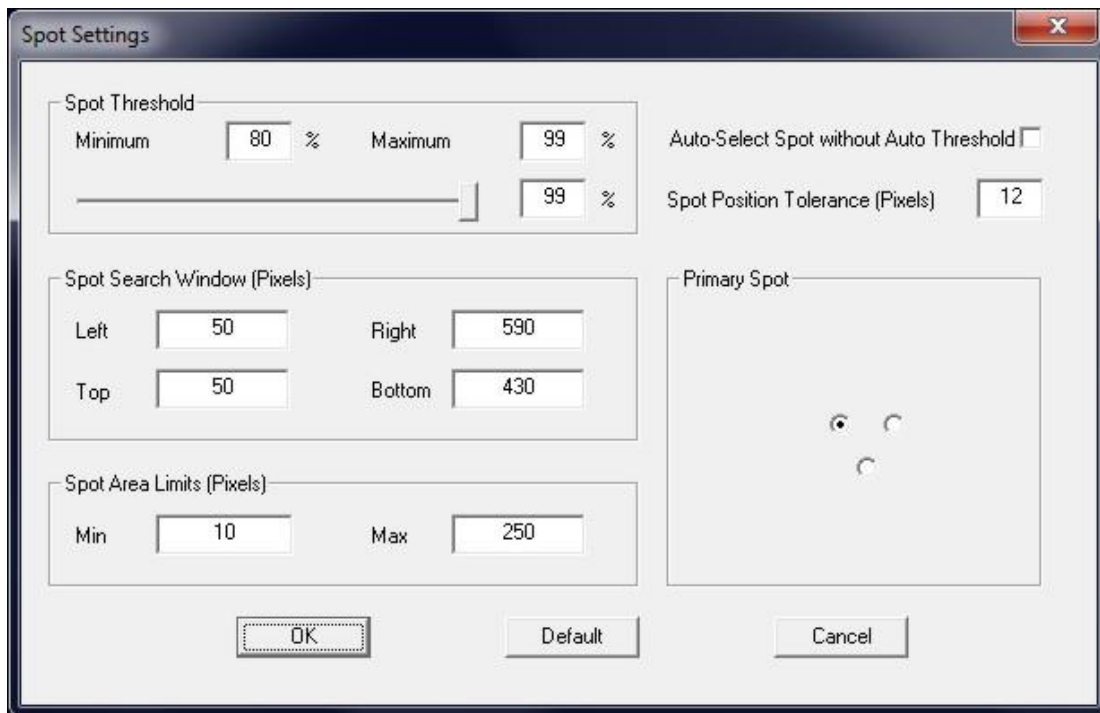
Configuration, Spot Settings dialog

Spot Threshold   Minimum and Maximum are the threshold values corresponding to the extreme left and right positions of the Threshold slider. The slider sets the current threshold value, between the min and max values, and is a duplicate of the Spot

Threshold slider on the main ETM window.

Auto-Select Spot without Auto Threshold	If this box is checked, when the "Auto" button is clicked under "Spot Threshold", on the main ETM screen, the ETM will automatically find the CR spots, but will do so using the current threshold setting. If this box is <u>not</u> checked, the system will also try to find the optimal threshold setting.
Spot Position Tolerance	The number of pixels of variability that will be tolerated on spot positions relative to the master spot. Changing this value will alter the variability between points that will be accepted and recognized as the CR spots. This allows for the accommodation of small changes in relative position due to the curvature of the cornea. Too large of a value may lead to the erroneous acceptance of ambient light noise as the spot cluster.
Search Window	Defines the area of the eye image searched for the spot cluster. This should usually be set to include most of the eye image. However, in some circumstances the eye image may contain large numbers of glints (usually from the sclera) that are being mistaken for spots. In these situations it is recommended that you try reducing the search area to exclude the glints but cover the normal range of eye movements. Recommended settings are Left=50, Top=50, Right=590, and Bottom=430
Spot Area Limits	The minimum and maximum sizes in pixels that will be accepted as spots. The default range is wide enough to include a large variation in spot size, but may occasionally require reduction in order to exclude glints or reflections. Recommended settings are Min = 10 and Max = 250

Note: For the *ETMobile* to perform at optimum levels the recommended "Spot Area Limits" are Minimum of 10 and a Maximum of 250; the recommended "Search Window" limits are 50, 50 and 590, 430.

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9.5.3 Pupil Settings
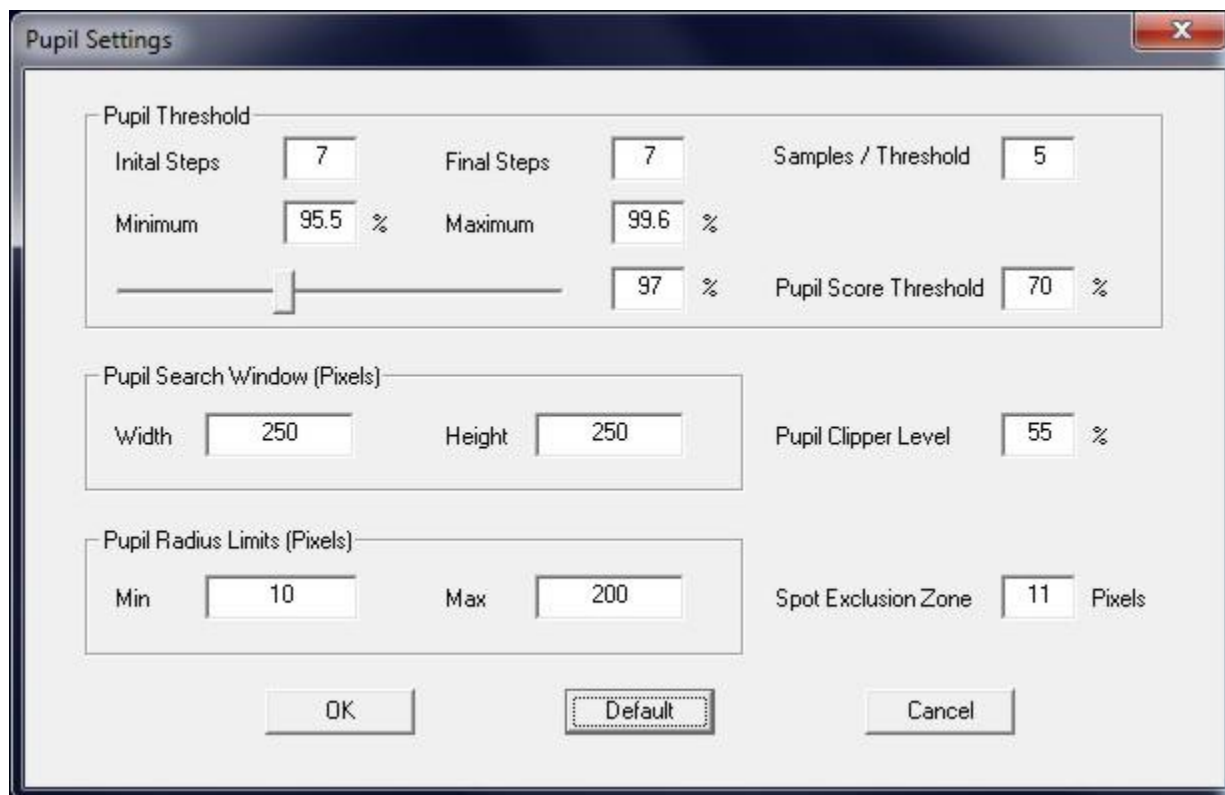
Configuration, Pupil Settings dialog

Pupil Threshold   **Minimum** and **Maximum** are the threshold values corresponding to the extreme left and right positions of the Threshold slider. The slider sets the current threshold value, between the min and max values, and is a duplicate of the Pupil Threshold slider on the main ETM window.

The **Pupil Score Threshold** sets the minimum acceptable reliability score for the pupil position. Be aware that setting this value too low may result in the system recognizing incorrect objects as the pupil.

Initial Steps, Final Steps, and Samples / Threshold are factory settings that should not be modified.

Pupil Search
Window   Pupil Search Window defines the area in which *ETMobile* will search for a valid pupil. The pupil window will change size as the pupil dilates and contracts up to a maximum size defined in this field (measured in pixels for width and height). It is unlikely that the pupil size will exceed the default values, but they can be changed if necessary.

Pupil Clipper Level	This value controls a threshold to remove the bright areas of the eye image before the Pupil Locator processes it. *It is preset by the factory and should not be modified.*
Pupil Radius Limits	These values set the minimum and maximum sizes for objects that will be accepted as the pupil.
Spot Exclusion Zone (SEZ)	The SEZ is the size of the zone that masks the CR spots so that they do not interfere with pupil detection. Spot Exclusion sets the radius of this mask in pixels.

9.5.4 Scene Settings
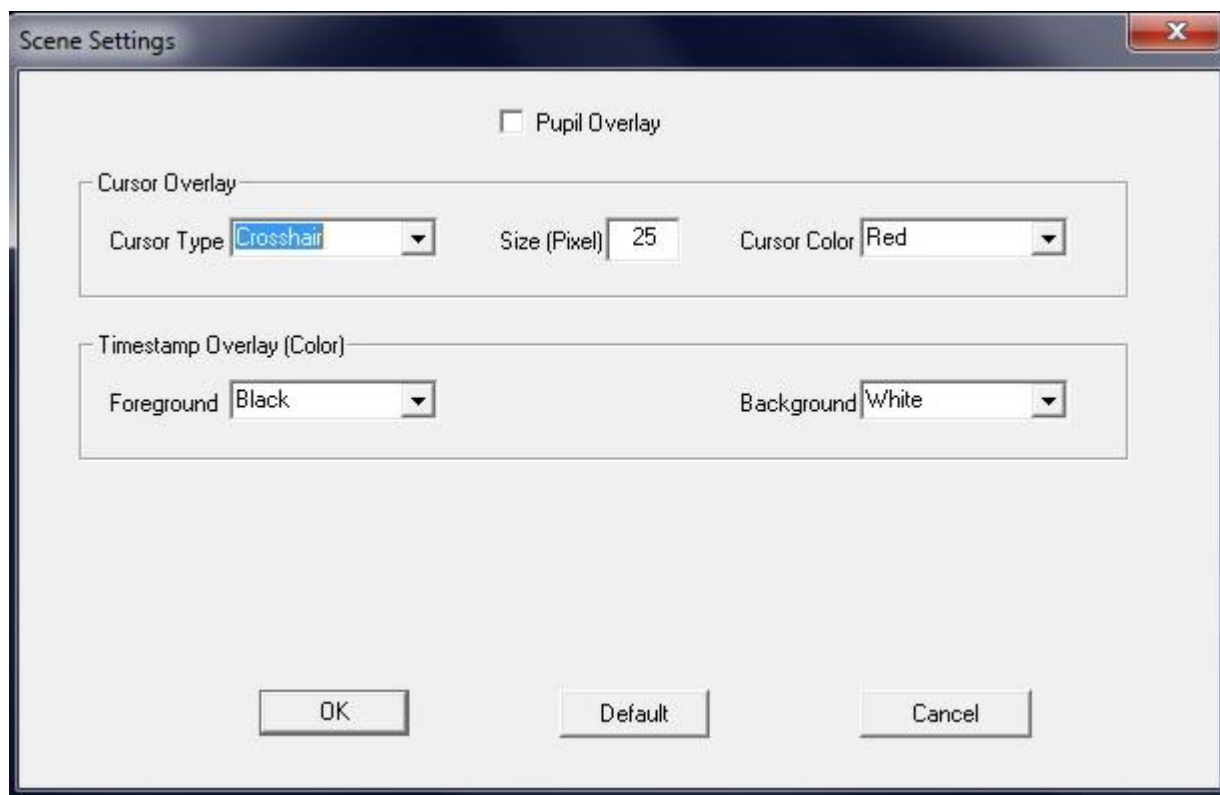
Configuration, Scene Settings dialog

Pupil Overlay	If this box is checked the scene image will be overlayed with a circle depicting the outline of the object recognized as a pupil, and a cross depicting the detected position of the primary corneal reflection (CR). A line connects the center of the pupil circle to the CR cross.
Cursor Overlay	Set the cursor type (small crosshair, large crosshair, circle or none), size

	and color.
Timestamp Overlay	Control the appearance of the Timestamp Overlay on the recorded video image.

9.6   ETMobile System Control Table

Open the *System Control Table* by left clicking the "Configuration" button in the "System" group box (right side panel of main *ETMobile* window). The dialog has 4 tabs

9.6.1 Data Configuration tab
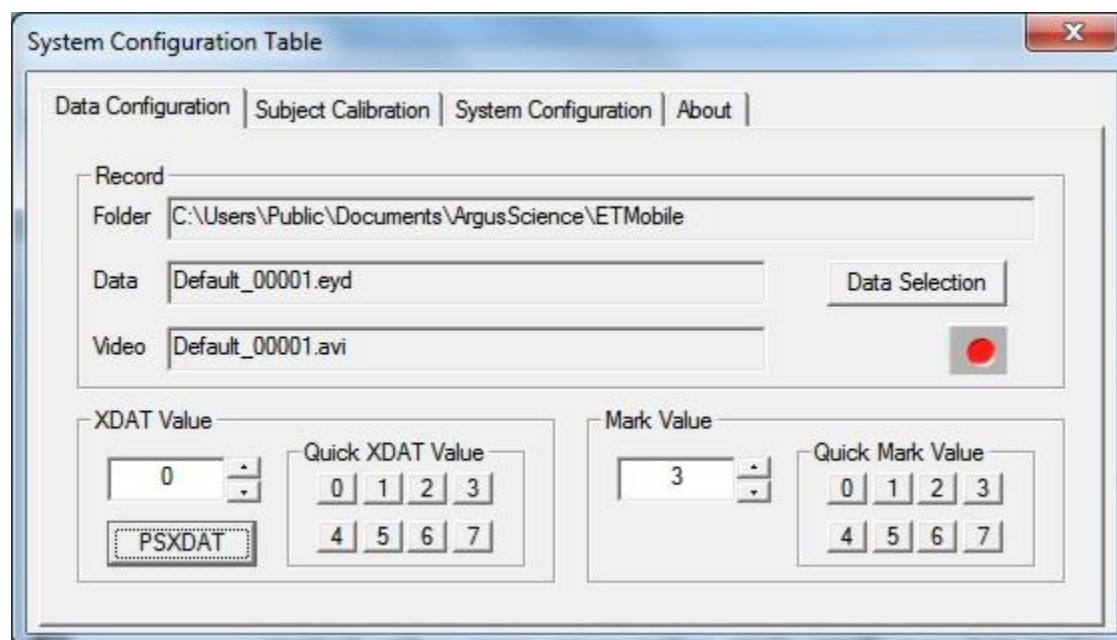
The "Record" group box shows the path ("Folder") and file names for the data and video files currently recording; or if not currently recording, the file names that will be used when recording is started.   These fields are for information only and cannot be modified from this dialog (see instructions for creating new subject profiles in section 9.4.2). The "Data Selection" button is a duplicate of the "Data Selection" button in the "Record Data/Video" group box on the main *ETMobile* window, and opens a dialog to select the contents of the data file (see section 9.4.12.1).   The Record/Pause button is also a duplicate of the button in the "Record Data/Video" group box on the main *ETMobile* window (see section 9.4.12.3).

The Mark Value and XDAT controls are explained in sections 9.4.12.4 and 9.4.12.5.

9.6.2 Subject Calibration tab
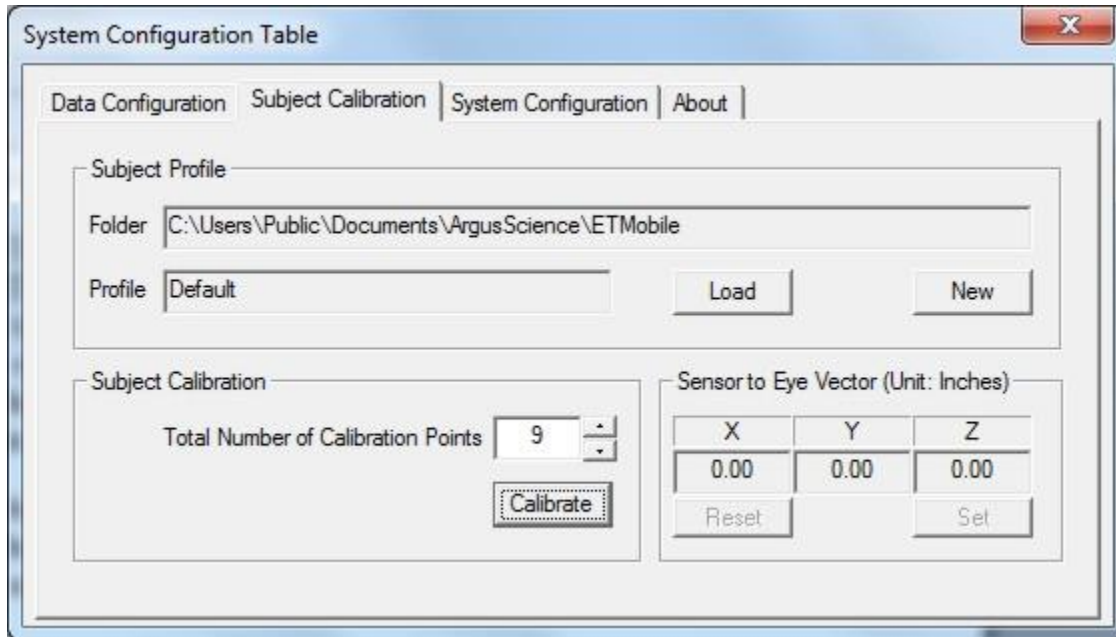
The "Subject Profile" group duplicates the folder and profile information shown in the "Record Data/Video" group box on the main *ETMobile* window. The "Load" and "New" buttons duplicate the function of the "Load Profile" and "New Profile" buttons on the main *ETMobile* window (see section 9.4.2).

The "Subject Calibration" group specifies the maximum number of calibration points to be used (described in section 9.4.7), and has a "Calibrate" button that duplicates the function of the "Calibrate" button in the "System" group box on the main *ETMobile* window (see section 9.4.7).

The "Sensor to Eye Vector" group box applies only to the *ET3Space* feature, and is explained in a separate *ET3Space* manual.

9.6.3 System Configuration tab
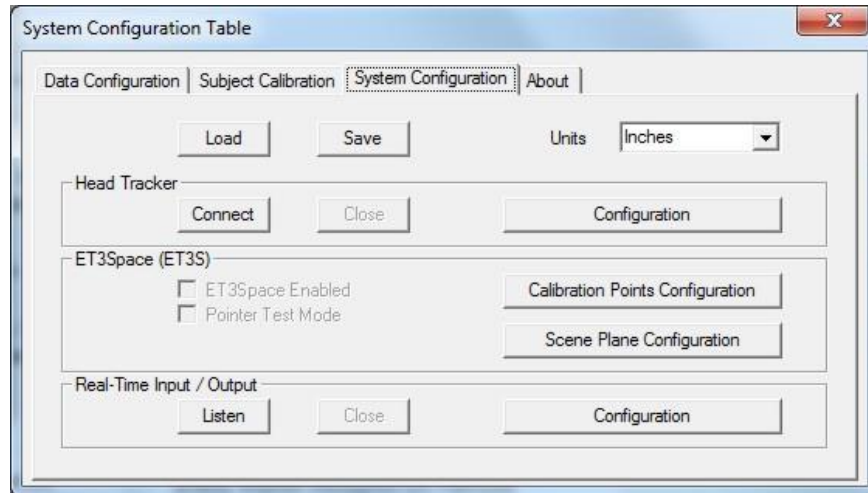
The "Units" specification as well as the "Head Tracker" and "ET2Space" group dialogs apply primarily to the optional *ET3Space* feature, and are described in a separate *ET3Space* manual.

The "Real-Time Input/Output" group buttons are used to configure and establish network communication with external devices. This is described in section 9.4.14.

The "Save" and "Load" buttons at the top of the dialog can be used to save and reload all of the parameters configured from the *System Configuration* tab dialog, including the Nework configuration settings. To save a configuration file, click the "Save" button to open a standard browser dialog. Specify and path and file name in the usual way, and click "Save" to save an XML type file (*.xml). To load a previously saved configuration file, click the "Load" button, use the browser to navigate to the desired file, and click "Open".

9.6.4 About tab

The About tab displays the ETMobile application version number, and provides links to Argus Science Web sites.

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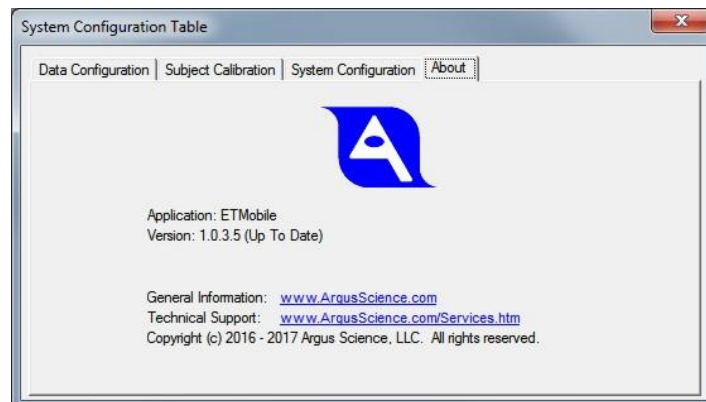
9.7 Manual CR and Pupil recognition adjustments

This section describes the manual CR and pupil recognition controls available on the *ETMobile* application. These should all be considered advanced features. Default settings and use of "Auto Threshold" buttons will usually be appropriate

9.7.1 CR spot recognition – manual settings

Select the **Spot** button, under the Video Display header, at the top right of the *ETMobile* screen. Use the Spot Threshold slider (under the "Spot" header) to adjust the video contrast level of the eye image so that the three corneal reflections are clearly visible and their relative positions need to be defined.
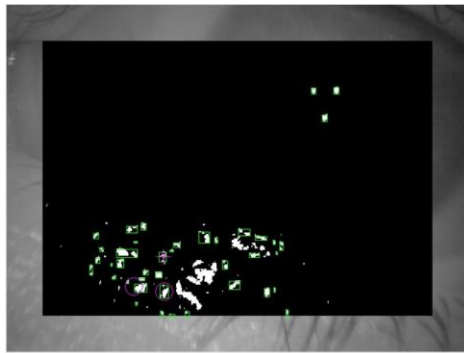
Spot display before setting the threshold with spot cluster found

Spot display after calibration

Display the Spot Binary Image	→ Select Spot button under Video Display. This will place a black box binary map over the area of the eye image that ETMobile is searching to find the spot cluster. This software routine is known as the Spot Locator.
	The spot cluster consists of three infrared reflections on the cornea being projected from LEDs in the SMU.
	The Spot Locator searches for bright objects in the spot binary image, which fulfill the size limits set in the User File. These are marked with a green box.
	The spot locator then looks for sets of candidate spots grouped as specified during the spot calibration (described below). If a group of candidate spots is found in the defined relative positions, the Master spot is marked with a purple cross and the other two spots with purple circles.
	Since the spots have not yet been defined, the Spot Locator will not yet properly perform this routine.
Set Up the Spot	→ Use the **Spot Threshold** slider to make the spot cluster the

Video Level	predominant feature in the image. Increasing the threshold reduces the amount of detail in the image while lowering the threshold increases the amount of detail.
Calibration of the Spot Cluster	This procedure tells the software the relative positions of the spots.

→ Ask the user to look straight ahead and then select the "Manual Select" button under the "Spot Threshold" header. This will freeze (take a snapshot of) the video image.

→ Click the cursor on the center of each of three spots in turn. The first spot selected will be made the "Master" spot and the other two will be the "Slave" spots.

  o *It is important to ensure that the spot selected as the Master is the least likely to be obscured during the user's activit*y. The most likely causes of spot loss from normal operation are the eye turning so that the spots fall over the sclera (white portion of the eye) or the eyelids narrow so that they occlude the eye.

As each spot is selected, a blue cross is placed over it. Selecting the third spot terminates the calibration and returns the Display Screen to normal play mode.

→ Check that the spot cluster is tracked reliably over a large range of eye movements.

  o The spot cluster will be recognized if the Master spot and *at least* one other spot is visible. If the system does not recognize the spot cluster, it will not be able to track eye gaze.

Configurable Settings	There are a number of settings for Spot Detection that can be configured using the ETMobileConfigTool.exe program. The default settings should be suitable for most applications; however there may be situations in which additional fine-tuning is necessary. See Section 9.5.2.

- Default Threshold
- Spot Position Tolerance
- Spot Area Limit

9.7.2 Pupil Recognition – manual settings

The video contrast level of the eye image needs to be adjusted so that the boundary between the pupil and the iris is well defined. This is done using the Pupil Video Display, and the controls under the **Pupil** header.

Display the Pupil Window
→ Select the Pupil button under the Video Display header. This will place a black box binary map over the area of the eye image that ETMobile is searching to identify the pupil. This software routine is known as the Pupil Locator.

When the pupil is recognized, it will be marked with a yellow circle. The Score in the top left corner of the Eye Display is a measure of the reliability of the calculated pupil position. If it drops below a set limit (see below), the pupil position for that frame is discarded.
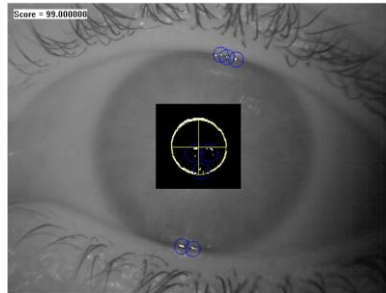
Set the Pupil Size Range
→ Select the **Settings** button, under the Pupil header, to bring up the Pupil Settings window. The Radius Min and Max values limit the size of the object that the Pupil Locator routine will search for and recognize as the pupil. Ensure that they allow the expected range of pupil sizes, allowing for pupil contraction and dilation. Making the range too large may affect the accuracy of the software.
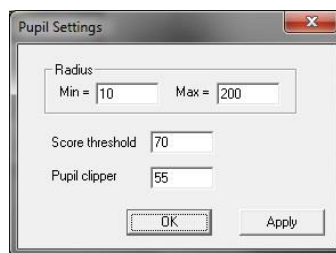
Set Up the Pupil Video Level	→ Use the **Pupil Threshold** slider to make the pupil boundary as complete of a circle as possible without including extraneous detail from the image. If the pupil boundary is too thick then uncertainty in fitting the circle to the pupil will cause jitter and a reduction in tracking accuracy. Increasing the threshold reduces the amount of detail in the image. Lowering the threshold increases the amount of detail.
	→ Check that the pupil is tracked reliably over a large range of eye movements, as indicated by the stability of the yellow pupil identification circle and crosshair.
Score Threshold	If you are having difficulty getting the pupil to track, try reducing the **Score Threshold** in the **Pupil Settings** dialog. This value sets the minimum acceptable reliability score for the pupil position.
	Be aware that setting this value too low may result in the system recognizing incorrect objects as the pupil.
Pupil Clipper	The **Pupil Clipper** value in the **Pupil Settings** dialog controls a threshold to remove the bright areas of the eye image before the Pupil Locator processes it. *It is preset by the factory and should not be modified.*
Configurable Settings	There are a number of settings for Pupil Detection that can be configured using the **ETMobileConfigTool.exe** program. The default settings should be suitable for most applications; however there may be situations in which additional fine-tuning is necessary. See Section 9.5.3.

- Default Threshold
- Spot Exclusion Zone
- Pupil Score Threshold Default
- Pupil Clipper Level Default
- Pupil Search Window
- Pupil Radius Limits

10 System Options

10.1 Over-Glasses Model

The ETMobile has an optional arrangement that allows subjects with prescription glasses to take advantage of the unique tether-less eyetracking offered by ETMobile. Tracking over glasses requires a non-standard frame for the ETMobile (it is not possible to use the standard spectacles with glasses).

This option uses the same optical module as the standard unit but is mounted on different frames. This arrangement allows the user to wear glasses that are up to 5.625"W x 2" H (140mm x 51mm). If the user has both frame types, it is easy to switch between the 2 configurations if required.

Due to safety concerns, it is recommended that a user wear the over-glasses frame *only* when wearing eyeglasses. If the user is not wearing glasses, they should use the standard spectacle frame to avoid potential eye injury in the event of an unexpected impact.

10.2 Swapping Optics Between Spectacles

10.2.1.1 Replacement of ETMobile SMU Optic Unit

To remove the optical unit, follow these directions:

1. Loosen the Dovetail Slide retainer screw.
2. Remove cable from Retainer clip (Or remove cable ty-wrap on glasses)
3. Gently slide the optical unit upward along dovetail.

To Install new optical unit:

1. Slide the new unit onto the dovetail.
2. Tighten retainer screw
3. Clip the cable into the retainer clip.
4. Note the previous location of the optical unit on the dovetail slide and position new unit in approximately the same position.

10.2.1.2   Changing SMU from Standard Spectacles to Over Glasses Spectacles

- Remove the Strain Relief Screw.
- Loosen the Vertical Slide Friction Screw
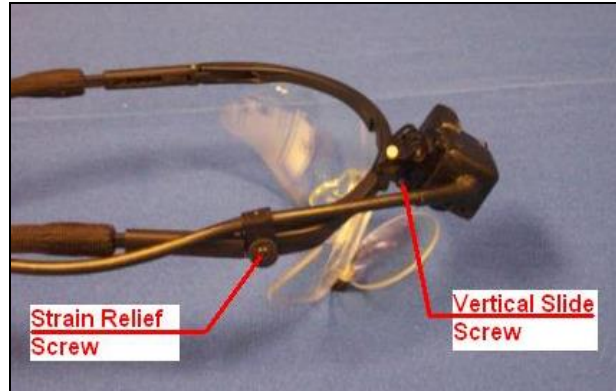
- Lift SMU upward along vertical slide until SMU is free.

- Slide SMU into New Spectacle Unit, Tighten Vertical Slide Screw and Install Strain Relief Screw.

- Note: On Over Spectacle version, the top of SMU should be flush with top of Vertical slide. On Standard version, the SMU should be flush with bottom of slide.

10.3 Using the ETMobile Outdoors

The ETMobile employs unique features to enable the subject to engage in activities in an outdoors environment with exposure to sunlight. The following section(s) describe considerations that need to be taken into account when tracking outdoors.

10.3.1.1 Dark Pupil Optical Approach:

The ETMobile's dark pupil approach delivers IR illumination to the eye, centered on 880nm wavelength, along a convergent path with the image axis of the eye camera. This results in the pupil acting as a "light sink," with the pupil appearing dark and the surrounding Iris having a bright appearance. The ETMobile recognizes this contrast to identify the pupil.

To account for potential interference from extraneous IR sources, such as the sun, the ETMobile employs three (3) IR LED's to project a "Triad" of corneal reflections. The ETMobile is taught this Triad relationship reducing the possibility of the ETMobile from latching onto a false Corneal Reflection from environmental light sources) that might otherwise cause a false point of gaze output.

The ETMobile also employs a narrow band-pass filter to only allow light centered on 880nm to reach the eye camera. This reduces the effect of the sun's illumination from interfering with Corneal Reflection and Pupil detection.

10.3.1.2 Algorithm Logic

The ETMobile requires both the Pupil and Corneal Reflection to perform a calibration. However, once a calibration is properly performed, the system may track with only the Corneal Reflection. This is important as in many lighting conditions, such as bright sunlight, the Pupil may be more difficult to discern. This approach allows for proper point of gaze determination in the most demanding outdoor lighting conditions.

The ETMobile has control over the eye camera gain which can be reduced to minimize the effect of sunlight on the eye image. The ETMobile also has parameter control over maximum and minimum allowable pupil diameter, which can help eliminate false pupil detection.

10.3.1.3 Increasing Outdoor Tracking Performance

The Sun is an extremely powerful light source at all wavelengths and some precautions can be made to increase performance of the ETMobile in intense sunlight:

- Wear a baseball cap or other headgear with a bill that will help shade the eye. This will serve to reduce the sun's direct light exposure on the eye. It will also help reduce the subject's normal squinting reaction to bright sunlight that may occlude CR and pupil identification.

- Avoid eye tracking at sunrise or sunset, especially when the task is oriented towards the sun, since the angle of the approaching sunlight can be directly in the subject's face.

- If possible, perform the calibration in a shaded area before performing the intended activity. Remember that calibration requires both pupil and CR identification, but post-calibration tracking is effective with just the corneal reflections.

- Bear in mind that tasks performed in sunlight bright enough to induce the subject to squint may cause the upper eyelid to occlude the eye features necessary for tracking, leading to intermittent or chronic data loss, depending on the frequency and severity of squinting behavior.

11 Appendices

11.1 Appendix A Recorded and Transmitted Data Items

11.1.1   Data Item List

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

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

The items in the table below are selectable (see Section9.4.12.1). Which ever items have been selected will appear in the order listed on both data files recorded by *ETMobile* and real time data packets transmitted by *ETMobile*. Some items are available only when using *ET3Space*.

Data Item	Type	Size (bytes)	Scale Factor	Comment
XDAT	UInt16	2	1	Always available
CU_video_field_num	UInt16	2	1	Always available
pupil_pos_horz	UInt16	2	1	Always available
pupil_pos_vert	UInt16	2	1	Always available
pupil_diam	UInt16	2	0.01	Always available
pupil_height	UInt16	2	0.01	Not available with ETMobile
cr_pos_horz	UInt16	2	1	Always available
cr_pos_vert	UInt16	2	1	Always available
cr_diam	UInt16	2	1	Always available
horz_gaze_coord	Int16	2	0.1	Always available
vert_gaze_coord	Int16	2	0.1	Always available
horz_gaze_offset	Int16	2	1	Not available with ETMobile
vert_gaze_offset	Int16	2	1	Not available with ETMobile
hdtrk_X	Int16	2	0.01	Available only if head tracker enabled
hdtrk_Y	Int16	2	0.01	Available only if head tracker enabled
hdtrk_Z	Int16	2	0.01	Available only if head tracker enabled
hdtrk_az	Int16	2	0.01	Available only if head tracker enabled
hdrtk_el	Int16	2	0.01	Available only if head tracker enabled
hdtrk_rl	Int16	2	0.01	Available only if head tracker enabled
ET3S_scene_number	Byte	1	1	Available only if ET3S enabled
ET3S _gaze_length	Single	4	1	Available only if ET3S enabled
ET3S _horz_gaze_coord	Single	4	1	Available only if ET3S enabled
ET3S _vert_gaze_coord	Single	4	1	Available only if ET3S enabled
eyeplot_x	Single	4	1	Available only if ET3S enabled
eyeplot_y	Single	4	1	Available only if ET3S enabled
ET3S _eyelocation_X	Int16	2	0.01	Available only if ET3S enabled

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

11.1.2   Data Item Explanation

Start of record byte – fixed value 0xFA

Status byte – contains eye tracer status information.

Bit	Meaning (if 1)
0 (least significant)	Head tracker enabled, monocular system or left eye binocular
1	Head tracker enabled, right eye (binocular system only)
2	Cornea Reflection found, right eye (binocular system only)
3	Pupil Found, right eye (binocular system only)
4	Cornea Reflection found, monocular system or left eye binocular
5	Pupil Found, monocular system or left eye binocular
6	Not used
7	Not used

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 or entered manually on *ETMobile*, *Data Configuration* dialog.

CU video field number – Internal field (or record) number kept by system.   Useful mostly for debugging purposes.

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

Pupil_diam – value proportional to diameter of the pupil image on the eye camera. The units are proportional to eye camera pixels. The units are eye camera pixels multiplied by 100. To find the value in pixel units, the value recorded on the file or transmitted in real-time must be converted to a float and multiplied by 0.01 (the scale factor shown on the chart, above). This pixel value is the value displayed on the *ETMobile* Interface (on the *POG Display Screen*), and the value shown by the Argus Science data analysis program, *ETAnalysis*. *ETMobile* pupil diameter data is usually used to track

relative changes in pupil diameter rather than to measure absolute pupil diameter. The scale factor to convert pupil diameter to millimeters will usually be approximately 0.03 millimeters per pixel unit.

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

cr_diam – CR diameter is not computed by ETMobile. If the "master spot" is detected, the cr-diam value is set to 2; if not detected the value is 0.

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

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

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

ET3S _gaze_length – Distance from the eye to the point of gaze on the scene plane designated by ET3S_scene_number, as computed by the *ETMobile, ET3Space* feature. The value is recorded or transmitted as a single precision floating point value with units of either inches or centimeters (depending on which unit system was set in *System Configuration* dialog).

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

eyeplot – The point of gaze values that would have been computed on the calibration surface (scene plane 0) if the subject's head had not moved since subject calibration. (Only available when using *ET3Space*). Another way to think of these values is to image that during calibration a duplicate of the calibration surface is magically connected to the subject's head so that moves with the head. "eyeplot" values are the *ET3Space* gaze coordinates on this imaginary surface. When using *ET3Space*, they are a convenient measure of gaze-with-respect-to-the-head. The units are inches or centimeters. "eyeplot_x" is really the Y or "horizontal" coordinate and "eyeplot_y" the Z or "vertical" coordinate of gaze on this imaginary scene plane.

ET3S _eye_location – The location in space, with respect to the *ET3Space* "global coordinate system, of the subject's eye. This location is computed, by the *ET3Space* feature, based on data received from the head tracker, and knowledge of the location of the eye with respect to the head

tracker sensor. It does not depend on eye pointing direction. The units are inches or centimeters multiplied by 100, and are stored or transmitted as signed integers. Convert to float and multiply by the scale factor 0.01 to get the values in inches or cm.

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

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

11.2 Appendix B – Troubleshooting

Problem	Cause	Solution
Part of the image of the eye looks shaded over or dark, as if a shadow passed in front of the camera. I cannot see an image in this section.	The shaded part is where the field of view of the camera falls off of the monocle. There is nothing reflecting the image of the face back to the camera here.	Adjust the monocle and/or camera pivot to adjust the angles appropriately. (Section 8)
I keep losing the CR all the time. It immediately falls into the sclera or behind an eyelid.	The angle of approach to the eye is probably too steep or too far to one side. This is causing the CR placement to be too far biased in one direction making it fall off of the pupil/iris very quickly.	Change the angle of approach to the eye by adjusting the monocle and camera pivot. In most situations, you will get the best result if (when your subject is looking straight ahead) the CR triad falls near the middle of the pupil. (Section 8)
When I try to calibrate certain locations on the screen, I keep getting yellow crosshairs.	The system is unable to recognize both the pupil and CR at those locations. The visual angle may be too extreme, the CR may be falling into the sclera or behind an eyelid, or your subject may be blinking whenever you hit the button.	Recheck the Spot and Pupil recognition and adjust the monocle if necessary. Try turning on the pupil overlay (from the Scene Settings dialog) and watching how the Pupil/CR vector overlay responds as they look around. (Section 9.4.7)
At one distance the calibration is very accurate but at another distance it is not.	This is caused by parallax: the apparent displacement of an object as seen from two different points not on a straight line with the object.	You should try to calibrate at the distance most likely to be worked at during your session, or an intermediate distance if there is a wide variation. If some distances have activities that are more critical to accurately track, consider what distances you may be able to accept a slight reduction in accuracy. (Section 9.4.7) If changes in working distance are predictable and a known object is focused on at a specific point, you can use the Calibration Offset feature to compensate for the change.

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I am using Over-the-Glasses ETMobile optics and get a spectacle reflection off the surface of the prescription glasses.		Tilt the *ETMobile* optics up or down slightly and re-center the eye in the monocle. Fixing this is a matter of changing the approach angle to the eye in such a way that the front surface of the prescription glasses is not normal (at a right angle) to the optical path of the *ETMobile*. (Section 10.1)
My subject spent too little time looking at the objects when calibrating. I cannot click quickly enough.		If the session is recorded to the SD card, use slow motion playback from the .avm file to allow easier calibration point identification. (Section 9.4.15)
I am having trouble operating in sunlight.		Try having the subject wear a brimmed hat

Try calibrating in the shade or even indoors. Calibration requires both spot and pupil detection, however it can give accurate point of gaze tracking with just the Spots.

Try your activities outdoors when the sun is not near the horizon (sunrise, sunset) as the low angle of the sun can detract from performance. (Section 10.3) |
| I can only track/calibrate properly in the bottom or top of the Scene image. | The Scene Camera may not be properly centered. | The Scene Camera can move independently of the rest of the SMU optics. Make sure that it is centered on the desired filed of view. (Section 8) |
| When I launch *ETMobile*, the wireless connection to the DTU does not show eye or scene on the ME Laptop | | 1. Make sure the wireless switch on the laptop is enabled. 2. Check the wireless configuration of the laptops (Section 11.3) 3. Check that the DTU wireless is enabled (Section 6.2) |

When I launch ETMobile, the LAN connection is not established and I do not see an eye or scene image on the ETMLaptop.		1. Close ETMobile and re-connect the CAT5 cable from the DTU to the laptop and launch ETMobile. See Section 11.3 for manual network configuration. 2. Close the ETMobile program, launch the ETMobile Network Config tool (Section 11.3) and set it to "LAN to DTU," then re-launch ETMobile. 3. Make sure that the ETMobile Laptop computer name is the same as the DTU remote host name.
When I record on the SD card and play the recording back, the image is jumpy.		Make sure that the SD card is of proper speed and is formatted properly. (Section 11.4)

11.3 Appendix C   ETMobile PC Network settings:

The *ETMobile* PC can communicate with the DTU either via a LAN cable (CAT5 Ethernet cable), or via a Wi-Fi connection. Normally, network settings for the built in network port and built in Wireless capability on the *ETmobile* PC are both set appropriately for communication with the DTU. If the system detects a LAN cable connection, this will take priority, and the two components will communicate via the network port. If a LAN cable connection is not detected, the system will try to establish a wireless connection via the built in wireless capability on the *ETMobile* PC.

It is also possible to use either the built in LAN port or wireless port for communication with external devices or with the Internet if not being used for DTU communication. However, PC Network settings must be set differently for these functions. An application called *ETMobile Network Configuration* is provided as a convenient tool to set the built in network port and built in wireless capability for either DTU or Internet communication. These settings can also be controlled manually using the Windows 7 or Windows 10 operating system dialogs. The following subjections describe the use of the *ETMobile Network Configuration* application as well as the proper manual settings for communication with the DTU or with the Internet.

11.3.1   *ETMobile Network Config* Tool

The *ETMobile* Laptop comes configured to communicate with the DTU either via a LAN (Cat5 network cable) or WLAN (Wi-Fi). This configuration does not allow for typical internet access in either mode.

To allow internet access, a utility application, called *ETMobile Network Config,* is provided to switch the built in LAN or WLAN capability from DTU communication to internet access and visa versa.

To launch *ETMobile Network Config* from Windows 7, use the "Start" button to select "All Programs->Argus Science->ETMobile->Tools-> ETMobile Network Config". To launch the application from Windows 10, use the "Start" button to select "All Programs->Argus Science->ETMobile Network Config"

Upon launch a pop up window will ask "Do you want to allow the following program to make changes to computer?". Select "YES".

The *ETMobile Network Config* dialog will appear, as shown below. Always make sure that *ETMobile* is closed before changing the LAN connection configuration. Simply click one of the buttons to set the labeled function.
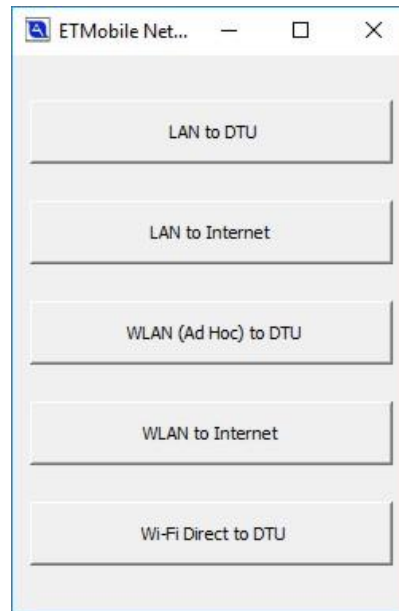
Note that the top two functions are mutually exclusive. The LAN port can be set to communicate either with the DTU or the Internet. Similarly, the next two choices (WLAN to DTU or WLAN to Internet) are mutually exclusive.

This application may be left open if desired, and it will show in the taskbar even if the dialogue window is minimized.

If using a "Win10 system", select "Wi-Fi Direct to DTU" to set the PC wireless function for connection the DTU.   If using a "Win 7 system", select 'WLAN (Ad Hoc) to DTU" to set the PC wireless function for connection the DTU. If the ETM system was originally shipped with a Windows 7 PC and later upgraded to Windows 10, see section 11.9 to decide whether "Wi-Fi Direct" or "WLAN (Ad Hoc)" is the appropriate choice for wireless connection to the DTU.

If running an *ETMobile* software version earlier than v 1.0.4.0, "Wi-Fi Direct" is not supported and the *ETMobile Network Configuration Dialog* will appear as below.
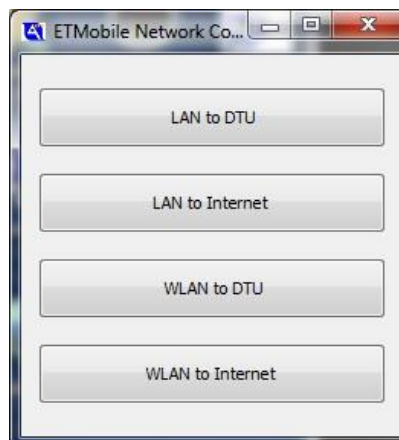
## 11.3.2 Manual Settings for the built in network (LAN) port

The PC network settings implemented by the *ETMobile Network Config* tool, as described in the previous section, can also be set manually using the Windows operating system dialogs.

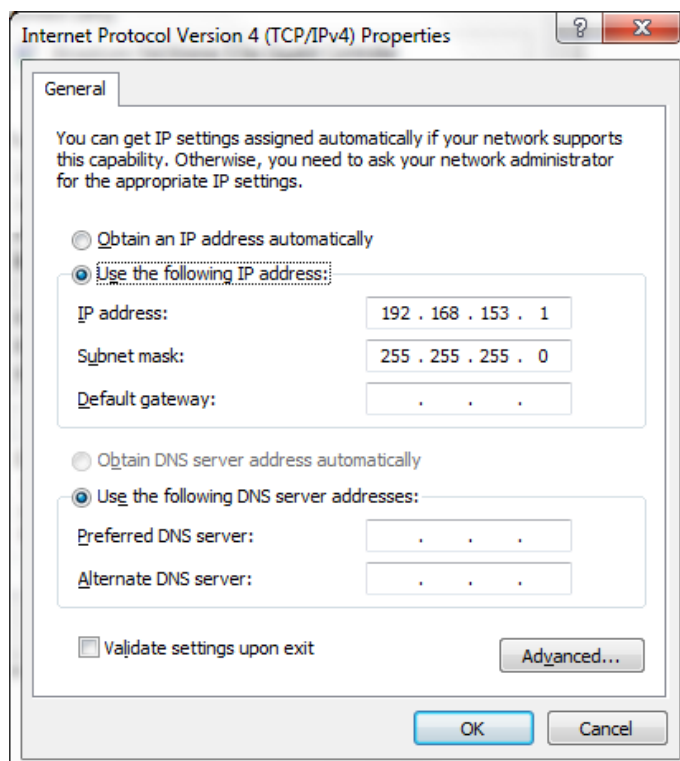Go to Control Panel -> Network And Internet -> Network and Sharing Center

On left side Menu, select "Change Adapter Settings", to bring up a dialog showing a "Local Area Connection" item.
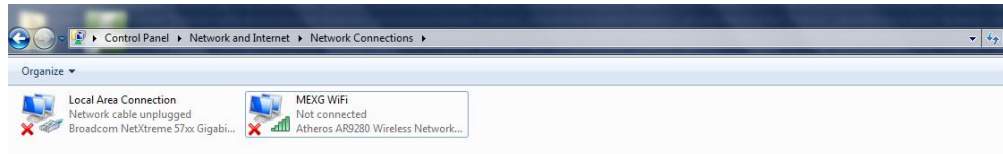
Right Click on "Local Area Connection" (LAN) to bring up the following dialog.
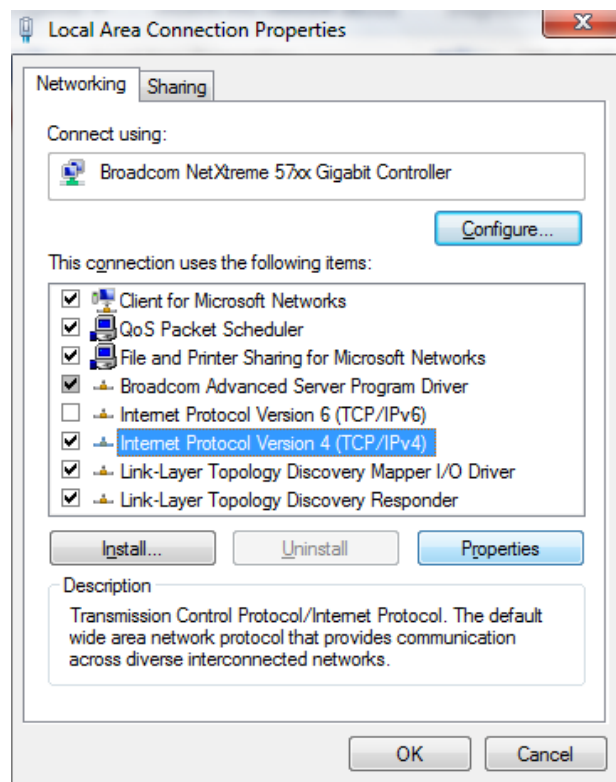
Highlight the "Internet Protocol Version 4 (TCP/Ipv4)" and choose Properties. The following dialogue will appear.
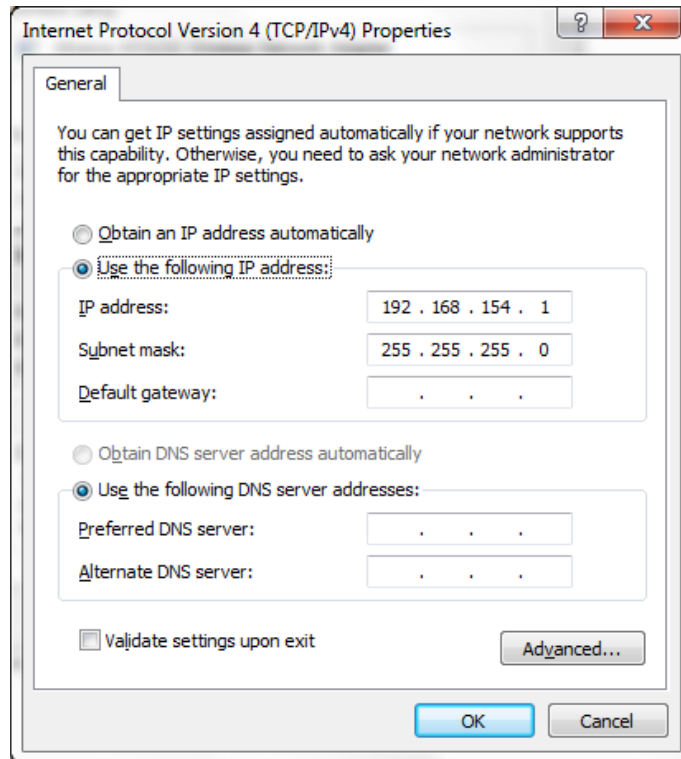

For communication with the DTU, the settings must be set exactly as shown above. Alternately, for Internet access, select "Obtain an IP address automatically". Note that while set to "Obtain an IP address automatically", the LAN port cannot be used for connection to the DTU.

11.3.3   Manual settings for built in wireless network communication

If the built in wireless card, on the ETMobile PC is to be used to talk to the Internet or some other external device, rather than the DTU, the wireless IPv4 properties can be manually changed to "Obtain an IP address automatically". (This is done automatically when the "WLAN to Internet" button is clicked on the *ETMobile Network Config* tool.)   Go to Change Adapter Settings as described in the previous section, right click on "ETM WiFi" and select Properties. Highlight the "Internet Protocol Version 4 (TCP/Ipv4)" and choose Properties. On the resulting dialog, set the radio button to "Obtain an IP address automatically".

To manually set the wireless IPv4 properties to enable Ad Hoc communication with the DTU (Win 7 system, or system that has been upgraded to Windows 10, but still uses Ad Hoc connection) use the same Internet Protocol Version 4 Properties dialog to set the IP address values shown below.

Only these specific IP address values will work for ETM wireless Ad Hoc communication with the DTU.

Note: If using multiple ETM's in the same area, specific IP address pairs will be set at the factory that may differ from these shown. Consult Argus Science for more information.

On Windows 10 systems configured for Wi-Fi Direct, if using wireless communication to the DTU, the IPv4 properties settings do not matter. There are some registry settings that affect this function, but Argus Science recommends that users not attempt to manually edit the Registry. Use the "Wi-Fi Direct to DTU" button on the *ETMobile Network Config* tool application to enable this function as described in section 11.3.1.

If unsure whether the system is configured for Ad Hoc or Wi-Fi Direct communication with the DTU, see manual section 11.9, or consult Argus Science.

11.4 Appendix D – SDHC Card Selection & Preparation

Argus provides a Pre-Formatted 16GB SDHC card with the delivery of each ETMobile system as recording media on the DTU.

If it is necessary to purchase additional SD cards, then the following is a list of Specifications and Preparation for each SD card to ensure maximum performance with the ETMobile.

Specification:

1. SDHC UHS-1 Card
2. Minimum 30 MB/s - 200X read/write speed
3. Class 10 or U1 Device (Labeled on Packaging)
4. Available as 4GB, 8GB, 16GB or 32GB

Recommended:

SanDisk "Extreme" family of SDHC Cards (Class10), SanDisk Part numbers:

1. 32GB: SDSDX3-032G-A31
2. 16GB: SDSDX3-016G-A31
3. 8GB: SDSDX3-008G-A31
4. 4GB: SDSDX3-004G-A31

SanDisk "Extreme Pro" family of SDHC Cards (U1), SanDisk Part numbers:

1. 32GB: SDSDXP1-032G-A75
2. 16GB: SDSDXP1-016G-A75
3. 8GB: SDSDXP1-008G-A75

Card Preparation:

1. Insert the SD card into the SD card reader slot of Laptop
2. Open SD as folder options
3. Right Click on Drive> Select "Properties">Select "Hardware" tab>Select "Properties">Select "Policies" tab>Select "Optimize for Performance". Close.
4. Right Click on Drive>Select "Format" (make sure to select the SD card!)>Select "NTFS" and as an option, you may add a name to the "Volume Label" (form example, "ETM").

The Card is now ready to be used with the ETMobile.

11.5 Appendix E – DTU Stand Installation and Use

An optional Stand Adapter is supplied with the ETMobile system that can be used as either a desktop stand or may be utilized to hold the SMU Optics set when creating an Environment Map.

Attaching the Stand Adapter to DTU:

1. The stand adapter has 2 attachment points, one is a "Pin" the other is a "Captive Thumbscrew". Fig 1 identifies these items on the Stand Adapter and Fig 2 shows the corresponding mounting points on the DTU.
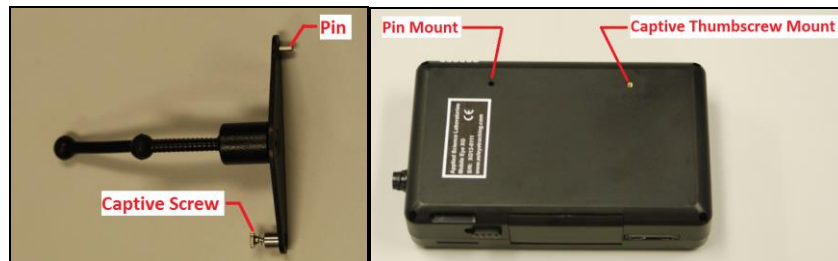

Fig 1   Fig 2

2. Insert the Pin of the Stand Adapter to the Pin Mount and then rotate the stand into place and secure with the Captive Thumbscrew. (Fig 3 and Fig 4)

Fig 3   Fig 4

To Use the Stand Adapter for creating an Environment Map, place the SMU on the top of the DTU with the Nosepiece placed on the shorter arm of the Stand Adapter. This allows for a stable platform to create the Environment Map while watching the scene image on the DTU as you create the Environment Map video. See Fig 5 for reference.

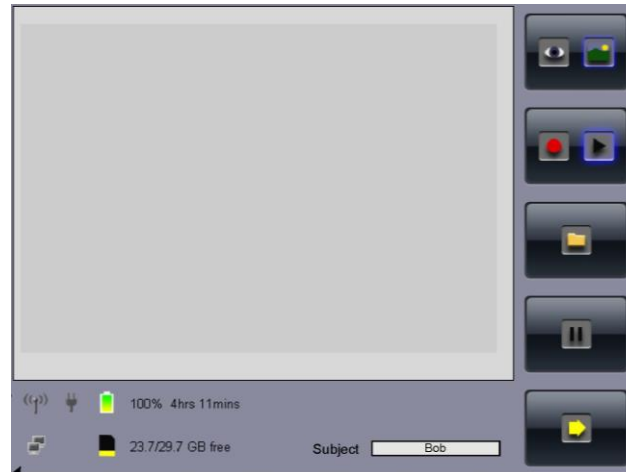

Fig 5

11.6 Appendix F - Subject Field

Fig 1

Fig 1 shows the initial power up screen. Note that there is a "Subject" field at the lower right.
This "Subject" name will be used when recording .avm files on the SD card of the DTU.
Tapping on this field will bring up the QWERTY keyboard so you may enter in the subjects
name or other unique identifiers.

Fig 2

Once the Subject field is invoked, you may enter a name or sequence for the subject using the
QWERTY Keyboard (Fig 2). When a satisfactory subject name is determined, select the "Enter"

key to save the subject name and close the QWERTY keyboard. The Black "X" will close
the keyboard without changing the name.

Some .avm naming conventions:

- You can select Lower or Upper case letter with the "Caps" key
- Leaving Subject Name empty will default to the previous time stamp naming convention
  for .avm files.
- The first recording with a new name will result in "name_00000.avm". The second
  recording, if the subject name is not changed, will increment by 1: "name_00001.avm"
  etc.
- Any displayed characters on the keyboard are legal entries.

11.7 Appendix G – DTU Carrying Case

The supplied ETMobile DTU carrying case is custom made for use with the ETMobile System.

Install or insert the DTU into the carry case by detaching the two Velcro straps at top of carry case and inserting the DTU into the carry case with Lan Connector Down. Access to the LAN, USB and Power Plug may be gained by opening the Velcro flap at bottom of DTU Carry Case.

Touch screen controls can easily be accessed by opening the access door as shown below:

There are three ways the DTU Carry Case may be configured:

1. **Back Pack Configuration**:
   The picture below shows a participant with the carry case in a backpack configuration. The supplied waist belt may be optionally used if the subject in engaged in a vigorous activity

2. **Lumbar Pack Configuration**:
   The picture, below, shows the carry pack in a lumbar pack configuration. Remove the shoulder straps and use the waist strap as the lumbar waist strap.

3. **Belt Loop Configuration**:
    The picture, below, shows the DTU carry case without any straps. The participants own belt
    is passed thru the webbing on rear of case

11.8   Appendix H – Software Upgrade

This procedure is to allow the upgrade of the *ETMobile* DTU from V1.0.3 or higher. If you have earlier DTU version than 1.0.3, please contact Argus Tech Support.

1. Configure a USB Flash Drive for automatic update:
   - Download the file ETM_DTU_Update_x_x_x.zip (where x.x.x.x is version number) from Link provided in accompanying email.
   - Right Click on file ETM_DTU_Update_x_x_x_x.zip and select "Extract All…" to your local drive. You should now have a folder "ETM_DTU_Update_x_x_x_x".
   - Open this folder and copy the "ETM_DTU_Update" folder (one folder down from the "ETM_DTU_Update_x_x_x_x" Folder) to any USB Flash Drive .
   - The USB Flash Drive should now contain a folder called ETM_DTU_Update which contains files "ETM_DTU_Update.dup", "ETM_DTU.exe" and possibly other files.
   - Note: The USB Flash Drive does not need to be formatted in any special way and it is OK to have other files on the USB Flash Drive.

2. Prepare the DTU for automatic Update:
   - Ensure the DTU is powered OFF
   - Ensure there are no computers running ETMobile software within wireless range
   - Ensure the Network LAN cable is NOT connected to the DTU
   - Ensure the SMU is NOT plugged into the DTU
   - Insert a SD card into the SD card slot (no files are written or deleted from SD card)
   - Power up the DTU normally and wait for main screen to appear

3. Initiate the Automatic Update
   - Insert the prepared USB Flash Drive in the USB port of the DTU
   - The system will begin an update process within 30 seconds
   - Wait for the DTU to Power down by itself

4. Complete the Automatic Update
   - With DTU Powered down, remove the USB Flash Drive from USB port of the DTU
   - Remove the SD card from DTU
   - Ensure that LAN cable and SMU cable are NOT plugged into DTU
   - Power up the DTU
   - The DTU will show a blue screen with system names and IP address information. Wait for this to time-out (20 seconds)
   - System will progress to the main screen and then go to a "Hibernation" process.
   - After Hibernation, DTU will automatically power down

5. Verify that upgrade was successful
   - You may now plug in the SMU and/or LAN if desired
   - Power Up DTU
   - When User Interface appears, go to system configuration page ("Wrench" Icon)

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- In top left corner of system config page, you should see the version that matches the version number of "ETM_DTU_Update_x_x_x.zip" from step 1

11.9 Appendix I – Type of Wi-Fi connection used for DTU-to-Computer Communication

The *ETMobile* PC and DTU (display and transmit unit) can communicate wirelessly, via a point-to-point wireless connection. Windows 10 allows use of a wireless point-to-point communication technique called Wi-Fi Direct. Windows 7 does not support Wi-Fi Direct and required use of an older type of point-to-point connection called Ad Hoc.

Recent *ETMobile* systems, shipped with Windows 10 PCs, use Wi-Fi Direct for wireless connection between the PC and DTU. Older systems, shipped with Windows 7 PCs, were configured to use the Ad Hoc type connection. Windows 10 is able to use either type of connection, but only the if PC is equipped with a wireless card that supports "Ad Hoc" as well as Wi-Fi Direct connections (most new wireless cards do not).

From the *ETMobile* user's point of view there is very little difference. With the older Ad Hoc connection use of multiple ETM systems in close proximity required that each DTU be set to a different channel number. With the newer Wi-Fi Direct system that is not required. When the *ETMobile Network Config* tool is used to set the PC for Wi-Fi communication with the DTU, the user has to specify a Wi-Fi Direct or Ad Hoc connection.

Generally, if the *ETMobile* PC is running Windows 10, it will use Wi-Fi Direct to communicate with the DTU and the user should follow the directions for "Win 10 systems". Conversely, if the ETMobile PC is running Windows 7, it will use an Ad Hoc connection to communicate with the DTU and the user should follow the directions for "Win 7 systems".

The exception may be some systems that were originally supplied as Windows 7 systems and on which the ETM PC was later upgraded to Windows 10. These systems may still be configured to use an Ad Hoc wireless connection even though the ETM PC is now running Windows 10. The easiest way to tell is to look at the DTU setup screen. If the DTU is configured for Ad Hoc wireless communication, the setup screen will show the wireless channel selection item. If this item is present on the DTU setup screen, the user should follow the "Win 7 system" instructions in manual sections 6.2.3, 9.4.14, and 11.3. If the channel selection item does not appear on the DTU setup screen, the DTU is setup for Wi-Fi Direct communication and the user should follow the "Win 10 system" instruction in these same sections. If unsure, consult Argus Science.