ET 3Space Manual
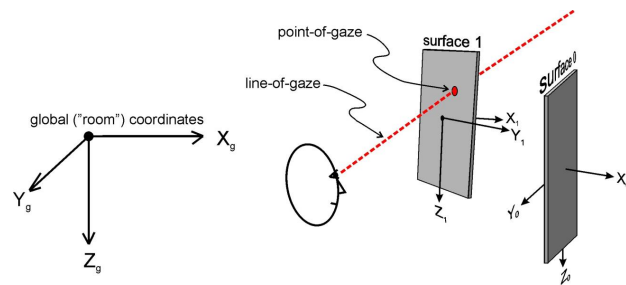
ET3SPACE WITH *ET MOBILE* WEARABLE OPTICS

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1. Introduction

The optional *ET3Space* feature for use with the *ETMobile* eye tracker (*ETMobile 3S*), enables integration of eye and head position data to compute point of gaze in a 3 dimensional ("3 space") environment. Line-of-gaze is computed with respect to a room fixed (or cockpit fixed) 3 dimensional scene space. The environment, within the scene space, is defined by a set of planes, consisting of one calibration plane and a variable number of additional, bounded planes. Point-of-gaze is computed to be the point at which line-of-gaze first intersects one of the defined surfaces within its boundaries.

The required hardware includes an *ETMobile* eye tracker system, a head tracker system, and other accessories to fasten a head tracking sensor to the subject's head gear and to help define the 3Space environment. The head tracker may be one of several commercially available systems (consult Argus Science for full list of possible head tracking systems). The other required accessories will vary depending on the type of head tracker used and the specific nature of the environment.

Required software is the standard *ETMobile* application with *ET3Space* option (*ETMobile 3S*), and the software that comes with the particular head tracking system to be used. The Argus *ETRemote* application is not required, but may be useful if the primary visual target is a display monitor (see *ETRemote* manual for details).

In most cases the ETM PC interfaces with the head tracker system via network or USB cable connection. Interface details depend on the type of head tracker being used.

This manual is for ETMobile software version 1.0.3.5 or higher.

2. Head Trackers

ETMobile 3S can interface to a number of head tracking systems. These include NDI *Polaris Spectra*, ART *Smarttrack*, Vicon *Nexus* and *Tracker*, Qualysis, Optitrack, Acension *Flock*, and others. They are all a bit different from each other. Some connect via RS232, some via USB, and some via network connection. Some require a separate PC to run the head tracker specific software and interface with the ETM PC, and some have software that can be run on the ETM PC along with the ETM application. In many cases Argus Science provides a manual or technical note to document connections and procedures specific to a particular head tracker system. Consult Argus Science for details.

Follow directions in ETM manual and manual or tech note for specific head tracker system, or consult Argus Science to make the proper physical connections.

If the head tracker requires a serial connection, a USB to serial adapter (such as Keyspan model USA19 HS) must be used to connect to the standard ETM laptop PC. If the head tracker communicates via network cable, and if the native network port on the ETM PC is being used for communication with ETM DTU, then a USB to network adapter will be needed.

All tracking systems that are compatible with ETMobile 3S measure the position and orientation of some object with respect to the environment. When used as a "head tracker" the object being tracked is attached to the head gear worn by the subject.

Magnetic tracking systems measure the position and orientation of a sensor (or "receiver") with respect to a stationary magnetic transmitter. Optical systems use a camera (or some sort of optical detector) to detect reflectors or small light emitters. These systems measure the position and orientation of some rigid structure containing multiple reflectors or emitters. Depending on the particular tracking system, the object being tracked may be referred to in the tracking system literature as "sensor", "rigid body", "object", "tracking tool", etc. In the ETM software and in this manual the object being tracked will usually be referred to as the "sensor". The tracking system measures the position and orientation of the sensor with respect to a room-fixed, Cartesian coordinate system defined by the head tracker system.   This will be referred to as the "global coordinate system".

3. Background

Before attempting to operate the *ET3Space* feature, it is necessary to understand some background concepts.

3.1 Reference Frames

The *ET3Space* "environment" consists of a "Global" (room fixed) coordinate system defined by the head tracker, and up to 20 surfaces of interest. These surfaces are assumed to be flat (although curved surfaces may be approximated as one or more flat surfaces), and are assumed to be fixed (not moving) with respect to the global coordinate system. Typical surfaces include monitor screens, keyboards, poster displays, slide screens, walls, etc.

All position and orientation information used by *ET3Space* is expressed with respect to either the global coordinate system or imaginary coordinate systems "attached" to surfaces, to the subject's head gear, or to sensors used by the head tracker system.

All coordinate systems used by *ET3Space*, including the global coordinate system, are "right handed" Cartesian coordinate systems. This means the coordinate axes are orthogonal to each other and have the relationship shown below.
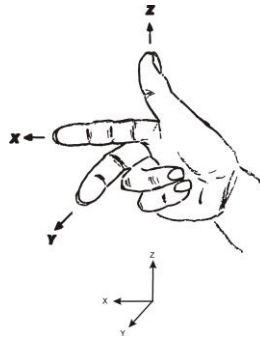
Orientation of one reference frame with respect to another is often expressed as a set of 3 "Euler" angles. When the axes are aligned, the angles are all zero. Other wise the angles describe 3 rotations that would be needed to align one with other. For instance head orientation is expressed as the set of rotations needed to move a coordinate frame aligned with global coordinates to an orientation aligned with the coordinates "attached" to the tracked object on the subject's headgear.

Rotation about the object Z axis, is considered to be "azimuth" (or "yaw") rotation; rotation about the object Y axis is "elevation" (or "pitch"); and rotation about the X axis is "roll". These angles are called "Euler" angles and, to uniquely describe an orientation, must be interpreted as having a

particular order. In this case, the order is azimuth, then elevation, and then roll. This concept is illustrated by sketch, below.
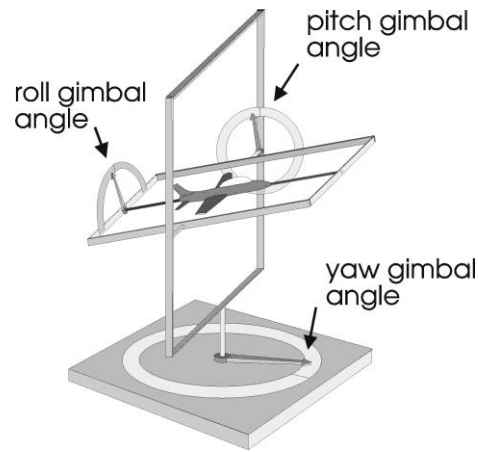
For use with *ET3Space*, the standard position and orientation for the global coordinate system and the calibration surface is shown below.
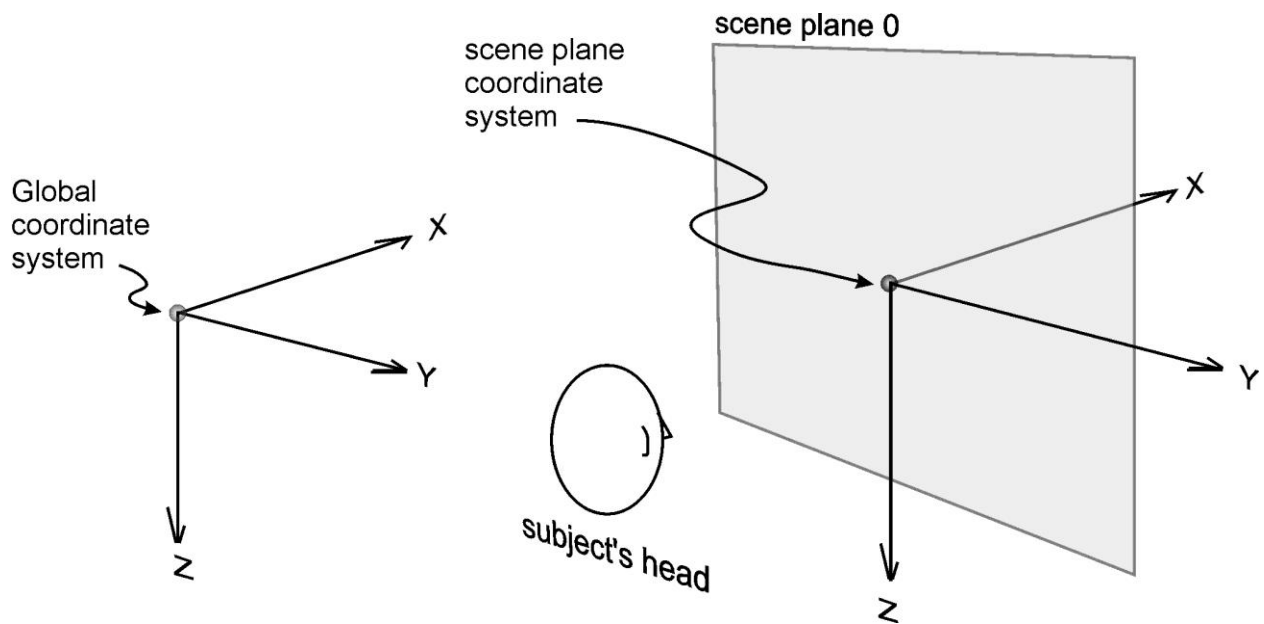
The origin is just behind the subject's central or standard position (usually the subject position during subject calibration and/or the position most central or usual during the subject's anticipated activities). The X axis points towards the direction faced by the subject and towards the calibration surface; the Y

axis points towards the subject's right, and the Z axis points down. (Note that his is consistent with the "right hand" convention diagramed above if the hand is rotated so that the thumb points down). The global coordinate system does not have to conform precisely to this standard, but it is highly recommended that it be a least approximately as described above. It is especially important that the Z axis point more or less down, as opposed to pointing up.

There is an exception to this recommended global reference frame orientation when one of the surfaces to be viewed is horizontal (floor, table top, etc.). ET3Space surfaces must not be parallel to the global reference frame X-Y plane. If there will be both vertical and horizontal surfaces, the global reference frame should tilt down a bit as shown below.
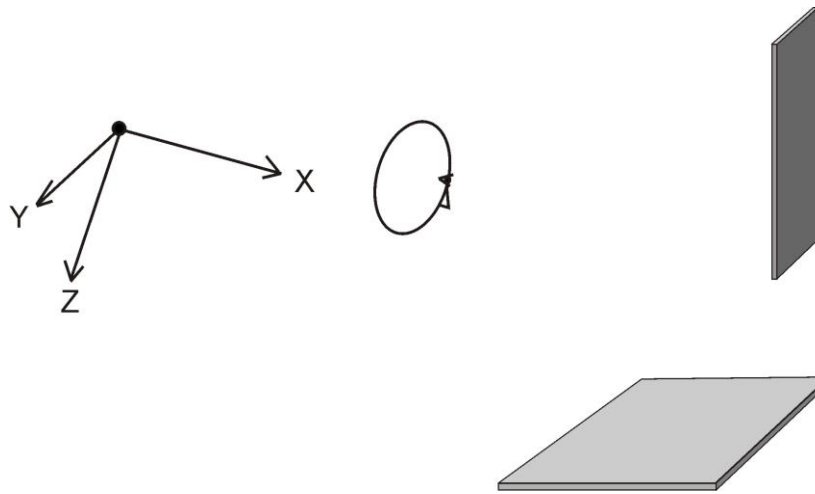
If there will be horizontal surfaces but no vertical surfaces, the global coordinates can, if desired, be rotated a full 90 degrees from the standard orientation so that the X axis points down and the Z axis points horizontally away from the subject.
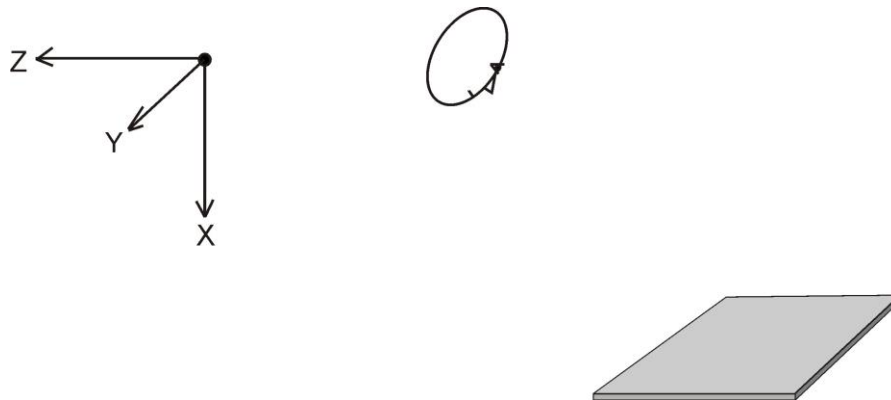
The tracking systems used as head trackers usually have the means to specify the Global coordinate system origin and the axes pointing directions, although the specific method for doing this is a bit different for each system. In the case of magnetic systems, the global origin is usually the center of the magnetic transmitter. In the case of optical systems, there is usually a procedure that involves placing an object, recognized by the tracker, at the desired origin point. Refer to the Argus Science manual describing use of the specific head tracker and to the tracker manufacturer's literature to find instructions for specifying the position and orientation of the global reference frame.

Before any *ET3Space* calculations can take place, all of the scene planes (flat surfaces) of interest must be defined to the *ET3Space* system. The procedures for doing this are described in the succeeding manual sections. However, before explaining the mechanics of entering environment information into the computer, the rules and theory for preparation of the physical environment are discussed below.

The surfaces in the environment must consist of a calibration surface (**plane 0**) and up to 20 additional scene planes.

Plane 0 must contain a set of 9 target points, arranged in a pattern of 3 rows and 3 columns as shown in the sketch, for the subject to fixate during an ET3Space subject calibration procedure (discussed in section 8). If possible, the calibration target points should cover an area that corresponds to 40-50 degrees of visual angle horizontally, and 30-40 degrees vertically, so that the subject's eye are exercised over a sufficient range of rotation. Furthermore, during the eye tracker calibration procedure, it is best if the vector from the subject's eye to the center target point (point 5) is roughly normal (perpendicular) to the surface, and point 5 is roughly in the center of the subject's field of view. In other words, the subject should be able to look at this surface "straight on" during calibration.
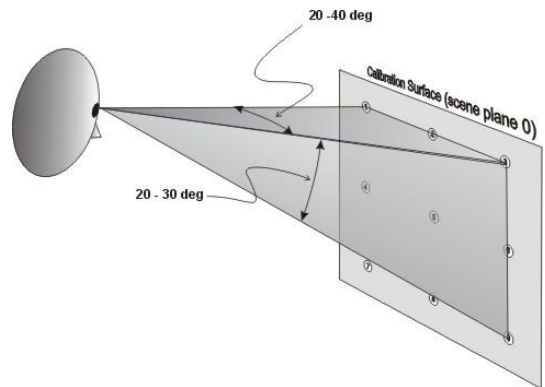
An imaginary coordinate frame must be assigned to each surface, including the calibration surface, as shown in the figure. The coordinate frame y-z axes must lie on the surface with y-axis units increasing to the right and z-axis units increasing from top to bottom. (The x-axis is normal to the surface) The y and z-axes will often be referred to as "horizontal" and "vertical" axes respectively. The nine target points must have known y-z coordinates in this frame, expressed in inches (or centimeters). It is **strongly suggested** (although not required) that eye calibration
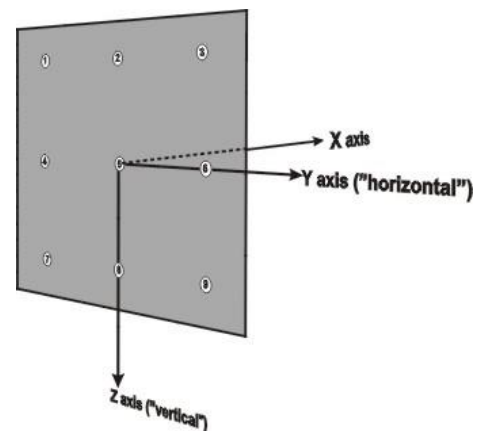
point 5 be at the origin of the calibration plane coordinate frame (y = 0, z = 0).

There are a couple of restrictions which all scene planes, including the calibration plane, must observe.

1. No surface may be parallel to the global coordinate frame X-Y plane.

2. No surface may be between the subject and the origin of the global reference frame.

All other designated scene surfaces must have an associated coordinate frame and must conform to the same guidelines as the calibration scene plane, with the following exceptions:

3. Whereas the calibration plane should be viewed "straight on" during calibration, other surfaces do not have this restriction.

4. Only the calibration plane need have nine eye calibration target points.

A rectangular boundary must also be determined for each scene plane, including the calibration plane, and is specified by a top, bottom, left, and right coordinates. The top coordinate is the z value at the top edge of the surface (minimum z value on the surface); the bottom coordinate is the z value at the bottom edge of the surface (max z value).

Similarly, left and right coordinates are the minimum and maximum y values. This boundary specifies the possible eye point of gaze intersection area for that scene plane. EXAMPLE: if the scene plane is a 17 inch monitor, the scene boundary coordinates might be Top - 8, Left - 8, Right 8, Bottom 8.

The calibration surface is designated as plane 0, and all other surfaces as planes 1 through 20. Point of gaze values will be specified as a plane number, a *y* (horizontal) value and a *z* (vertical) value. The *y-z* values will correspond to the coordinate frame that is attached to the designated plane as described above.

Three points must be chosen on each plane to enable the computer to define that plane relative to the Global Reference Frame. These will be referred to as "scene plane definition points", and are labeled A, B, and C. Looking towards the scene plane from the Global Reference Frame origin, the three points should have the relative positions shown in the drawing. Note that the three points form an "L" shape, with A at the lower right, B at the vertex, and C at the upper left.

The 3 point pattern should cover a large percent of the area on which gaze will be measured, and each point should be a visible
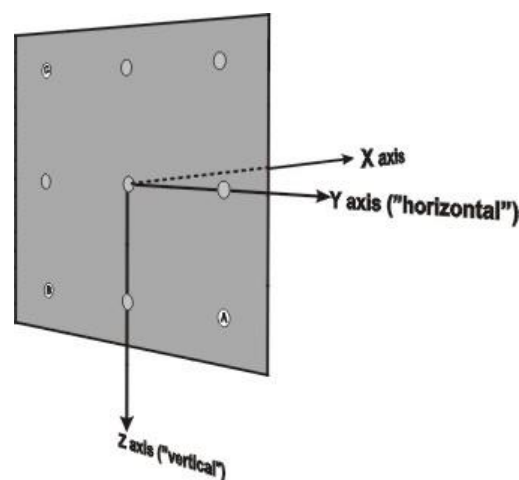
target or landmark on the surface. In the case of the calibration surface (plane 0), it is often most convenient to make Point A the lower right calibration point, point B the lower left calibration point, and point C the upper left calibration point. Other planes must simply adhere to the relative positioning described above. The scene plane coordinates of these points can be determined by measuring along the axes lines of the coordinate frame assigned to the surface.

In most cases, the "head tracker" system really tracks the position and orientation of a small object which, during normal operation, is attached to the subject's head gear. During parts of the environment set-up procedure, it may temporarily be mounted to a pointing device. Different position tracking systems refer to this object as "sensor", "rigid body", "object", "tracking tool", etc. In this document it will be referred to as the "sensor". There is an imaginary reference frame attached to the sensor, and the tracker system reports the position and orientation of this sensor coordinate system with respect to the global coordinate system. It is important to know the precise position and orientation of this coordinate frame on the sensor.

3.2 Computations and data

During normal operation the system will determine the location of the eye and the direction of the gaze vector with respect to the global coordinate system. It will then determine which scene plane surfaces are intersected by line-of-gaze.

Point of gaze is considered to be on the first scene plane intersected by line-of-gaze at a point within the scene plane boundaries. The line-of-gaze intersection point on that surface is considered to be the point-of-gaze, and point-of-gaze coordinates are reported with respect to the coordinate frame defined on that surface. If line-of-gaze does not intersect any scene plane within its boundaries, point-of-gaze is reported as the intersection point of line-of-gaze with an infinite extension of scene plane 0.

The scene plane number, point-of-gaze coordinates with respect to the scene plane coordinate frame, distance from the eye to the point of gaze, location of the eye with respect to the global coordinate system, and direction of the gaze vector with respect to the global coordinate frame can all included on data recorded by *ETMobile*, and all of these data can also be transmitted to an external device in real time. Only the scene plane number, point-of-gaze coordinates, and eye to point of gaze distance are displayed in real time by the *ETMobile 3Space* program.

On the *ETMobile 3S*, *Data Display Screen* (visible when ET3Space is enabled), the point-of-gaze coordinates are labeled "Hpos" (horizontal position) and "Vpos" (vertical position). The "horizontal", and "vertical" coordinates do not necessarily line up with true horizontal and vertical. In most cases, these are the axes that will people will naturally think of as "horizontal" and "vertical" directions on the surface; but, as explained in the previous section, they are really the coordinates along the scene plane y and z axes whatever the orientation of those axes. The distance from the eye to the point-of-gaze is labeled "Magn" (Magnitude).

The position of the eye in space is recorded (and/or transmitted to an external device) as 3 coordinate values specifying x, y, and z position with respect to the global coordinate frame. The direction of line-of-gaze is specified as 3 values that define a vector in the global coordinate frame. Line-of-gaze direction is always specified as a "unit vector", meaning its length (sqrt[$x^2+y^2+z^2$]) is always 1.
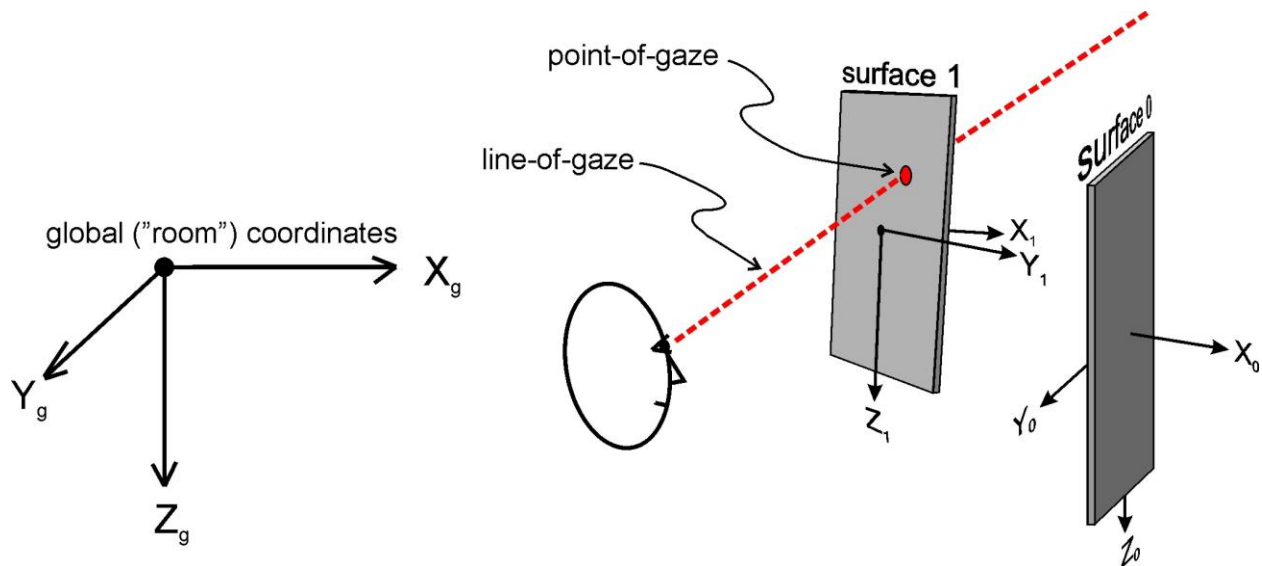
3.3 Units

The user can choose to specify *ET3Space* environment parameters in either English Standard, or Metric distance units. This choice is made on the *System Control Table, System Configuration* tab (shown in next section). Use the "Units" drop down menu to select either "inches" or "centimeters". Angles are always given in "degrees".

Whenever length values are entered on any dialog, the system will assume that they are being entered in the currently specified units (inches or centimeters). If the "Position Units" specification on the *System Configuration* dialog is changed, any values already entered will be converted to the new units.

4. ET3Space Software

The *ET3Space* is part of the *ETMobile* application and will already be installed on the ETM PC when delivered. Installation (if needed) and operation of the *ETMobile* application is described in the *ETMobile* manual.

Configuration and activation of the head tracker as well as environment set-up and activation of ET3Space are all initiated from the *ETMobile*, *System Configuration Table*, *System Configuration* tab.
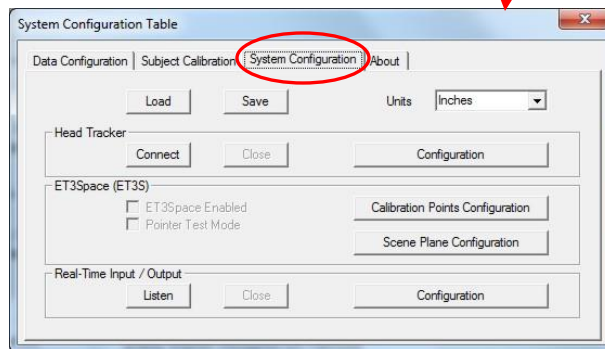
Real-time display of ET3Space Data will be on a *POG Display Screen* that is opened by clicking the "POG Display" button, in the "System" group box (bottom of right side panel on ETMobile window).
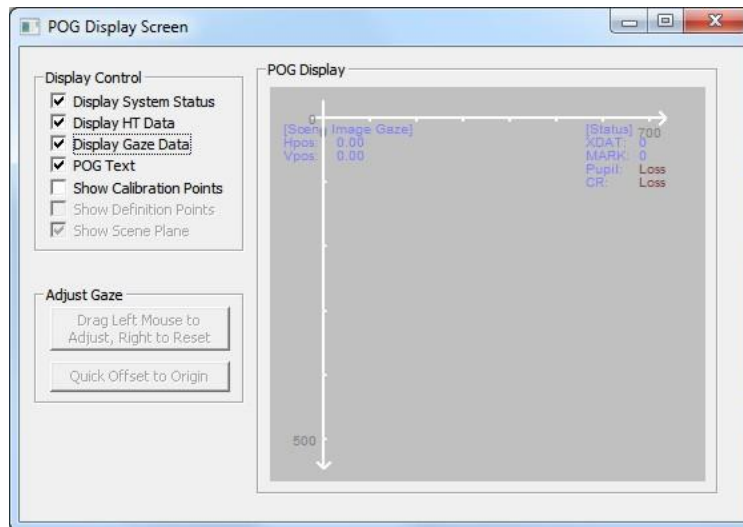
5. Enable communication with head tracker

Be sure the head tracker and eye tracker are properly connected. A separate manual or Tech Note is provided by Argus Science with instructions for specific use of *ET3Space* with each particular head tracker type.

Select the *System Configuration* tab on the *System Control Table* window (see previous section). If a head tracker is connected and has previously been configured, simply click the "Connect" button, in the "Head Tracker" box, to establish communication between the head tracker and the *ETMobile*.
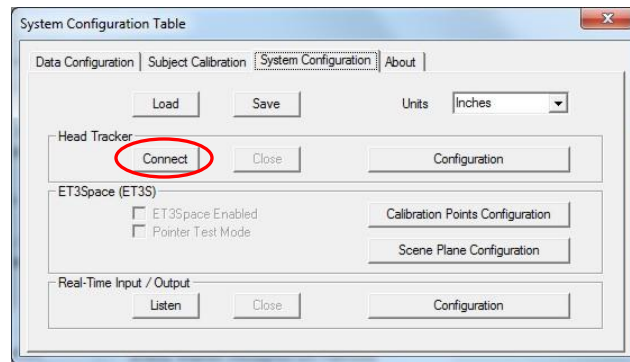
If successful, the "Connect" button will turn gray, and the "Close" button will become active. The "ET3Space Enabled" check box will also become active. If the *POG Display Screen* is open (see previous section), live head tracker data will appear on the *Data Display Screen*. The position units will be those indicated on the *System Configuration Table*, *System Configuration* tab dialog. Position values can be chosen to be either inches or centimeters. Orientation angles are always shown in degrees.

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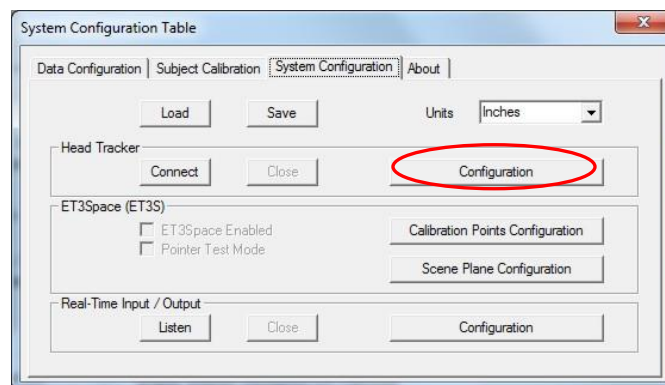
The Head Tracker configuration dialog will appear as shown below.
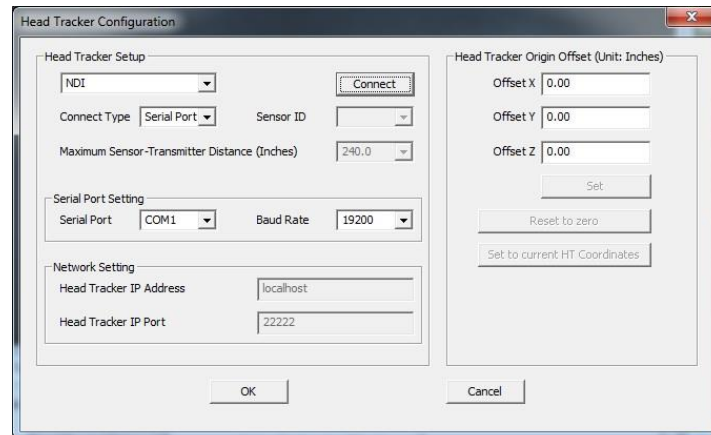
Choose the head tracker type and connection type from the drop-down menus. If a connection type is not supported for the chosen head tracker type, that selection will not be allowed. If the connection type is serial or network, associated RS232 or network parameters can be set. There is a manual or TechNote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

Assuming that the head tracker is properly connected, click the Connect button on the "Head Tracker Configuration" dialog, or click OK to close the "Head Tracker Configuration" dialog and click "Connect" on the *System Configuration* tab dialog. If communication with the head tracker is successfully established the "Connect" button will change to a "Close" button. If the *POG Display Screen* is open (see previous section), live head tracker data will appear on the *POG Display Screen.*

6. Configure ET3Space Environment

The "ET3Space (ET3S)" group on the "System Configuration" dialog has a check box to enable *ET3Space* mode, and 3 buttons that bring up dialogs used to specify the environment. The first of these dialogs is used to specify the location of calibration points on the calibration surface (scene plane 0); the next is used to specify the location and orientation of all scene plane surfaces; and the last is used to specify the relationship between scene plane reference frames and a stationary scene camera field of view.

If connected to a head tracker, check the "ET3Space enabled" box to enable the *ET3Space* mode. If the system is not yet communicating with a head tracker, this check box will be "grayed out". In this case, establish head tracker communication as described in the previous section, and then check the "ET3Space enabled" box.
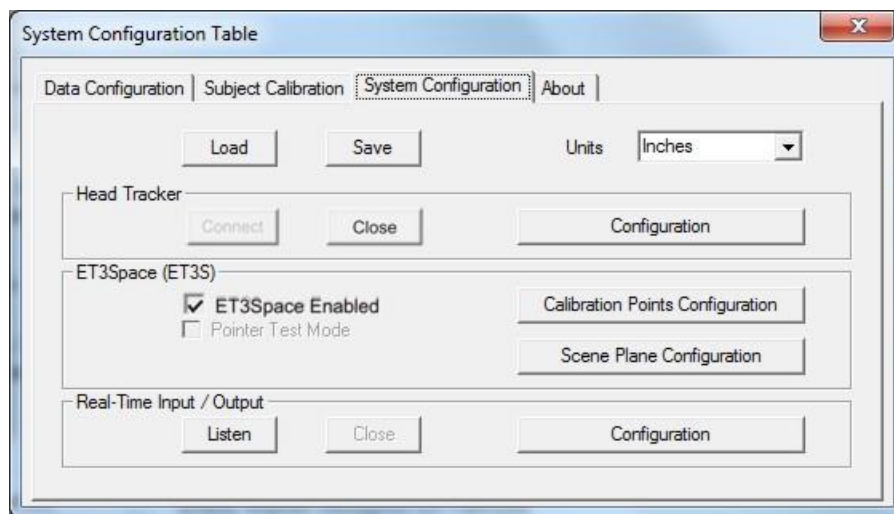
6.1 Calibration target points

In the "ET3Space (ET3S)" group box, click the "Calibration Points Configuration" button. A Calibration Points dialog will appear containing a box specify the number of calibration points that will be used, and table to specify the horizontal (y axis) and vertical (z axis) coordinates of each point.

ET3Space Calibration Points Configuration

Total Number of Calibration Points: 9

Use coordinates of Point 1 and Point 9 to calculate coordinates of rest Points — Auto Set

Calibration Point Positions in ET3Space Calibration Plane Coordinates (Unit: Inches)

Point	Horizontal (y)	Vertical (z)	Point	Horizontal (y)	Vertical (z)
1	-6.00	-6.00	11		
2	0.00	-6.00	12		
3	6.00	-6.00	13		
4	-6.00	0.00	14		
5	0.00	0.00	15		
6	6.00	0.00	16		
7	-6.00	6.00	17		
8	0.00	6.00	18		
9	6.00	6.00	19		
10			20		

OK   Cancel

As previously discussed, the recommended number of calibration points is nine, arranged in a pattern of 3 rows and 3 columns. If possible, the calibration target points should cover an area that corresponds to 40-50 degrees of visual angle horizontally, and 30-40 degrees vertically, so that the subject's eye are exercised over a sufficient range of rotation.

The calibration point positions are specified in units of inches or centimeters with respect to the Scene
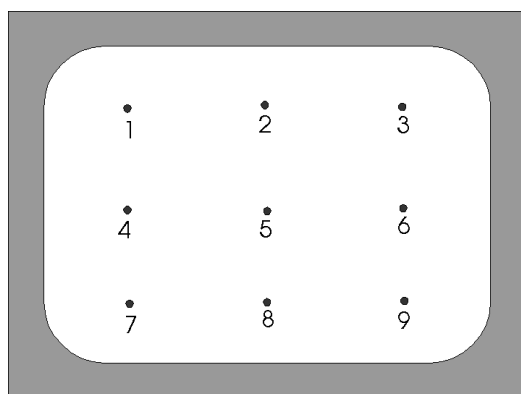
Plane 0 coordinate frame. Usually the origin of the coordinate frame is chosen to be the center of the calibration pattern (point 5 if the standard 9 point arrangement is used). Horizontal (Y) values are positive to the right. Vertical (Z) values are positive down. Therefore, if the standard 9 point pattern is used and if point 5 is defined as the origin (0, 0), calibration point 1, at upper left, will be (-,-); point

3, at upper right will be (+,-); point 9, at lower right will be (+,+); etc. Use a ruler or other measuring device to measure the true spacing between the points.

If the standard 9 point pattern is used and if horizontal spacing between all points is the same and vertical spacing between all points is the same (pattern is symmetrical about a vertical and horizontal axis), then simply type in the coordinates of point 1 and point 9, and click the "Auto Set" button to enter the others.

6.2 Scene Plane Configuration

To begin defining the position of each scene plane surface and coordinate frame attached to the surface click the "Scene Plane Configuration" button to open the *ET3Space Scene Plane Configuration* dialog.

Specify the scene plane to be defined by selecting its number from the drop down "Scene Plane" menu.   This is the "currently selected" scene plane. If doing this for the first time, Scene Plane 0 will be the only one on the list. When the highest existing scene plane is selected, the "Next" button will change to "New". To add an additional surface to the menu, click "New".   To delete an existing scene plane, select it and click "Delete". If it is not currently the highest number existing plane, the numbers of all higher number planes will be decremented by one.   The exception is plane 0. If plane 0 is deleted, it is immediately replaced by a "blank" plane 0, with all defined values cleared.

To define the scene plane in the most straight forward way, follow the steps on the dialog, in order of the numbered boxes on the dialog. Step 1 will establish the location of the three plane-definition-points ("A", "B", and "C") with respect to the global coordinate system. Step 2 will establish the location of the same 3 points with respect to the coordinate system "attached" to the scene plane. Step 3 will specify the boundaries of the scene plane surface. Step 4 is a manual adjustment factor that is not always needed, and is explained further on, in section 6.2.4.

Perform the steps as described in the following sub-sections for each surface in the "Scene Plane" list. Click "Next" to add a scene plane to the list, or "Delete" to remove a scene plane.   To make the surface currently selected (in the "Scene Plane" list) identical to another (same position, orientation, coordinate system, and boundaries), use the "Copy from" button.

To make the currently selected scene plane invisible, check the box labeled "Transparent".

If using many scene planes, it is suggested that after defining only one or two, click "OK" to close the *ET3Space Scene Plane Configuration* dialog, and use the "Pointer Test", described in section 6.3, to check that the procedure has worked correctly. Then open the dialog again and define additional surfaces. Click "OK" to close the dialog when all scene planes have been defined.

6.2.1 Determine Global Coordinates of scene plane definition points A, B, C

First, decide where the points will be on the surface as previously discussed in section 3.1. It is important that there be visible targets or landmarks at these points (stick on dots, or pieces of tape can be used if necessary). Use the first numbered box on the *ET3Space Scene Plane Configuration* dialog to determine the location of these points in the Global Coordinate system.

There are several methods available for determining the location of points "A", "B", and "C" in the global coordinate system. Most involve using the head tracker system to help do this.   Remember that the global coordinate system is defined by the head tracker system, and is the reference frame in which the tracking system reports positions and orientations. The methods available are listed in the pull down menu labeled "Select Method to Auto Detect". Most involve some sort of pointing device provided by Argus Science. The pointing device supplied by Argus, and the method recommended, generally depends on the type of head tracker that will be used and the characteristics of the intended

environment. Usually the recommended method is one of the first two listed, below. Consult Argus for specific advice about the best method for a particular situation.

If "Manual Data Entry" is selected, simply type the values in the provided table. For other methods, click the "Detect Point A, B, C Global Positions" button, and follow instructions on the dialog window that appears. The methods are described briefly below, and in more detail in section 12.

- **Laser Pointer** – The head tracker sensor is mounted to a free held laser pointer. The operator points the laser at each definition point (A, B, and C) from two different angles (from a position to the right of the surface and from a position to the left of the surface). The system computes the point at which the two laser lines meet to find the position of the point in the global reference frame.

- **Pointer wand** – The pointer wand is a freely moving rod. One end contains a mount to hold the tracking device sensor, while the other end has a pointed tip for touching surface points. The head tracker sensor attaches to the pointer in such a way that the sensor position and orientation define the location of the pointer tip in the global reference frame. The pointer tip is touched to each of the scene plane definition points to determine the point's position in the global reference frame. The sensor end of the wand must remain within the range of the tracking system operational field.

- **Gimbal laser** – This method is usually used only with magnetic tracking devices. The laser gimbal mechanism mounts around the HT Magnetic Transmitter device and allows a laser pointer to swing freely around the central point of the Transmitter. The head tracker Sensor is placed in a holder attached to the gimbal assembly. With this measurement method, the operator points the laser at the appropriate surface points and physically measures the distance from the end of the laser pointer to the surface point.

- **Place sensor directly on points** – With this method, the operator places the HT Sensor directly on the surface points, such that the sensor coordinate frame origin touches (or comes very close to) the point. All points must be within the range of the tracking device operational field.

- **Manual entry** – With this method, the operator types the spatial coordinates into the system manually.
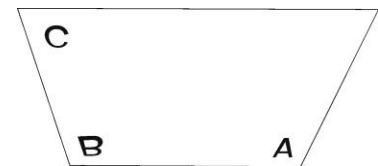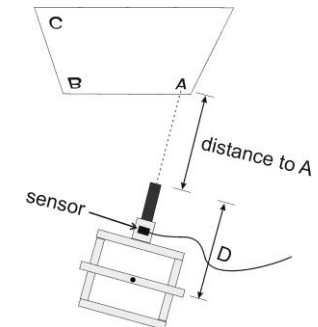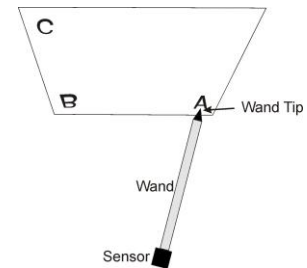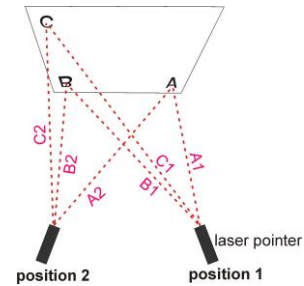
Point	X	Y	Z
A	40.18	7.38	3.13
B	40.05	-5.38	2.94
C	40.27	-5.06	-4.70

6.2.2 Determine Scene Plane Coordinates for definition points A, B, C

Use the second numbered box on the *ET3Space Scene Plane Configuration* dialog to specify points A, B, and C in scene plane coordinates. Remember that this is the coordinate system defined on the scene plane.

If it is the calibration surface (plane 0), and if the calibration point coordinates have already been entered (see section 6.1) then clicking "Auto Set" will enter the coordinates of the lower right, lower left and upper left calibration points as A, B, and C.

For other planes the coordinates can simply be typed in if they have been determined by measurement. Alternately, if the coordinates are typed in for point A, and if line AB is parallel to the Y (horizontal) axis of the scene plane coordinate system, the "Set B C" button can be clicked to make the program compute the scene plane coordinates of B and C from their Global coordinates (determined as described in the previous section).

Hint: even if the coordinates of all three points are known, it is useful to use the "Set B C" button to check the computed coordinates for B and C. Although the computed values will never come out precisely the same as the measured values (there is some noise and error in the head tracker system), they should be reasonably close. If the values seem very different from measured values, repeat the procedure for determining Global coordinates (see previous section).

6.2.3 Set the Scene Plane Boundaries

Using the third numbered box on the *ET3Space Scene Plane Configuration* dialog, specify the scene plane boundaries. Click "Auto Set" to specify boundaries 20% larger than the rectangle that would just enclose the definition points ("A", "B", "C"), or type in boundary coordinates. The boundaries are specified with respect to the scene plane coordinates (the imaginary coordinate frame attached to the scene plane surface).

ET3Space boundary for scene plane

in example shown, boundaries are:
Left = - *l*   Right = + *r*
Top = - *t*   Bottom = + *b*
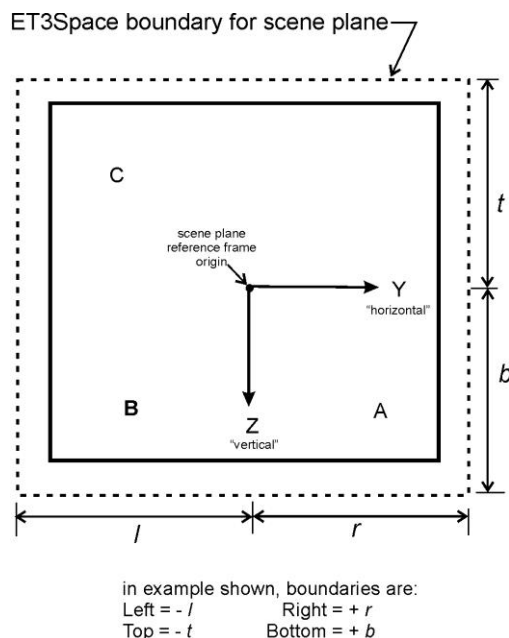
If there is no other visual target near the an edge of the physical surface, it is suggested that the *ET3Space* boundary specified for that edge be a bit beyond the physical edge of the surface. This will lessen the chance that a small measurement error will cause gaze to be reported as off the surface when it is really just very close to the edge. Of course if two surfaces of interest touch, the real physical boundary must be specified.

6.2.4 Manual Offset Correction

Since the process of defining the each scene plane involves some manual measurements, and use of a tracking device that will always have some noise and error, there is likely to be some error in the result even if great care is taken. The Manual Offsets, at the bottom the *ET3Space Scene Plane Configuration* dialog, can be used to remove any systematic offset error. Gaze measurements determined to be on a particular scene plane will be shifted by the amount specified. Different manual offset corrections can be specified for each scene plane.

When scene planes are first defined, as discussed in the preceding sections, the manual offsets should be set to zero. Later on, the amount of error, if any, can be determined as a result of the pointer test procedure discussed in section 6.3 and by observing data after subject calibration. Methods for determining offset error, and entering the corresponding correction are discussed in section 8.2.

6.3 Checking Environment Configuration with "Pointer Test"

The laser pointer or pointer wand tool can be used to test *ET3Space* environment configuration with out a human subject.

Fasten the head tracker sensor to the laser pointer or pointer wand. If the laser pointer or pointer wand have just been used for environment configuration, the sensor will already be attached. If the system has most recently been used with a subject, the sensor will need to be removed from the eye tracker head gear and attached to the pointer device. The method of attachment is a bit different for each type of head tracker device. Refer to the Argus Science manual documenting use of the particular head tracker type being used.

Be sure that a head tracker is enabled and communicating with *ETMobile*, that an *ET3Space* environment has been configured as described in the previous sections, and that *ET3Space* is enabled ("ET3Space Enabled" check box is checked).

On the *System Configuration* tab of the *System Control Table* check the box labeled "Pointer Test". A prompt will appear to "Point at the origin of scene plane 0". (Note that if the usual 9 point calibration pattern is being used this will be calibration point 5.) Hold the pointing device approximately where the subject's head will be, aim the laser at the scene plane 0 origin or touch the origin with the wand tip, and click OK. This will often require two people, one to hold the pointer and another to operate the computer mouse; although a single person can do it if the pointer device is supported by a tripod. Be sure that the head tracker is functioning properly, and actually reporting the sensor position when OK is clicked .

The scene plane number and gaze coordinates displayed at the upper left of *POG Display Screen* "POG Dispay" area, as well as the position of the POG cursor plotted in the "POG Display" area, should correspond to the point being indicated by the laser or the wand pointer tip. If a stationary scene camera has been configured and is enabled, a POG cursor (large blue cross) should indicate the proper spot on the *Scene Image Screen* whenever the pointer is aimed at surface visible to the camera.

Test by pointing to the origin and all calibration points on plane zero, and to the origin and points A, B, and C on other scene planes. Also point to other landmarks visible on the SSC or with known coordinates that can be observed on the *Data Display Screen*.

There will sometimes be a small offset in the data, especially on surfaces other than the calibration surface. The gaze data may report a point that is, for example, always the same small amount to the right of the actual aim point. Such offset errors can be quickly corrected as follows.

Point the laser or touch the wand tip to the origin of the scene plane in question. Verify, on the *POG Display Screen*, that the system is detecting gaze on that scene plane; and click the *POG Display*

Screen button labeled "Quick Offset to Origin". The appropriate data offset will automatically be entered to place gaze at the scene plane origin.

Alternately, point the laser or wand at any visible landmark on the scene plane, click the button labeled "Drag Left Mouse Button to Adjust" and left drag in the *POG Display* area. Observe either the Data Display Screen POG cursor or the Stationary Scene Image cursor, and drag it to the correct position. Note that this affects only ET3Space data on the scene plane on which the system currently detects point of gaze. Note also that the "Drag Left Mouse Button to Adjust" button will remain depressed. Click it again to deactivate this functionality (to prevent introducing offsets by accidently dragging the mouse in the POG Display area).

6.4 Environment Configuration Backup

When the *ETMobile* program is closed, the Head Tracker configuration, *ET3Space* environment specification, and Network Interface configuration are automatically saved, and restored next time the program is opened.   This data can also be explicitly saved, at any time, by the user, in a user named XML type file.   Configuration files saved in this way can be re-loaded by the user at any time.

To save configuration data click the "Save" button on the *System Configuration Table*, *System Configuration* tab. The system will default to a file name consisting of "cfg_" followed by the current date and time, and in the current directory. Use the normal browser function to change the file name and path if desired.   The "xml" extension should be retained. To re-load that configuration information at a later time, click the "Load" button, on the same dialog, and browse to the saved file.

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

7. Sensor-to-Eye Vector

The head tracker system reports the position and orientation of an object ("sensor") that is mounted to the headgear worn by the subject.   More specifically, it reports the position and orientation of an imaginary coordinate system that is attached to the sensor with respect to the global (room fixed) coordinate system. Usually the sensor coordinate system has an origin that is located somewhere on the sensor object., and it is the position of this point that is reported to the eyetracker.

The information really needed for *ET3Space* computations is the location of the eye, rather than the location of the sensor.   One of the *ET3Space* parameters is a "sensor-to-eye" vector which tells the system where the eye is with respect to the sensor coordinate frame. If the vector that connects the sensor coordinate frame origin to the eye is known, the system can use information about the sensor position and orientation to compute the position of the subject's eye. Procedures for specifying this vector vary somewhat depending on the type of head tracker being used.

Before calibrating a subject be sure the sensor to eye vector has been properly set using one of the methods described below. Refer to the Argus Science manual or Tech Note for *ET3Space* operation with the particular head tracker being used to find the recommended method for that system.

7.1 Manual Entry of Sensor to Eye Vector

In some cases it will most efficient to compute a sensor-to-eye vector for a single "standard" subject, and then continue to use the same values for everybody.   There will be differences from subject to subject as well as for variations of head gear orientation on the same subject. For example the system might sometimes behave as though the eye were up under the eye brow, or too near the bridge of the nose, etc. However, those deviations from true eye location will usually be very small compared to the distance from the eye to the point of gaze, and will call little or no error in the point-of-gaze computation.

When Argus Science supplies head gear with a fixed mounting position for a particular type of sensor, x, y, and z values for a standard sensor-to-eye vector are also supplied (usually on a stick-on label on the head gear). This standard
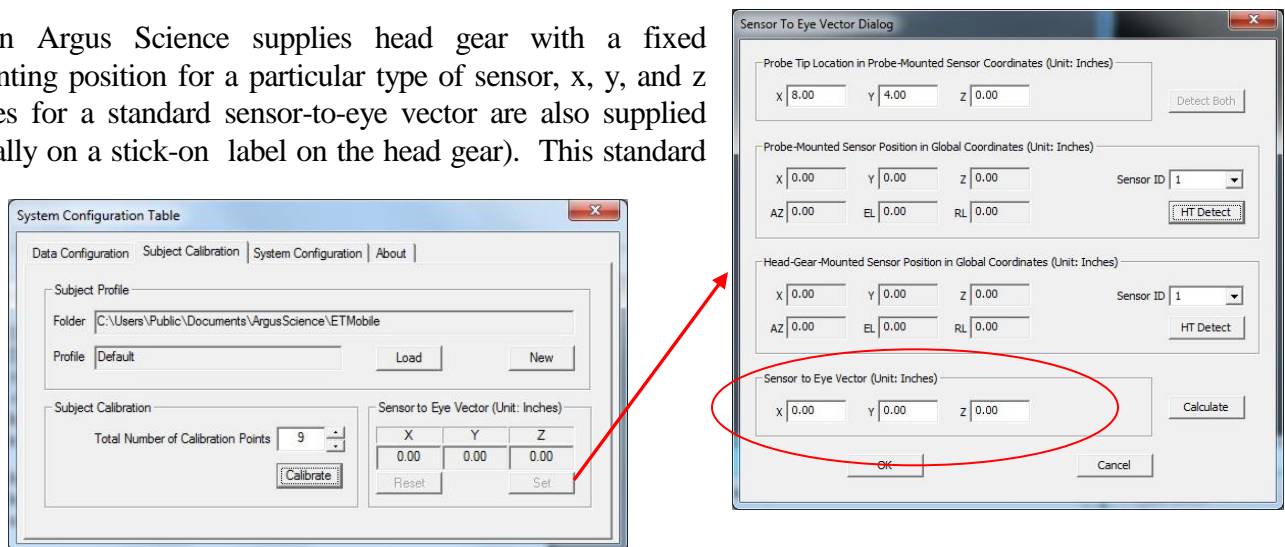
vector can be used for all subjects, as just described. From the *System Control Table*, *Subject Calibration* tab, click "Set" in the "Sensor to Eye Vector" group box. On the resulting *Sensor To Eye Vector* dialog, type the vector X, Y, and Z coordinate values in the group box, at the bottom, labeled "Sensor to Eye Vector". Ignore the other items on the dialog and click OK to close.

7.2 Using the Head Tracker system for computation of sensor-to-eye vector

With some head tracking systems there is very convenient way to quickly designate the sensor-to-eye vector for each subject, before subject calibration. Sometimes the tracking system provides a means to quickly place the sensor coordinate frame origin at the eye, rather than on the sensor object itself. In this case, the *ET3Space* sensor-to-eye vector is set to zero since the information received from the head tracker will be the eye location. Type in zeros for X, Y, and Z components of the "Sensor to Eye Vector" on the *Sensor To Eye Vector* dialog.

With other systems the eye tracker can receive data simultaneously from two different sensor objects, one fastened to the head gear, and another fastened to a pointing tool. The pointer tool (or "probe") tip is held close to the eye, and *ET3Space* computes the vector from the sensor origin to the probe tip.

- Bring up the *Sensor To Eye Vector* Dialog (click "Set" on the *System Control Table*, *Subject Calibraton* tab), and enter the probe tip position in the top group box. Consult the Argus Science document for the particular head tracker being used to find a description of the probe provided for that tracker system and the tip location coordinates.

- Use the drop down "Sensor ID" menus to select the sensor fastened to the probe and the sensor fastened to the head gear.

- **Have the subject close his/her eyes**. Have one person hold the probe near, but not touching, the front of the eye being tracked, and have another person click the "Detect Both" button at the top right of the dialog. Click "Calculate", at the bottom of the dialog to compute the sensor-to-eye vector, and click OK to close the dialog.

CAUTION: *The probes provided by ASL are always designed so that the tip section can point towards the nose (parallel to the plane of the face), rather than towards the eye.* **Never aim the tip towards the eye.** *Support the probe tip with one hand as shown in the photo. It is not necessary for the tip to be closer than about ½ inch (about 1 cm) from the front of the eye.* <u>*Subjects should always have their eyes closed when the probe is used*</u>*.*

The Photo shows MobileEye optics mounted to a headband containing the rigid body object mount. Usually the head band contains just the head tracker rigid body and the MobileEye optics, mounted to the usual safety glasses frames, are completely separate. In this case, the procedure shown here (set sensor-to-eye vector) can be performed <u>before</u> the subject puts on the MobileEye glasses. It is only necessary that the subject be wearing the head band with the rigid body mount.

8. Subject Calibration

8.1 Performing the Calibration

The calibration target points must be visible to the subject on the surface designated as "Scene Plane 0". The location of these points is specified as part of the *ET3Space* environment configuration procedure. The environment configuration procedure, as described in section 4 of this manual, must be completed before calibrating a subject. There must also be a valid "sensor-to-eye vector" specified, as described in the previous section. *ET3Space* must be enabled ("ET3Space enabled" check box on the *System Configuration* tab of the *System Control Table* dialog).

Adjust the *ETMobile* optics and obtain proper pupil and spot (CR) recognition as described in the *ET3Space* manual.

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 the *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.

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

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

1. **On the *Subject Calibration* tab of In the *System Control Table* click the "Calibrate button".** The button label will change to "Finish". Set the "Video Display" to "Scene" ("Scene" button in "Video Display" group box, at upper right of ETMobile screen). Note that when the mouse arrow is hovered over the scene image display, the number of the current

calibration point (point the subject is expected to fixate) is displayed under the mouse arrow. Initially, this should be point 1 (upper left on the standard 9 point pattern).

2. **Ask the subject to look at the point indicated by the number shown under the mouse arrow,** use the purple pupil/spot overlay display to check that both the spot and pupil are being found reliably. **Left click the image of calibration point 1 on the head mounted scene camera image**. Data for the point is entered at the mouse click. It is important that the mouse arrow is accurately pointing at the target point image.

3. **If the data is accepted by the system a green cross will appear** at the indicated spot on the scene image, as well as on the Data display, and the calibration point number, displayed under the mouse arrow, will advance.

4. **If data is not accepted a yellow cross appears at the indicated spot, and the calibration point number does not advance**. This means that either the pupil or the CR was not recognized or recognition was too noisy.

5. **If repeated left clicks do not result in a green cross**, try having the subject rotate their head a very small amount (about 5 degrees) in some direction and try again. **If still not successful** after several small movements in different directions (red cross appears), **either right click to skip the point**, and proceed to step 7 below; **or abort the calibration and attempt to improve feature recognition** before repeating the procedure. In the latter case, click "Finish" to abort the current calibration, and follow the directions in the *ETMobile* manual to position and focus the eye image, and to adjust the Pupil and Spot threshold settings.

   If a right click is used to skip the point, the yellow cross will turn red and the point number (displayed under the mouse arrow) will advance. Do not attempt to move on to the next point without first right clicking to skip the current point. The prompt under the mouse arrow must correctly indicate the point that the subject is attempting to fixate.

6. **With the subject attempting to maintain the same head position, repeat steps 2 – 6 for all calibration target points.**

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

8. If desired, **re-enter data for any calibration point** by asking the subject to fixate that point, and left clicking on its image.

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

Note that points can be skipped by right clicking. In this case the program will compute the best calibration possible using data from the remaining target points. It is best to use all 9 if possible, but acceptable calibration can often be obtained even if a small number of points are skipped.

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

8.2 Checking the Calibration

To confirm accuracy of calibration, ask the subject to look at each target point again. At each point note the position of the point-of-gaze cursor or cross hairs on the scene monitor, and, in the case of *ET3Space*, on the *Data Display Screen*. Each target point position should be correctly indicated to within about 1-degree visual angle.
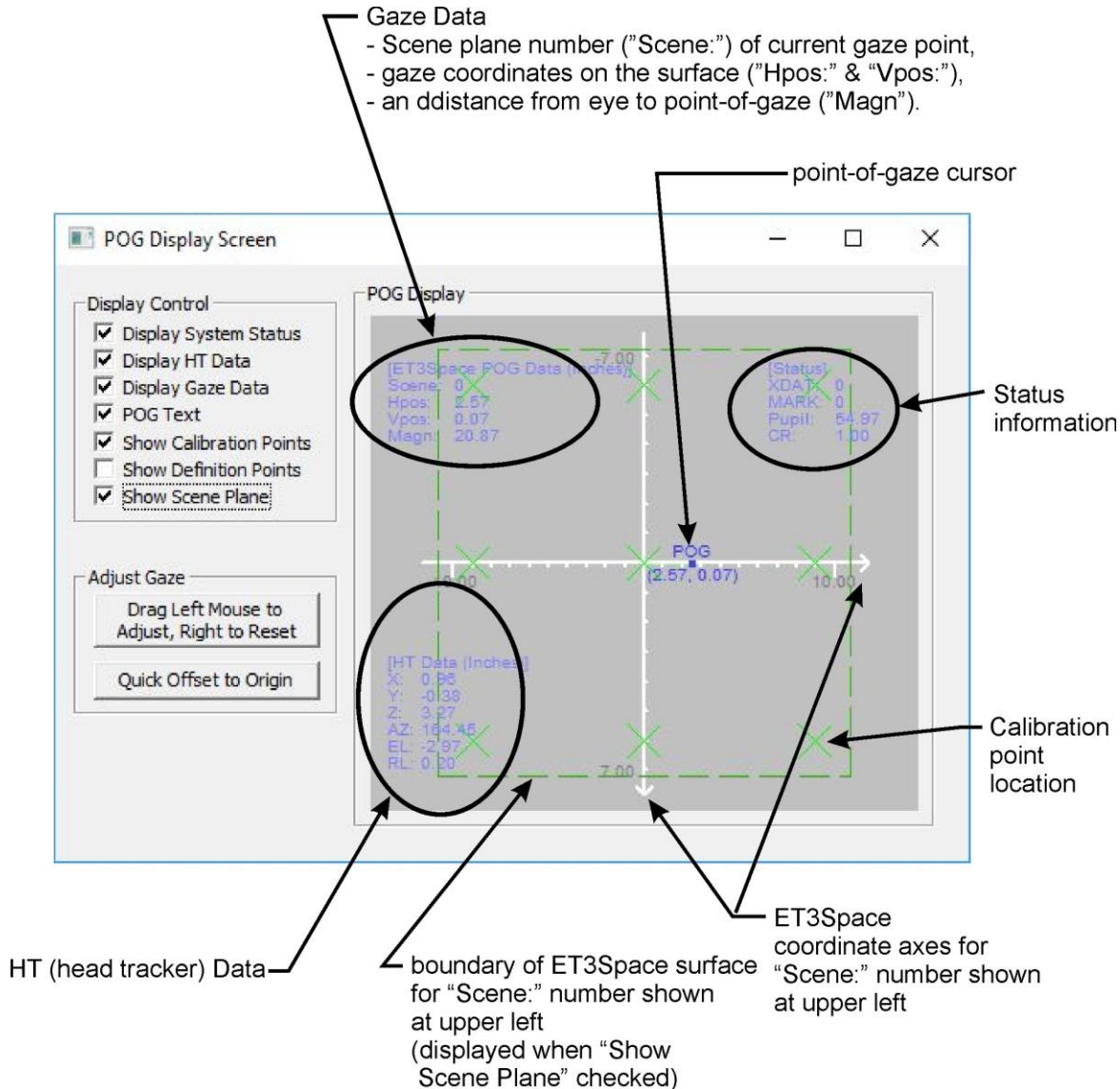
If one or more target points are not correctly indicated repeat the calibration procedure.

If using *ET3Space*, be sure to note performance on the *POG Display Screen* as well as the head mounted scene camera display. Discrepancies between these results can provide a clue to the source of the error. For example, error on the scene video display might mean that calibration needs to be repeated. Error on the *POG Display Screen*, but not on the scene video display, might signal an error in *ET3Space* environment set-up, or a problem with the head tracker.

Any error caused by poor subject calibration will show up when the subject looks at the plane 0 calibration points. If the ET3Space measurement (as shown on the *POG Display Screen*, is accurate on plane 0 but has more error on other scene planes, this is will not be improved by repeating the subject calibration. Large errors only on scene planes other than plane 0 may indicate some error or inaccuracy in *ET3Space* environment set-up. Some variation in offset error between scene planes is expected and can be quickly corrected as described in section 9.3.

9. POG Display Screen

The *POG Display Screen* displays the digital data available from the *ET3space* function as well as a graphical point-of-gaze (POG) display.   A set of check boxes on the *POG Display Screen* determine display content.   In addition, the *POG Display Screen* contains controls for entering manual offset corrections to the point-of-gaze data.

Gaze Data
- Scene plane number ("Scene:") of current gaze point,
- gaze coordinates on the surface ("Hpos:" & "Vpos:"),
- an ddistance from eye to point-of-gaze ("Magn").

point-of-gaze cursor

Status information

Calibration point location

ET3Space coordinate axes for "Scene:" number shown at upper left

boundary of ET3Space surface for "Scene:" number shown at upper left (displayed when "Show Scene Plane" checked)

HT (head tracker) Data

9.1 POG Display Screen "Display Control" Group

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

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

The remaining check boxes control graphic display elements.

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

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

The "Stationary Scene Camera Mapping Points" are the 4 points on each scene plane used, as part of the *ET3space* setup procedure, to relate the Scene Plane coordinates to the corresponding scene camera pixel coordinates.   These are plotted as green crosses on the Stationary Scene Camera Image and are shown as green X's for the current scene plane on the POG Display plot.

9.2 POG Display Screen "POG Display" area

The POG Display area plots point-of-gaze as a moving spot on a display area that represents the current scene plane surface.   If "POG text" is checked, digital horizontal and vertical coordinate values will appear just below the POG dot and travel with it. These values are in the form "*(h, v)*", where *h* is the horizontal coordinate and *v* is the vertical. In *ET3Space* mode, *h* and *v* correspond to the *y* and *z* axes of the scene plane coordinate system.

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

If the manual offset function has not been enabled (see section 9.3), the mouse can be used to left drag the axes display origin to different positions on the display area. The mouse wheel can be used to zoon in or out. Right dragging the mouse in the area restores default origin position and zoom.

9.3 Manual Offset Correction

There will sometimes be a small offset in the data, especially on surfaces other than the calibration surface. The gaze data may report a point that is, for example, always the same small amount to the right of the actual aim point. There is a means to quickly correct offset errors (errors of approximately the same direction and size over the entire field) without needing to repeat the subject calibration procedure.

ET3Space has a separate manual offset correction capability for each scene plane. There is a way to drag the POG cursor to make the correction, and also a place to type in a manual offset correction value on the set-up dialog for each scene plane.

If *ETServer* is enabled, the *POG Display Screen* will show the number of the scene plane on which gaze is currently detected, and the point-of-gaze with respect to that scene plane. If point of gaze on any particular scene plane appears to have an offset error (error of about the same amount and direction over whole surface), it can be corrected by the following methods.

To correct an offset by dragging the POG, click the *POG Display Screen* button labeled "Drag Left Mouse Button to Adjust" and left drag in the "POG Display" area. Observe either the *Data Display Screen* POG cursor or the Stationary Scene Camera image cursor (on the *Scene Image Screen*), and drag it to the correct position. When the "Drag Left Mouse Button to Adjust" is on, the offsets can be reset to zero by dragging with the right mouse button in the "POG Display" area.

Note that when the "Drag Left Mouse Button to Adjust" feature is on, the mouse cannot be used to adjust the scale and origin of the *POG Display* area graphics. These capabilities are restored when the "Drag Left Mouse Button to Adjust" feature turned off. To disable the "Drag Left Mouse Button to Adjust" function (turn the feature "off"), and protect against accidently creating offsets, click the button to un-depress it.

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

Note that the above methods affect only the scene plane on which the system currently detects point of gaze, and affects only *ET3Space* data. The POG cursor on the head mounted scene camera image will not be affected. Offset adjustments can also be made to correct the POG cursor on the scene camera image using the "Shift Gaze" button, and this is described in the *ETMobile* manual.

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

10. Data Collection

Digital data and video file recording by the *ETMobile* program is described in the *ETMobile* manual, and the procedure is the same when ET3Space is in use. The difference is that when ET3Space is enabled, the digital data file will be given an "ehd" extension (instead of "eyd"), and additional data items will be available for recording.

In addition to the data items described in the ETMobile manual, head position and orientation data is available from the head tracker, and the results of the ET3Space computations are available. The latter include the number of the scene plane on which each gaze sample is calculated to fall, the y ("horizontal") and z ("vertical") coordinates of gaze with respect to the scene plane coordinate frame defined for that surface, the distance of the eye from the point of gaze, the position of the eye with respect to the global reference frame, and the direction of gaze with respect to the global reference frame.

The video (.avi) file will be exactly the same whether or not ET3Space is enabled.

File names will be the user profile name followed by a 5 digit integer suffix as described in the *ETMobile* manual. Whenever data recording stops, the suffix is incremented in preparation for the next file recording. Detailed instructions for creating new subject profiles, and a more detailed description of the File and profile system, are in the *ETMobile* manual.

10.1 Select data set for digital data file

To see the data available for digital recording, 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.

The "Eye Data Selection" items are the same as those described in the *ETMobile* manual. If a head tracker is enabled, the "Head Tracker Data Selection" items will also be available (not grayed out). If *ET3Space* is enabled, most of the "ET3Space Selection" data items will be available as well.   The default data items, if a head tracker and *ET3Space* are enabled, include all of the default "Eye Data Selection" items (see *ETMobile* manual); all of the "Head Tracker Selection" data items; ET3S_Scene_number, ET3S_gaze_length, ET3S_horz_gaze_coord, and ET2S_vert_gaze_coord from the "ET3Space Selection" list. A more complete description of all data items can be found in section 13.2.

Note that **horz_gaze_coord** and **vert_gaze_coord** describe gaze with respect to the head mounted scene camera field of view, in scene camera pixel units; while **ET3S_horz_gaze_coord** and **ET3S_vert_gaze_coord** describe point of gaze on the designated scene surface in real distance units (inches or centimeters) with respect to the scene plane coordinate frame.

Left click to check or uncheck any available data items, and left click the close symbol at the upper right to close the *Data Selection* dialog.

10.2 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.
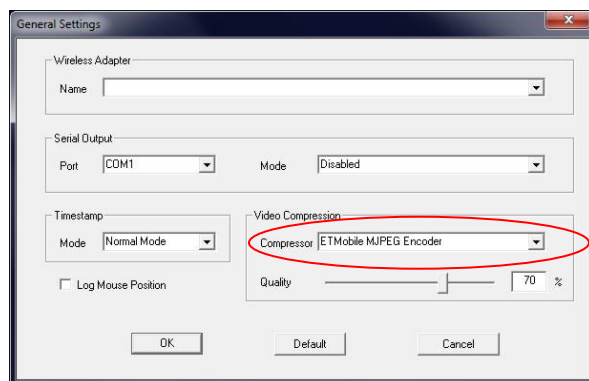
10.3   Start Stop Recording data and video files

Select the **Scene** button, under the "Video Display" heading to 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. If *ET3Space* is enabled, the data file will have an *ehd* extension. If *ET3Space* is not enabled, the data file will have *eyd* extension as described in the *ETMobile* manual. 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 overlay can be switched on or off using the **Pupil Overlay** button in the *Scene Settings* dialog.

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

10.4   Recording Manual Event Marks and External Data Values

While a data file is recording, it is possible to manually enter a mark value of from 0 to 255 on the file, and it is possible for external devices to send 16 integer values ("XDAT" values) to be recorded along with gaze data. Detailed instructions for using Mark and XDAT values are in the *ETMobile* manual.

10.5 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 binary digital 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.

11. Communication with external devices

ETMobile can send real time data, including *ET3Space* data, to external devices via local area network. The data items sent will be the list of items selected on the *Data Selection* dialog previously described. External devices can also control data recording by ETMobile, and can send external data to be recorded by ETMobile along with gaze data. Detailed instructions are in the *ETMobile* manual and a separate manual called *NetworkComWithETMobile*.

Argus Science provides a program called *ETRemote* which can communicate with *ETMobile* from an external Win 7 or Win 10 PC via LAN connection. Instructions for using *ETRemote* are provided in a separate manual (*ETRemote_with_ETM*).

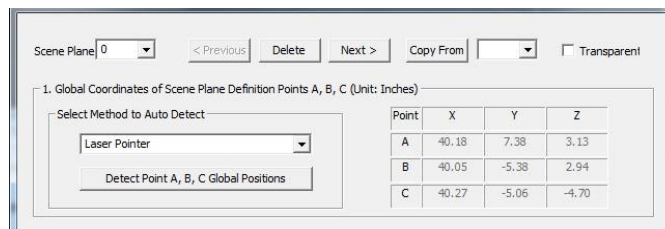# 12. Methods for specifying Global Coordinates of scene plane definition points ABC – detailed description

As part of the environment setup procedure, it is necessary to specify "definition points" for scene plane in the global coordinate system. There are several possible methods for doing this, and they were all described briefly in section 6.2.1. Each method is described in more detail below.

Argus Science usually provides the hardware for one of the methods described below as part of an *ET3Space* package. The choice is usually made in consultation with the customer at time of purchase, and reflects the method that seems most applicable to the head tracker type that will be used to the intended environment. Contact Argus Science to inquire about hardware for alternate methods.

As previously discussed, the *ET3Space* environment setup procedure is controlled from the *System Control Table*, *System Configuration* tab dialog. Usually, "Calibration Points Configuration" is done first, as described in section 6.1.
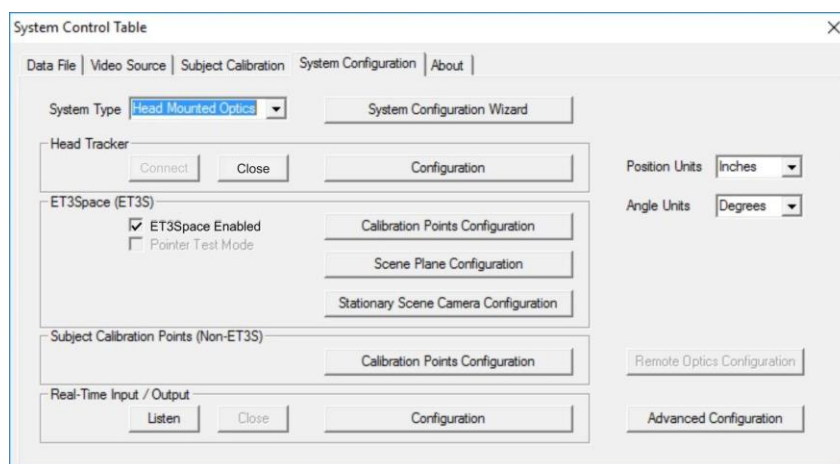
Open the *Scene Plane Configuration* dialog by clicking "Scene Plane Configuration". And select the desired scene plane number from the "Scene Plane" drop down menu.

In the group box labeled "Global Coordinates of Scene Plane Definition Points A, B, C", there is a pull down menu to select the method for specifying the coordinates in the global reference frame. Remember that this must be done for each scene plane in the environment.

12.1 Laser Pointer Method

Argus can provide a version of the laser pointer device specific to each of the head tracking devices compatible with Argus *ET3Space*. The laser pointer device includes a laser pointer mounted in an alignment tube, and a mounting mechanism for the head tracker sensor. The sensor mounting mechanism is specific to the type of head tracker being used. The laser is precisely aligned with the center of the alignment tube. In most cases the sensor mount is arranged so that an imaginary backward extension of the laser beam would pass through the origin of the sensor coordinate frame.

Photos, below, show two versions of the laser pointer. On the "Version 1" device, the laser is activated with a button on the bottom of the alignment tube. An opening in the top of the alignment tube allows access to the laser battery compartment for battery replacement. The photo shows a rigid body object with reflectors mounted to the device. CAUTION: The laser is a class II laser. Do not look directly at the laser source or its mirror reflection.

Version 1 laser pointer
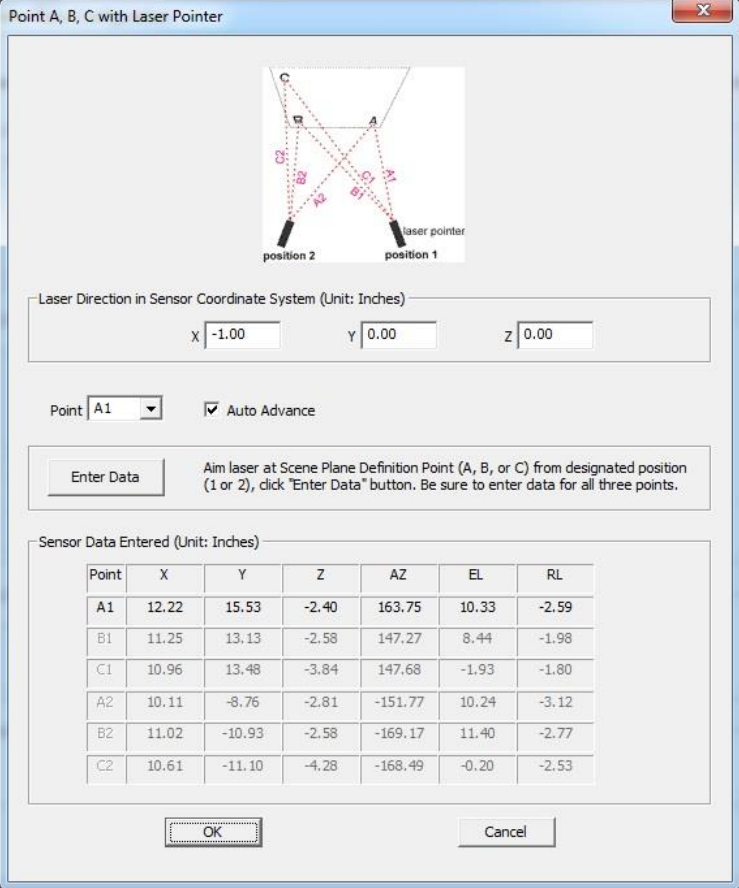
The "Version 2" device is shown with no rigid body attached to the mounting plate. The laser is activated by a small rotation of the battery container unit. If the battery container unit is rotated far enough, it can be removed for battery replacement.   Be sure to turn off the laser when not in use to preserve battery life. CAUTION: The version 2 device is includes a class IIIa laser. Do not look directly at the laser source or its mirror reflection.

Rigid body mounting plate

Battery container unit
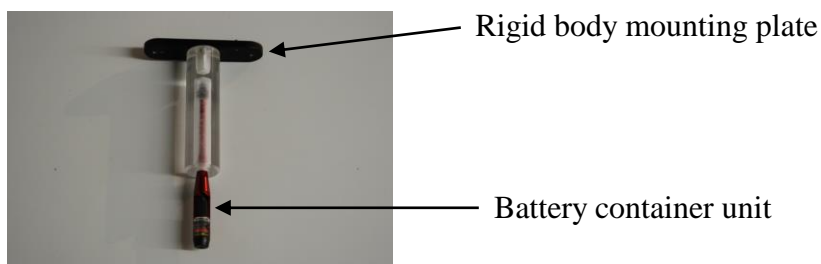
Version 2 laser pointer

The laser is pointed at each definition point from two different positions. The system computes the position at which the two laser paths converge, and this is taken as the position of the point in the global coordinate system. The photo below shows a laser pointer device equipped with a "sensor" for an optical tracking system (rigid plate with optical markers).

Under "Select Method to Auto Detect", Select "Laser Pointer" from the pull down menu and click the button labeled "Detect Point A, B, C global Positions". This will bring up a dialog window labeled "Point A, B, C with Laser Pointer".

Argus Science provides separate manuals describing things that are specific to particular types of supported head tracker systems. Consult this document for sensor mounting instructions specific to the head tracker being used, and also for the Laser Direction coordinates to specify for the particular device being used. Type the Laser Direction coordinates in the boxes provided. Be sure to type values in the units indicated. (Units of measure were chosen on the System Configuration dialog.)

It will be necessary to point the laser at points A, B, and C from two different positions, as shown by the diagram on the dialog window shown above. The positions should be separated along a path more or less parallel to the scene plane Y ("horizontal") axis. "A1" means to aim at point A from position 1, "A2" means to aim at point A from position 2, etc. Aim the laser at the target indicated in the "Point" box, <u>be sure that the sensor is being properly recognized by the head tracker system</u>, and left click the "Enter Data" button. Repeat for A1, B1, C1, A2, B2, and C2.   Each time the Enter Data button is clicked the <u>sensor</u> position and orientation (not the position of the point the laser is aimed at) is added to table at the bottom of the dialog.

Note that this usually requires two people, one to point the Laser, and another to click the "Enter Data" button. The laser pointer usually includes a tripod mount. If desired, a standard camera tripod can be used to help steady the pointer while performing the procedure.

The system will find the position of point A, for example, by computing the place where the A1 and A2 laser lines converge. This computation is most accurate when the angle between the A1 and A2 lines is close to 90 degrees.   Much smaller (or much larger) angles will produce less accurate results.
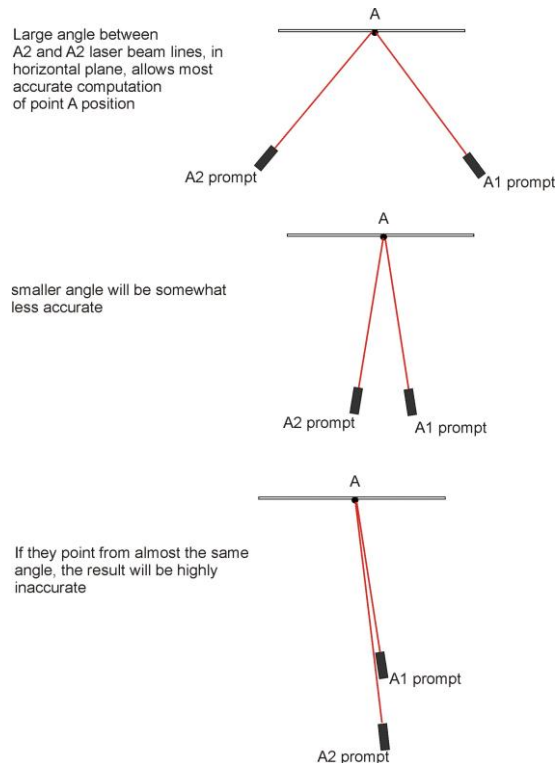
Of course the distance between position 1 and position 2 is also limited by the area over which the head tracking system can accurately recognize the head tracker sensor. and a 90 degree angle is often not possible. Just come as close as practical.

When all points have been entered, click OK to exit the "Point A, B, C with Laser Pointer" window. The *ET3Space Scene Plane Configuration* dialog will still be displayed, and should now show the correct global coordinates for points A, B, and C in the step1 box. Knowledge of the Global reference frame origin and axes directions can be used to check that these values make sense. (Do the coordinates specify roughly the right directions and distances from the Global origin?). If the values do not seem sensible, repeat the procedure, being sure that the laser direction is specified properly and that the head tracker is making a valid measurement for all points.
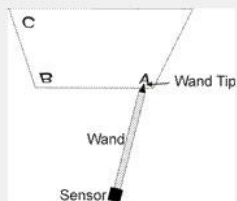
12.2 Pointer Wand Method

The sensor wand is a freely moving rod. One end contains a mount to hold the tracking device sensor, while the other end has a pointed tip for touching surface points. The head tracker sensor attaches to the pointer in such a way that the sensor position and orientation define the location of the pointer tip in the global reference frame. The pointer tip is touched to each of the scene plane definition points to determine the point's position in the global reference frame. Note that the wand can only be used if the sensor, when mounted to the wand, remains within the range of the tracking system operational field when the wand tip is touching the scene plane definition points.

Argus Science can provide pointer wands with sensor mounting hardware specific to each of the head tracking devices compatible with ET3Space.

Under "Select Method to Auto Detect", Select "Pointer Wand" from the pull down menu, and click the button labeled "Detect Point A, B, C global Positions". This will bring up a dialog window labeled "Touch A, B, C with Wand Tip".

Argus Science provides separate manuals or Tech Notes describing things that are specific to particular types of supported head tracker systems. Consult the appropriate document for sensor mounting instructions specific to the head tracker being used, and also for the vector coordinates that specify the location of the wand tip. Type the wand tip position coordinates in the boxes provided. Be sure to type values in the units indicated. (Units of measure were chosen on the System Configuration dialog.)

Remove the sensor from the subject headgear, if necessary, and mount it to the pointer wand.

The "Point" prompt will first default to "A". Touch the wand tip to point A and click the "Enter Data" button. This procedure will often require two people, one to hold the wand and another to click the "Enter Data" button. Before entering data, be sure that the head tracker sensor is within the proper operating range and is generating valid data. With optical tracking systems, it is often important for the person holding the wand to take care to stand in a position that does not block the reflectors (or emitters) from the tracker camera field of view.

Each time data is entered the sensor position and orientation measured by the tracking system will be entered in the table at the bottom of the dialog, and the "Point" prompt will advance. Touch the wand

tip to the indicated point, and click "Enter Data". To enter data out of order, use the drop down menu to select a point before entering data.

Note that the values that appear in the table at the bottom of the dialog are the position of the sensor when data was entered, not the position of point A, B, or C. The values in the table can be checked to make sure that they are sensible. For example if an optical tracker was blocked when one point was entered, the values may be zero, or some other impossible value. Points can be repeated if necessary. Be sure to enter valid data for all three points, then click OK to close the dialog.

The *ET3Space Scene Plane Configuration* dialog will still be displayed, and should now show the correct global coordinates for points A, B, and C in the step1 box.   Knowledge of the Global reference frame origin and axes directions can be used to check that these values make sense. (Do the coordinates specify roughly the right directions and distances from the Global origin?). If the values do not seem sensible, repeat the procedure, being sure that wand tip position is specified properly and that the head tracker is making a valid measurement for all points.

12.3 Gimbal Laser Pointer Method

The gimbal laser method is usually used only with magnetic tracking devices. (It should be noted that the laser pointer and pointer wand methods can also be used with magnetic tracking devices, and in fact are now more commonly used with these devices).

The laser gimbal mechanism usually mounts around the HT Magnetic Transmitter device (which is also usually the origin of the global coordinate system) and allows a laser pointer to swing freely around the central point of the Transmitter. The head tracker Sensor is placed in a holder attached to the gimbal assembly. The laser mounted in an alignment tube and is precisely aligned with the center axis of the alignment tube.
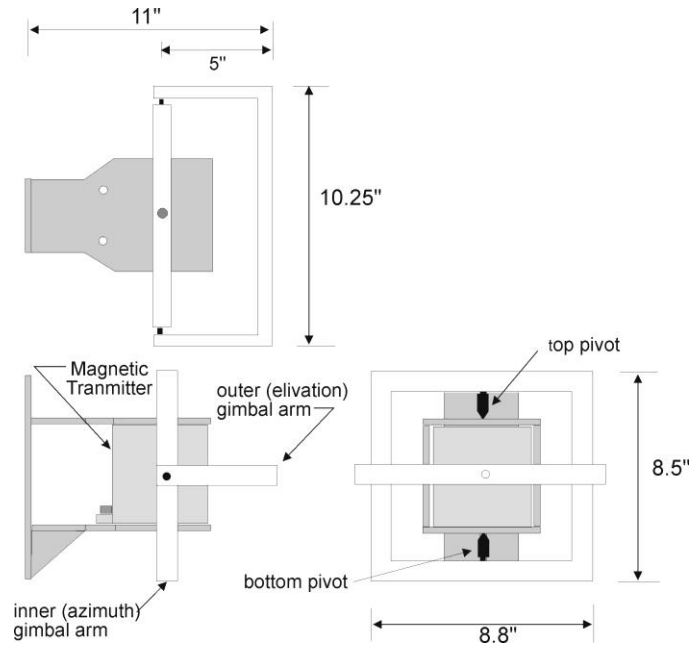
Top, side and front view of transmitter mount and gimbal assembly for Ascension Flock of Birds magnetic transmitter
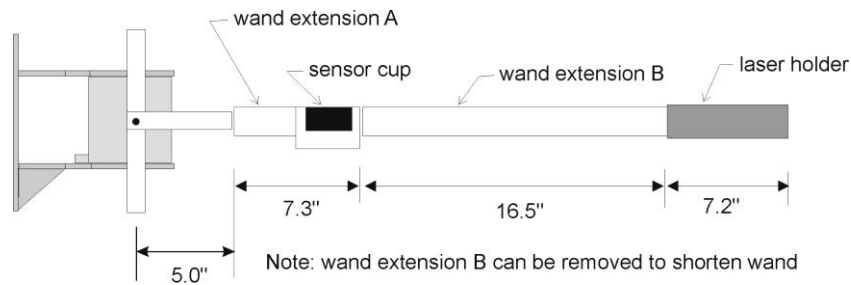
Side view of transmitter mount and Gimbal assembly with laser wand attached to outer gimbal

CAUTION: The laser is a class II laser. Do not look directly at the laser source or its mirror reflection.

With this measurement method, the operator points the laser at the appropriate surface points and physically measures the distance from the end of the laser pointer to the surface point.   The tracking device measures the direction of vector from the Global origin to each definition point, but the length of vector is computed from a physical measurement.

Place the magnetic sensor in the holder, on the wand. Be sure that it is secured with the plastic screws provided.

Under "Select Method to Auto Detect", Select "Pointer Wand" from the pull down menu, and click the button labeled "Detect Point A, B, C global Positions". This will bring up a dialog window labeled "Point A, B, C with Gimbal Laser".
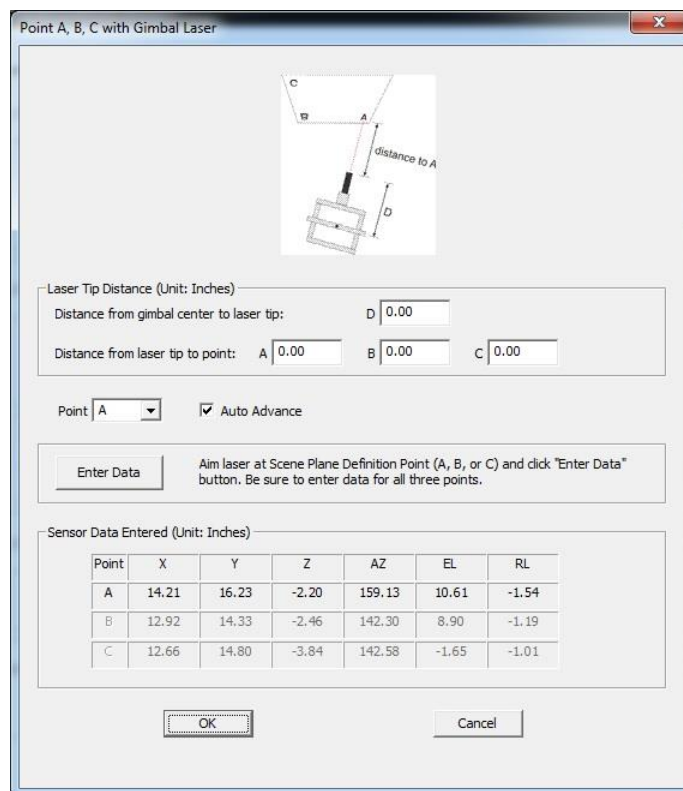
Type in the distance from the center of the gimbal system to the tip of the laser. For the gimbal laser assembly as diagramed at the beginning of this section, the value would be 7.2"+16.5"+7.3"+5"=36". (If metric units were chosen on the System Configuration Dialog, this would be entered as 91.4 cm.)

Point the laser at Point A, and have a second person use a tape measure to measure from the end of the laser to point A. Type this value in the indicated box. Repeat for B and C.

The "Point" prompt will first default to "A". Point the laser at point A and click the "Enter Data" button.   This procedure will often require two people, one point the laser assembly and another to click the "Enter Data" button.

Each time data is entered the sensor position and orientation measured by the tracking system will be entered in the table at the bottom of the dialog, and the "Point" prompt will advance. To enter data out of order, use the drop down menu to select a point before entering data. Note that the values that appear in the table at the bottom of the dialog are the position of the sensor when data was entered, not the position of point A, B, or C. Be sure to enter valid data for all three points, then click OK to close the dialog.
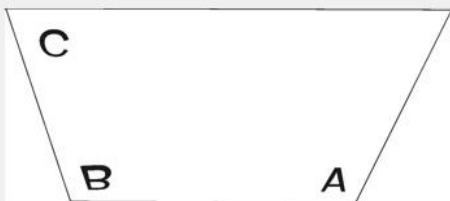
The "EHI Scene Plane Configuration" dialog will still be displayed, and should now show the correct global coordinates for points A, B, and C in the step1 box.   Knowledge of the Global reference frame origin and axes directions can be used to check that these values make sense. (Do the coordinates specify roughly the right directions and distances from the Global origin?). If the values do not seem sensible, repeat the procedure, being sure that the sensor is mounted securely the holder, that the distance measurements typed in are correct, and that the head tracker is making a valid measurement for all points.

12.4 Place Sensor Directly on ABC

In some cases it is possible to place the sensor origin point directly on the scene plane definition points ("A", "B", and "C"). For example, if a scene plane does not contain metal and is within measurement range of the transmitter on a magnetic tracking system, then the sensor can simply be placed on each point. Optical systems are sometimes equipped with pointer tools, and can be temporarily set so that the position of the pointer tool tip (instead of the head mounted object) is reported to the eye tracker. If this pointer tool is in measurable range when touching the scene plane, then the tip can be held against each definition point. In these cases the "Place Sensor Directly on ABC" method can be used.

Under "Select Method to Auto Detect", Select "Place Sensor Directly on ABC" from the pull down menu, and click the button labeled "Detect Point A, B, C global Positions". This will bring up a dialog window labeled *Place sensor directly on A, B, C*.

Touch the origin of the head tracker sensor to the indicated point and click "Enter Data". Two people will often be required, one to position the sensor, and another to click the "Enter Data" button.

Each time data is entered the sensor position and orientation measured by the tracking system will be entered in the table at the bottom of the dialog, and the "Point" prompt will advance. To enter data out of order, use the drop down menu to select a point before entering data. Note that the values that appear in the table at the bottom of the dialog are the position of the sensor when data was entered. In this case, unlike other methods, the position values are also the positions of points A, B, or C. Be sure to enter valid data for all three points, then click OK to close the dialog.

The *ET3Space Scene Plane Configuration* dialog will still be displayed, and should now show the correct global coordinates for points A, B, and C in the step1 box. Knowledge of the Global reference frame origin and axes directions can be used to check that these values make sense. (Do the coordinates specify roughly the right directions and distances from the Global origin?). If the values do not seem sensible, repeat the procedure, being sure that the head tracker is making a valid measurement for all points.

12.5 Manual Data Entry

Occasionally the location of surface definition points, in the global coordinate system, may be known independently of any procedures defined by Argus Science *ET3Space*. For example, it may

sometimes be possible to find the coordinates of these points using just the head tracking device and software provided by its manufacturer. If the definition point locations are known, the coordinates can be entered manually.

On the *ET3Space Scene Plane Configuration* dialog, under "Select Method to Auto Detect", Select "Enter Points Manually" from the pull down menu. The table of values on the *ET3Space Scene Plane Configuration* dialog will become active, and the known coordinates can simply be typed into the table.

13. Recorded and Transmitted Data Items

13.1 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 Section10.1). 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

13.2 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.