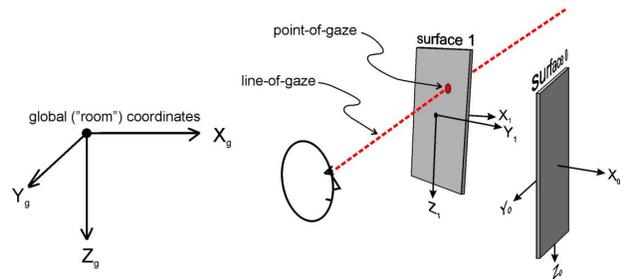


ET3Space Manual

ET3SPACE FOR USE WITH ETSERVER HEAD MOUNTED OPTICS

MANUAL VERSION 1.1
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Table of Contents

1.	INTRODUCTION	1
2.	HEAD TRACKER	2
2.1	INTERCONNECTIONS.....	2
2.2	ENABLE COMMUNICATION WITH HEAD TRACKER	2
3.	STATIONARY SCENE CAMERA CONNECTION	5
3.1	WEB CAM	5
3.2	STIMULUS COMPUTER SCREEN	5
4.	EYEHEAD ENVIRONMENT SPECIFICATION	7
4.1	REFERENCE FRAMES	7
4.2	COMPUTATIONS AND DATA	12
4.3	UNITS.....	13
4.4	ET3SPACE SETUP.....	13
4.4.1	<i>Calibration target points</i>	14
4.4.2	<i>Scene Plane Configuration</i>	15
4.4.3	<i>Stationary Scene Camera Configuration</i>	20
4.5	CHECKING ENVIRONMENT CONFIGURATION WITH “POINTER TEST”	22
4.6	ENVIRONMENT CONFIGURATION BACKUP	23
5.	SENSOR-TO-EYE VECTOR	24
5.1	MANUAL ENTRY OF SENSOR TO EYE VECTOR	24
5.2	USING THE HEAD TRACKER SYSTEM FOR COMPUTATION OF SENSOR-TO-EYE VECTOR	25
6.	SUBJECT CALIBRATION	27
6.1.1	<i>ET3Space with SSC video</i>	27
6.1.2	<i>ET3Space with head mounted scene camera</i>	29
6.2	CHECKING THE CALIBRATION	31
7.	DATA DISPLAY SCREEN	32
7.1	DATA DISPLAY SCREEN “DISPLAY CONTROL” GROUP	32
7.2	DATA DISPLAY SCREEN “POG DISPLAY” AREA	33
8.	SCENE IMAGE SCREEN	35
9.	MANUAL OFFSET CORRECTION	36
9.1.1	<i>Correcting Gaze with respect to EyeHead Integration scene planes</i>	36
9.1.2	<i>Correcting Gaze with respect to Head Mounted Scene Camera</i>	37
10.	COLLECTING DATA WITH ET3SAPCE	39
11.	COMMUNICATION WITH EXTERNAL DEVICES	40
12.	METHODS FOR SPECIFYING GLOBAL COORDINATES OF SCENE PLANE DEFINITION POINTS – DETAILED DESCRIPTION	41
12.1	LASER POINTER METHOD.....	42
12.2	POINTER WAND METHOD	45
12.3	GIMBAL LASER POINTER METHOD.....	47
12.4	PLACE SENSOR DIRECTLY ON ABC.....	49
12.5	MANUAL DATA ENTRY	50

1. Introduction

The *ET3Space* (ET3S) package, for use with *ETServer* head mounted eye trackers, enables integration of eye and head position data to compute point of gaze. Point of gaze is computed with respect to a room fixed (or cockpit fixed) scene space. The scene space is defined by a set of planes, consisting of one calibration plane and a variable number of additional, bounded planes. If a Stationary Scene Camera (SSC) is used, then point of gaze in the environment can be superimposed on the image from a stationary (as opposed to head mounted) video camera, or directly from the source creating a subject display.

Digital *ET3Space* gaze data and pupil diameter data are recorded at the *ETServer* eye camera update rate. This is 60 Hz with standard system, and 120, 240, or 360 Hz with the high speed (HS) option. Eye and Scene Image video recordings are usually at 30 Hz.

The required hardware includes *ETServer* head mounted eye tracker, a compatible head tracker system, the mounting assembly to fasten the head tracker sensor to the eye tracker headgear, and some mechanical fixtures used as part of the environment set up procedure. Optionally, a USB Web camera can be used as a Stationary Scene Camera. Required software is the *ETServer* operating software, and the software that comes with whichever head tracker system is used.

Connection between the *ETServer* and head tracker system varies depending on the head tracker type. Connections for some commonly used head tracker systems are diagrammed in the *ETServer Head Mounted Optics* manual. Consult Argus Science for a complete list of compatible head trackers. In some cases a separate manual is provided by Argus Science with instructions for specific to use of *ET3Space* with a particular head tracker type.

Basic operation of the eye tracker and navigation of the *ETServer* User Interface program are described in the *ETServer Head Mounted Optics* manual.

2. Head Tracker

All tracking systems that are compatible with Argus Science *ET3Space* 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.

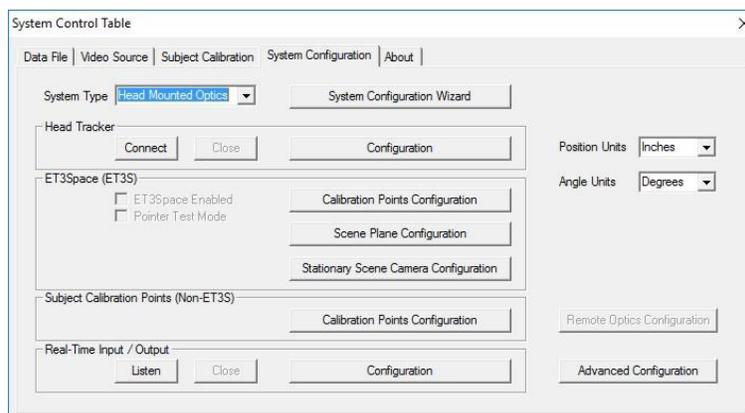
Magnetic tracking systems measure the position and orientation of a sensor (or “receiver”) with respect to a stationary magnetic transmitter. Optical systems use a camera (or some sort of optical detector) to detect reflectors or small light emitters. These systems measure the position and orientation 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 *ETServer Head Mounted Optics* manual 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”.

2.1 Interconnections

Be sure the head tracker and eye tracker are properly connected. Connections for some commonly used head tracker systems are diagrammed in the *ETServer Head Mounted Optics* manual. In some cases a separate manual is provided by Argus Science with instructions for specific use of *ET3Space* with a particular head tracker type.

2.2 Enable communication with head tracker

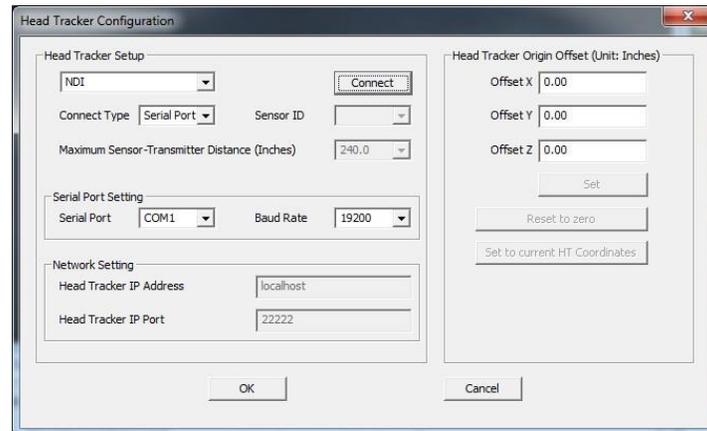
Run the *ETServer* Interface application as described in the *ETServer Head Mounted Optics* manual. Select the “System Configuration” tab on the *System Control Table* window.



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 *ETServer*. If

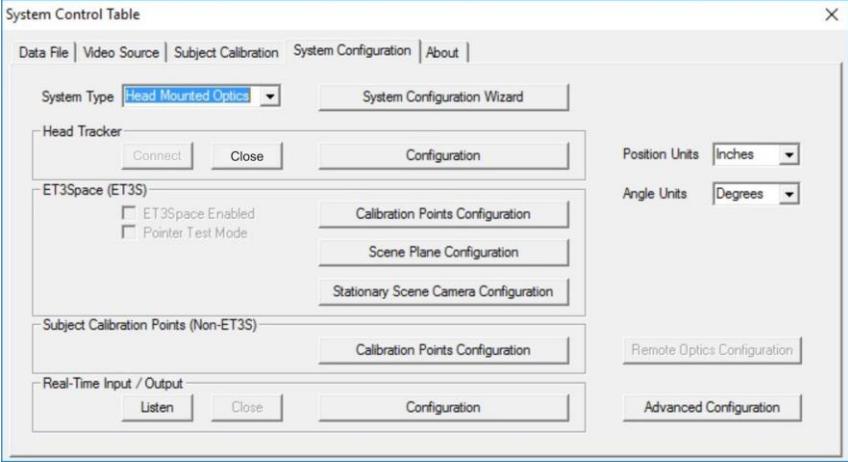
successful, the “Connect” button will turn gray, and head tracker data will appear on the Data Display window. The position units will be those indicated on the “System Configuration” tab window. Position values can be chosen to be either inches or centimeters. Orientation angles are always shown in degrees.

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



Choose the head tracker type and connection type from the drop-down menus. If a connection type is not supported for the chosen head tracker type, that selection will not be allowed. If the connection type is serial or network, associated RS232 or network parameters can be set. There is a 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 window. If communication with the head tracker is successfully established the “Connect” button will change to a “Close” button, and live head tracker data will appear in the lower left corner of the “POG Display”, on the *Data Display screen*.



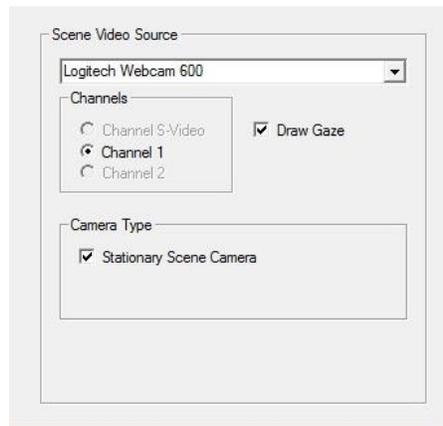
3. Stationary Scene Camera Connection

When using *ET3Space* a point of gaze cursor can be superimposed on the image from a camera that is fixed to environment. The scene video can be the image from a USB Web Camera positioned to have all or a subset of the *ET3Space* scene plane surfaces in its field of view. Alternately, if the primary scene of interest is a Win 7 or Win 10 computer monitor screen, the image from that monitor can be used directly, via network connection, as the “stationary scene camera” image. Note that, in this case, only the scene image can show only one scene plane.

3.1 Web Cam

To use a USB Web Cam, connect the camera to one of the USB ports on the *ETServer* PC, and mount the camera so that one or more of the *ET3Space* scene plane surfaces are within its field of view. If possible, orient that camera so that, the surfaces appear “right side up”. In other words, it is best if the surfaces appear with roughly the same orientation as they will appear to the subject.

On the *ETServer* program, *System Control Table*, *Video Source* tab, select the Web Cam from the “Scene Video Source” pull down menu. Set the radio button to “Channel 1”. The image from the camera should appear on the *Scene Image Screen* and will update at approximately 30 Hz. Be sure to check the box, under “Camera Type” labeled “Stationary Scene Camera”.



If some scene planes are not visible to the scene camera, there is provision for indicating this when configuring the stationary scene camera environment, as detailed in section 4.4.3.

3.2 Stimulus Computer Screen

To directly use a Win 7 or Win 10 PC stimulus screen as the scene image source, it first necessary to load the *ETRemote* application, provided by Argus Science, on the stimulus PC; to establish a network connection to the *ETServer*; and to set *ETRemote* to “Send Video”. “Network” can then be selected

from the Scene Video Source pull down menu, on the *ETServer* program. This procedure is described, in detail, in section 11 of the *ETServer Head Mounted Optics* manual.

The image from the stimulus PC screen should appear on the *Scene Image Screen* and will update at approximately 10 Hz. Be sure to check the box, under “Camera Type” labeled “Stationary Scene Camera”.

If this is not the only scene plane configured for *ET3Space*, all other planes will need to be set as “This plane not visible in SSC” when configuring stationary scene camera environment (section 4.4.3).

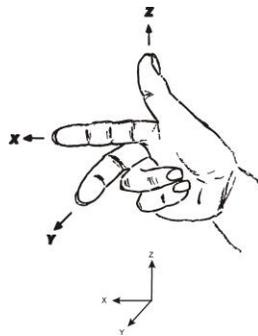
4. EyeHead Environment Specification

4.1 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.

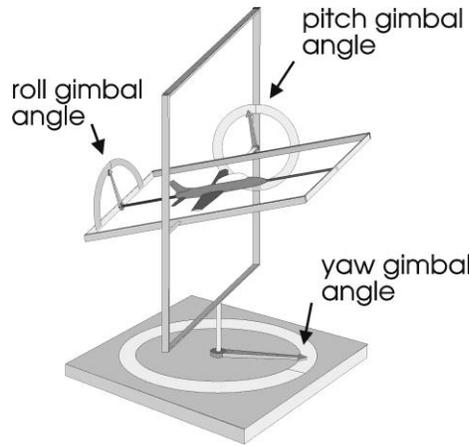
All position and orientation information used by *ET3Space* is expressed with respect to either the global coordinate system or to imaginary coordinate systems “attached” to surfaces, to the subject’s head gear, or to sensors used by the head tracker system.

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.

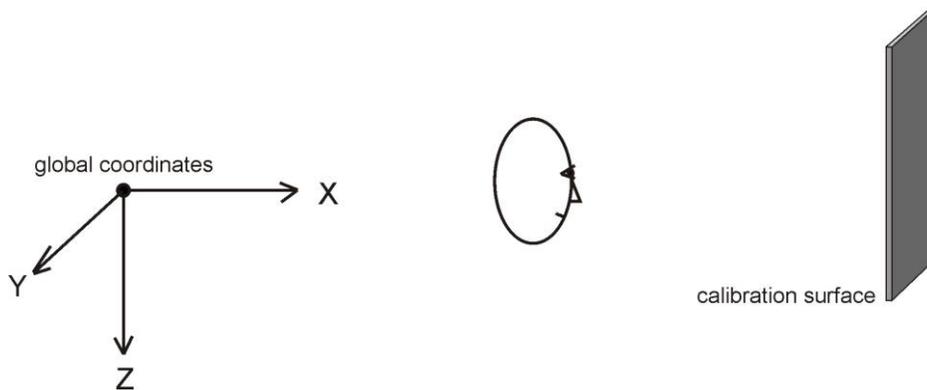


Orientation of one reference frame with respect to another is often expressed as a set of 3 “Euler” angles. When the axes are aligned, the angles are all zero. Other wise the angles describe 3 rotations that would be needed to align one with other. For instance head orientation is expressed as the set 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, azimuth, then elevation, and then roll. This concept is illustrated by sketch, below.

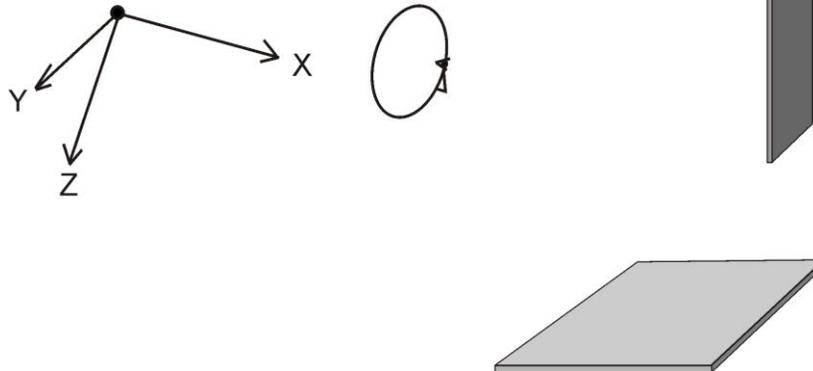


For use with *ET3Space*, the standard position and orientation for the global coordinate system and the calibration surface is shown below.

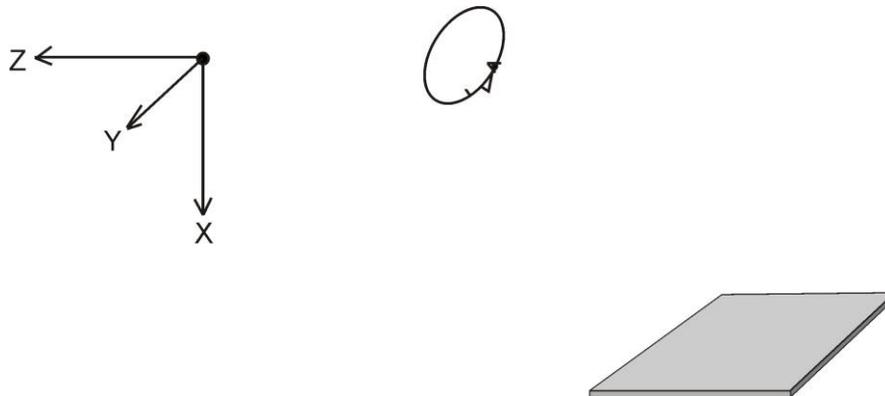


The origin is just behind the subject’s central or standard position (usually the subject position during subject calibration and/or the position most central or usual during the subject’s anticipated activities). The X axis points towards the direction faced by the subject and towards the calibration surface; the Y axis points towards the subject’s right, and the Z axis points down. (Note that this 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 at 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.

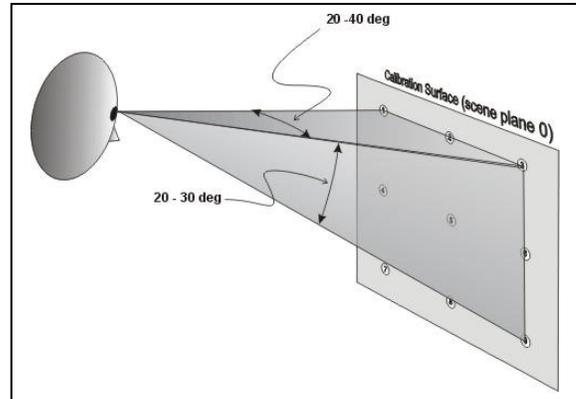


The tracking systems used as head trackers usually have the means to specify the Global coordinate system origin and the axes pointing directions, although the specific method for doing this is a bit different for each system. In the case of magnetic systems, the global origin is usually the center of 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 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.

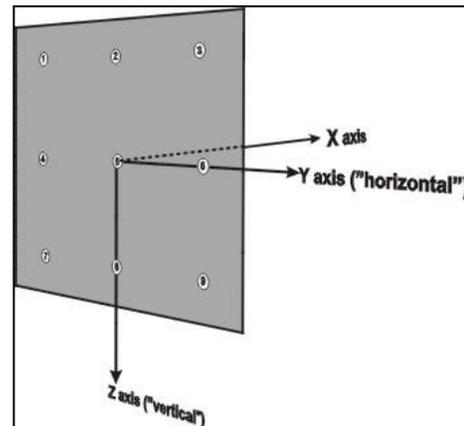
Before any *ET3Space* can take place, all of the scene planes (flat surfaces) of interest must be defined to the *ETServer* system. The procedures for doing this are described in the succeeding manual sections. However, before explaining the mechanics of entering environment information into the computer, 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 target points for the subject to fixate during a subject calibration procedure. Although any number of points between 2 and 20 may be used, the recommended number is nine, arranged in a pattern of 3 rows and 3 columns, as shown in the sketch. 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 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.

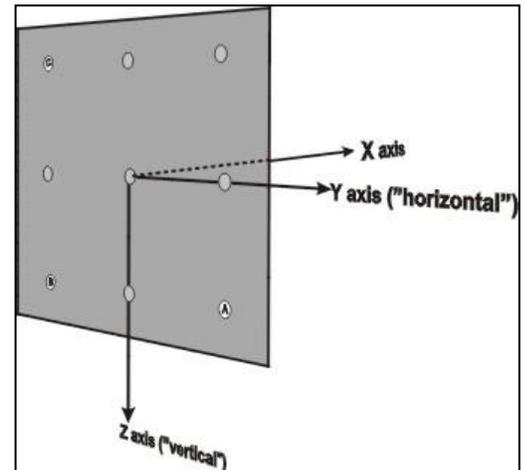
A rectangular boundary must also be determined for each scene plane, including the calibration plane, and is specified by a top, bottom, left, and right coordinates. The top coordinate is the z value at the top edge of the surface (minimum z value on the surface); the bottom coordinate is the z value 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 your scene plane was a 17 inch monitor, your 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. 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.

4.2 Computations and data

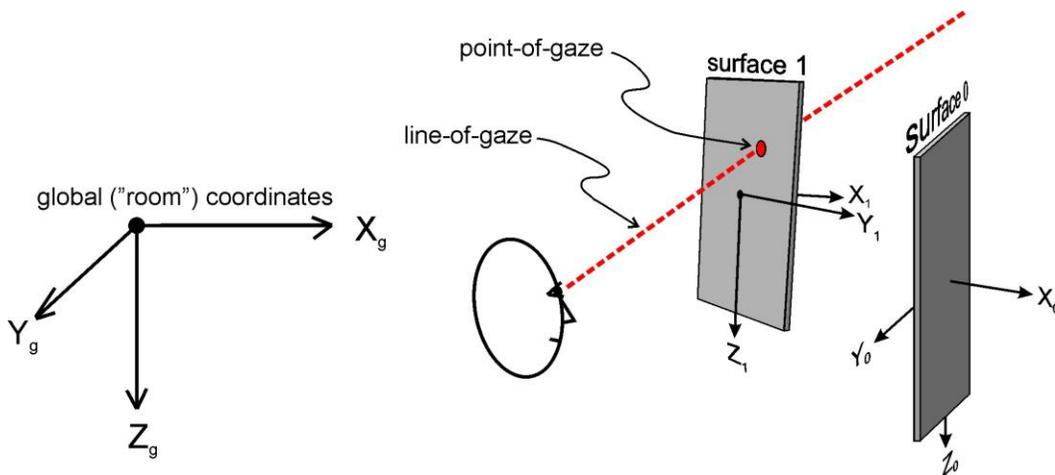
During normal operation the system will determine the location of the eye and the direction of the gaze vector with respect to the global coordinate system. It will then determine which scene plane surfaces are intersected by line-of-gaze.

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 be included on data recorded by *ETServer*, 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 on the *ETServer, Data Display Screen*.

On the *ETServer, Data Display Screen*, 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 naturally be thought 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 which 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.



4.3 Units

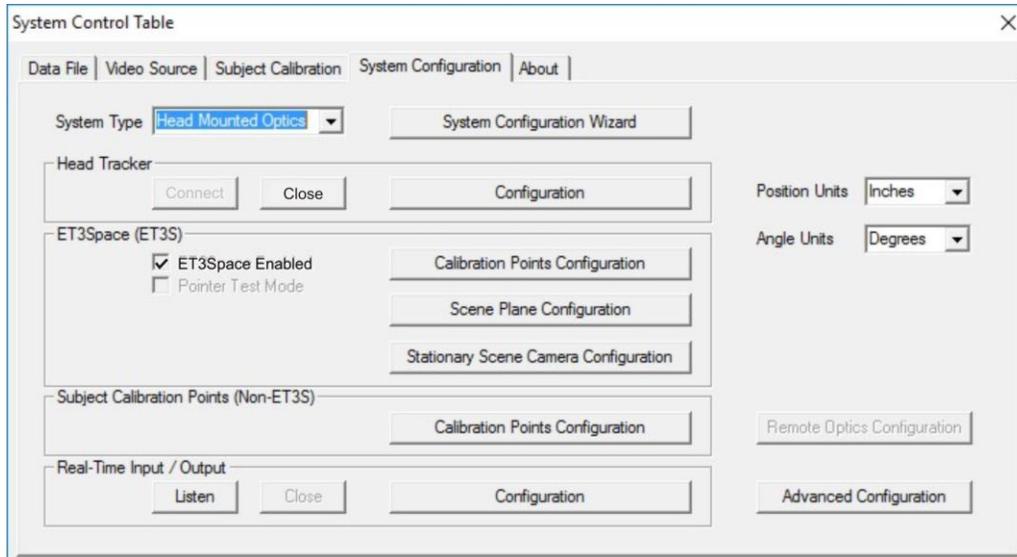
The user can choose to specify *ET3Space* environment parameters in either English Standard, or Metric distance units. This choice is made on the *System Control Table, System Configuration* tab. Use the “Position Units” drop down menu to select either “inches” or “centimeters”. Angles are always given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

4.4 ET3Space Setup

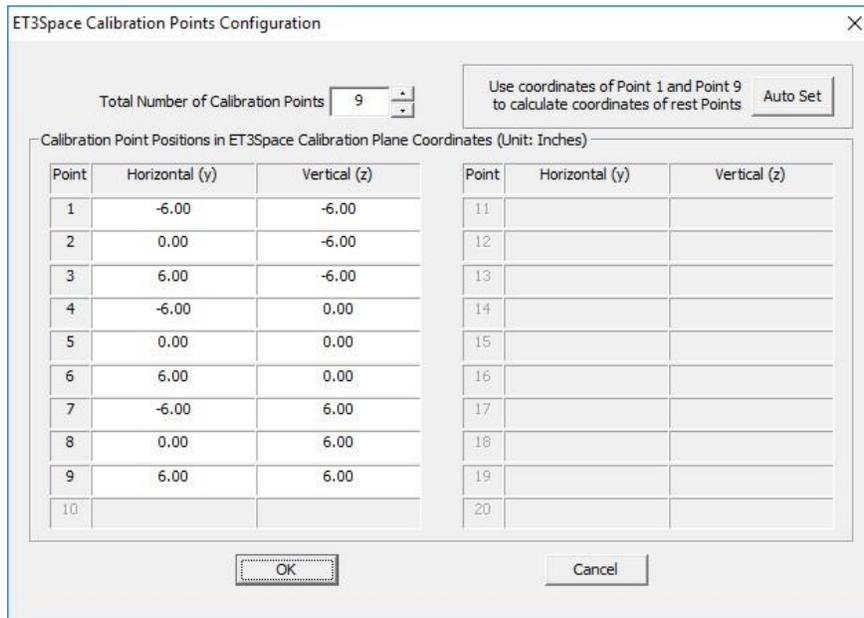
The “ET3Space (ET3S)” group on the “System Configuration” dialog has a check box to enable *ET3Space* mode, and 3 buttons that bring up dialogs used to specify the environment. The first of these dialogs is used to specify the location of calibration points on the calibration surface (scene plane 0); 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 section 2, and then check the “ET3Space enabled” box.



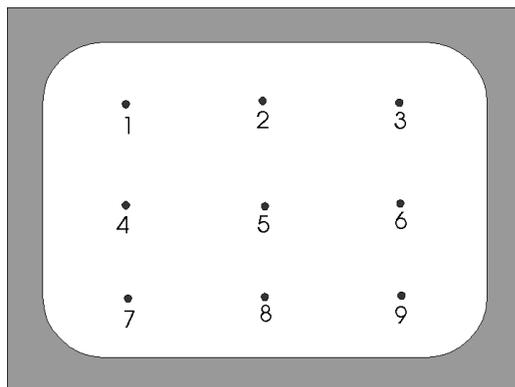
4.4.1 Calibration target points

In the ET3Space 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.



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.

4.4.2 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.

ET3Space Scene Plane Configuration

Scene Plane: 0 < Previous Reset New Copy From: Transparent

1. Global Coordinates of Scene Plane Definition Points A, B, C (Unit: Inches)

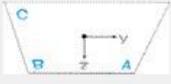
Select Method to Auto Detect:
 Detect Point A, B, C Global Positions

Point	X	Y	Z
A	0.00	0.00	0.00
B	0.00	0.00	0.00
C	0.00	0.00	0.00

2. Scene Plane Coordinates of Definition Points A, B, C (Unit: Inches)

Use Scene Plane Coordinates of Right-Bottom, Left-Bottom, Left-Top Calibration Points as Scene Plane Coordinates of A, B, C respectively Auto Set

If line AB is parallel to Scene Plane y-axis, use Scene Plane Coordinates of A and Global Coordinates of A, B, C to calculate Scene Plane Coordinates of B, C Set B, C



Point	Y	Z
A	6.00	6.00
B	-6.00	6.00
C	-6.00	-6.00

3. Scene Plane Boundaries in Scene Plane Coordinates (Unit: Inches)

Set to be 20% larger than outline connecting points A, B, and C Auto Set

Left: -10.00 Right: 10.00
 Top: -10.00 Bottom: 10.00

4. Manual Offset in Scene Plane Coordinates (Unit: Inches)

Offset H: 0.00 Offset V: 0.00

OK Cancel

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 4.4.2.4.

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 4.5, 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.

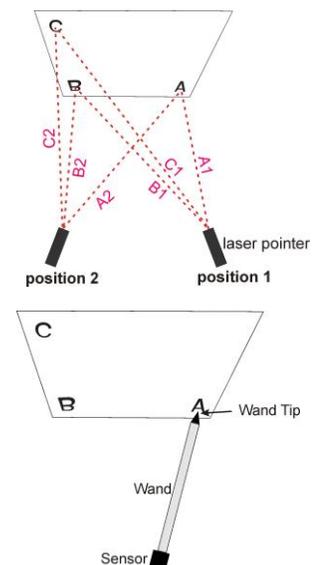
4.4.2.1 Determine Global Coordinates of scene plane definition points A, B, C

First, decide where the points will be on the surface as previously discussed in section 3. 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. Consult Argus for specific advice about the best method for a particular situation.

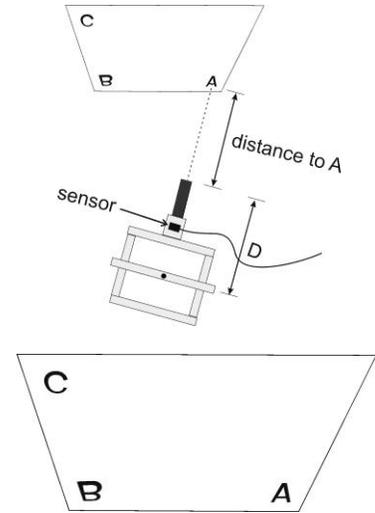
If “Manual Data Entry” is selected, simply type the values in the provided table. For other methods, click the “Detect Point A, B, C Global Positions” button, and follow instructions on the dialog window that appears. The methods are described briefly below, and in more detail in section 12.

- 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

4.4.2.2 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.

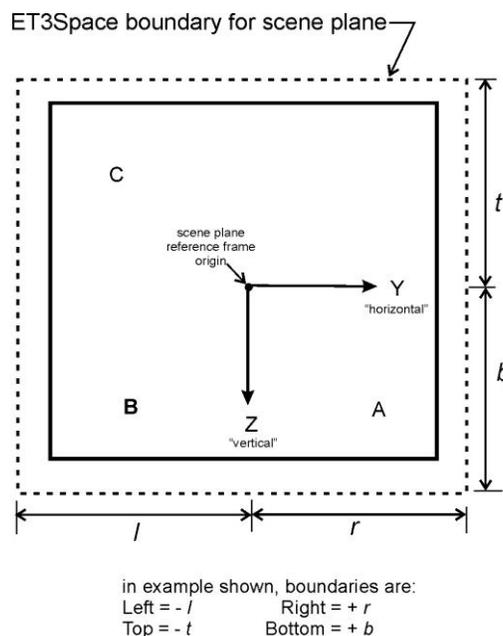
If it is the calibration surface (plane 0), and if the calibration point coordinates have already been entered (see section 4.4.1) then clicking “Auto Set” will enter the coordinates of the lower right, lower left and upper left calibration points as A, B, and C.

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).

4.4.2.3 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).



If there is no other visual target near the an edge of the physical surface, it is suggested that the EHI 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.

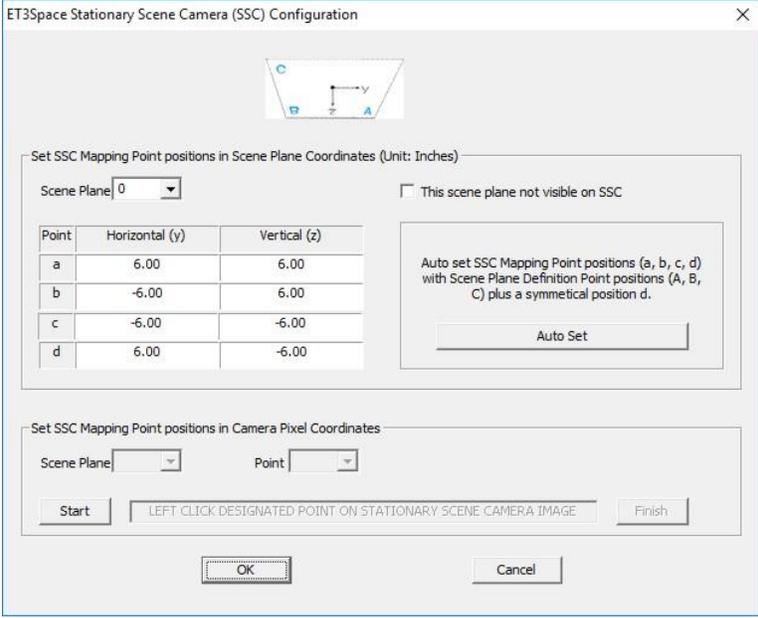
4.4.2.4 Manual Offset Correction

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.

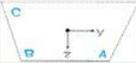
When scene planes are first defined, as discussed in the preceding sections, the manual offsets should be set to zero. Later on, the amount of error, if any, can be determined as a result of the pointer test procedure discussed in section 4.5 and by observing data after subject calibration. Methods for determining offset error, and entering the corresponding correction are discussed in section 6.2.

4.4.3 Stationary Scene Camera Configuration

If using a stationary scene camera click the “Stationary Scene Camera Configuration” button, on the *System Configuration* tab to open the *ET3Space Stationary Scene Camera Configuration* dialog.



ET3Space Stationary Scene Camera (SSC) Configuration



Set SSC Mapping Point positions in Scene Plane Coordinates (Unit: Inches)

Scene Plane: This scene plane not visible on SSC

Point	Horizontal (y)	Vertical (z)
a	6.00	6.00
b	-6.00	6.00
c	-6.00	-6.00
d	6.00	-6.00

Auto set SSC Mapping Point positions (a, b, c, d) with Scene Plane Definition Point positions (A, B, C) plus a symmetrical position d.

Set SSC Mapping Point positions in Camera Pixel Coordinates

Scene Plane: Point:

On each scene plane visible to the stationary scene camera, it is necessary to specify both scene plane coordinates and scene camera pixel coordinates for 4 different scene camera “mapping points” (“a”, “b”, “c”, and “d”). Although not a requirement, points “a”, “b”, and “c” are usually the same as the three plane definition points “A”, “B”, and “C”. The fourth point, “d”, is usually a symmetrical point at the upper right (horizontal coordinate the same as “a”, and vertical coordinate the same as “c”).

Be sure that the “Scene Plane” number, in the box titled “Set SSC Mapping Points positions in Scene Plane Coordinates”, is set to the scene plane being configured. To set scene plane coordinates for the standard a b c d positions (as described in the preceding paragraph), simply click the “Auto Set” button. Otherwise type in coordinates for the 4 points. If other scene planes have been configured, select the next from the Scene Plane pull down menu and click Auto Set or type in coordinates. Repeat for all configured scene planes.

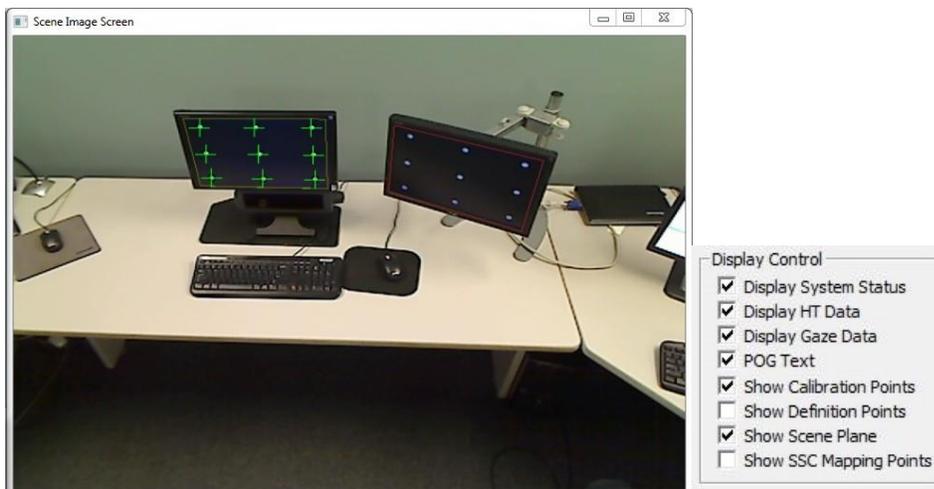
If a configured scene plane is not visible to the stationary scene camera (or if for some other reason the operator does not want the system to display a point-of-gaze cursor a plane) set the Scene Plane

number in the “Set SSC Mapping Points positions in Scene Plane Coordinates” box to that scene plane and check the box labeled “This scene plane not visible on SSC”.

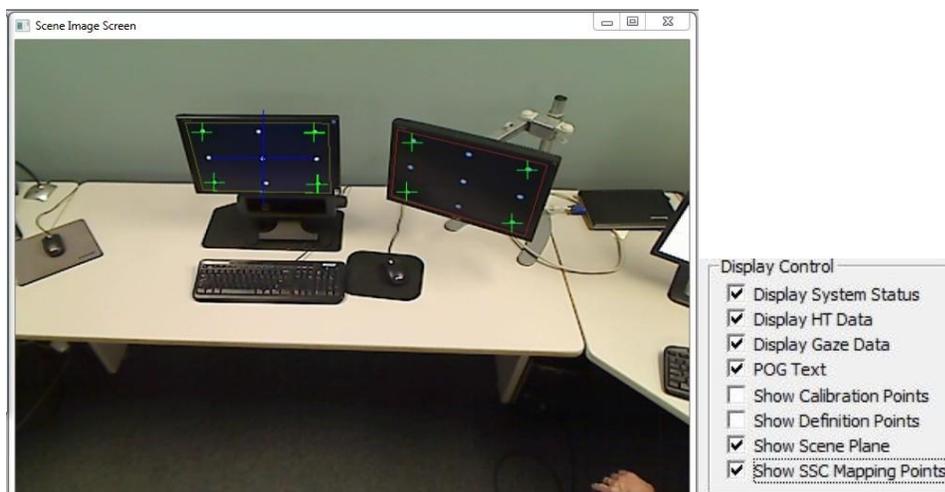
The scene camera pixel coordinates for the points will be set by clicking on them in the scene image. In the box title “Set SSC Mapping Point positions in Camera Pixel Coordinates”, click “Start”. The Words “Setting Positions” will appear in large text on the *Data Display Screen*. Be sure the proper Scene Plan number is showing, and, on the *Scene Image Screen*, left click the image of the indicated point. A green cross will appear on the point on the *Scene Image Screen* and at a corresponding point on the *Data Display Screen*. Repeat for the other 3 points.

If other scene planes have been configured, the Scene Plane number will advance, and the operator can click on those 4 points. Repeat for all configured Scene planes that are visible to the stationary scene camera. Click “Finish” when done. The “Setting Positions” text will disappear. The green crosses showing the scene camera mapping points will also disappear unless “Show SSC Mapping Points” is checked on the *Data Display Screen*.

If a stationary scene camera (SSC) has been configured, the scene plane boundaries and definition points, subject calibration points, and the SSC mapping points can be displayed by checking the corresponding box on the *Data Display Screen*, under the “Display Control” heading.



Example of Scene Plane outlines and Subject Calibration displayed on SSC image



Example of Scene Plane outlines and SSC mapping points displayed on SSC image

4.5 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 *ETServer*, 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 *Data Display Screen* “POG Display” 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 *Data Display* window, that the system is detecting gaze on that scene plane; and click the *Data Display Screen* button labeled “Quick Offset to Origin”. The appropriate data offset will automatically be entered to place gaze at the scene plane origin.

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 EHI data on the scene plane on which the system currently detects point of gaze. Note that the “Drag Left Mouse Button to Adjust” button will remain depressed. Click it again to deactivate this functionality (to prevent introducing offsets by accidentally dragging the mouse in the *POG Display* area).

4.6 Environment Configuration Backup

When the *ETServer* program is closed, all configuration information, including *ET3Space* environment specification, is automatically saved, and restored next time the program is opened. Configuration data can also be explicitly saved, at any time, by the user, in a user named file. Configuration files saved in this way can be re-loaded by the user at any time.

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

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

5. Sensor-to-Eye Vector

The head tracker system reports the position and orientation of an object (“sensor”) that is mounted to the head gear 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.

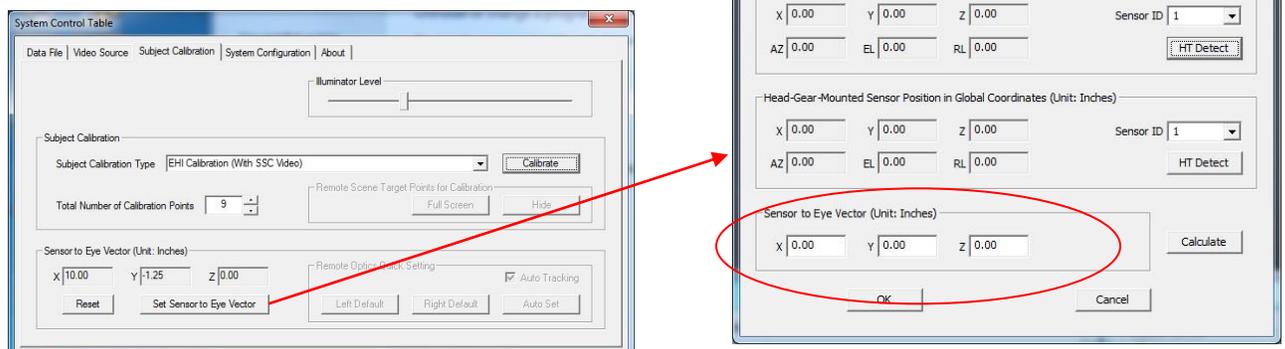
The information really needed for *ET3Space* computations is the location of the eye, rather than the location of the sensor. One of the *ET3Space* parameters is a “sensor-to-eye” vector which tells the system where the eye is with respect to the sensor coordinate frame. If the vector that connects the 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.

5.1 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 Sensor to Eye Vector”. On the resulting “Sensor To Eye Vector Dialog” window, 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.

5.2 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 Sensor to Eye Vector” on the *System Control Table, Subject Calibration* 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 Argus Science 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 1/2 inch (about 1 cm) from the front of the eye. Subjects should always have their eyes closed when the probe is used.

6. Subject Calibration

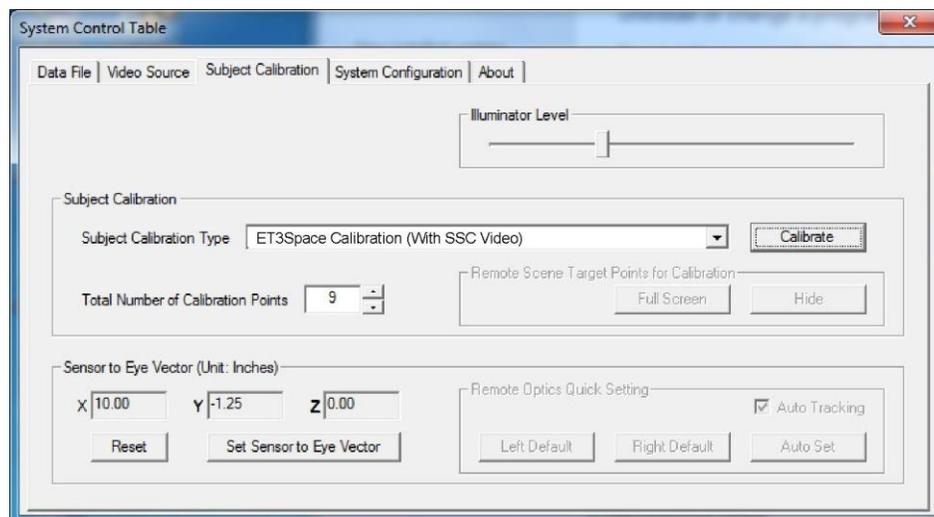
When *ET3Space* is enabled, if also using a “Stationary Scene Camera” the “Calibration Type” pull-down menu will offer only one choice: “ET3Space with SSC video”. If a Stationary Scene Camera (SSC) is not enabled, there will be two choices: “ET3Space with no scene video”, and “ET3Space with head mounted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

In all cases, the calibration target points must be visible to the subject on the surface designated as “Scene Plane 0”. The location of these points is specified as part of the *ET3Space* environment configuration procedure. 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 section 5.

6.1.1 ET3Space with SSC video

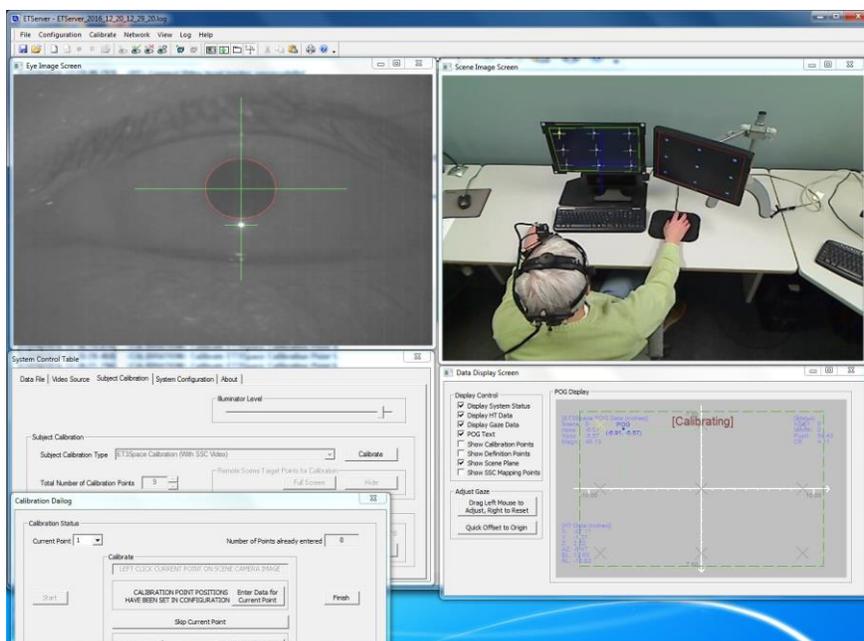
ET3Space must be enabled (“ET3Space enabled” check box on the *System Configuration* tab of the *System Control Table*). On the Video Source tab of the System Control window, under Scene Video, Camera Type, the Stationary Scene Camera Check box must be checked.

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



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

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



2. **Instruct the subject to hold his head still and use just his eyes to fixate current calibration target point.**
3. When satisfied that the subject is looking at requested point, and the eye features (pupil and CR) are being stably recognized by the system, **Left click “Enter data for current point” button.** Data for the point is entered at the mouse click. It is important that the subject be fixating that point and that pupil and CR recognition is good when the left mouse button is clicked. (See *ETServer Head Mounted Optics* manual for description of proper pupil and CR recognition).
4. **If the data is accepted by the system a green cross will appear** at the indicated spot on the scene image.
5. **If data is not accepted** (cross did not turn green), it means that either the pupil or the CR was not recognized or recognition was too noisy. Either repeat the mouse click, move the “Data Acceptance” slider towards “More Tolerant” and repeat the mouse click, or click “Skip” to calibrate without using that point.
6. **Repeat the above steps 2 through 6 for all target points.**
7. After all points have been entered, ask the subject to look at all the points again to be verify accuracy. The point of gaze cursor, on the scene video image, as well as the cursor and digital data on the Data Display window, should accurately indicate the subject’s point-of-gaze.
8. If desired, **re-enter data for any calibration point** by setting the “Current Point” value to the desired point and repeating steps 3-5.

9. When satisfied with the result, **click “Finish”**. Once “Finish” is clicked, points cannot be re-entered without repeating the entire process from step 1.
10. **Click OK to close the Subject Calibration dialog.**

6.1.2 ET3Space with head mounted scene camera

ET3Space must be enabled (“ET3Space enabled” check box on the System configuration tab of the System Control window). On the Video Source tab of the System Control window, under Scene Video, Camera Type, the Stationary Scene Camera Check box must be unchecked.

On the *System Control Table*, *Subject Calibration* tab, set “Calibration Type” to “ET3Space with head mounted scene camera”.

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

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

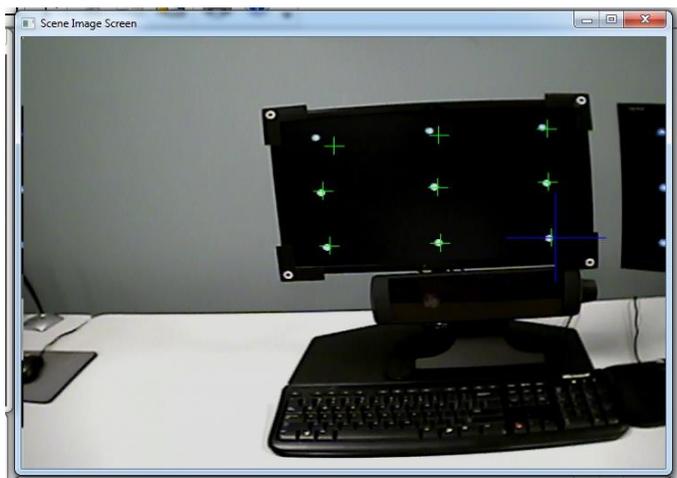
If necessary, ask the subject to make slight adjustments in head position or adjust the scene camera, so that the target points on the scene surface appears centered on the scene monitor, and then ask the subject to hold his head still. It is actually OK if there is some head motion, but it is best if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

1. In the “Calibration Status” box **click “Start”**. The scene video display will not yet show any calibration points, but the Data display should show all the *ET3Space* subject calibration points as gray crosses, except for the first, which will be yellow. The “Current Point” should be 1.
2. **Have the subject fixate the current target point**, and verify that the pupil and CR are being correctly recognized on the eye image window. (See *ETServer Head Mounted Optics* manual for description of proper pupil and CR recognition).
3. **Left click on the image of the target point in the scene image window**. Data for the point is entered at the mouse click. It is important that the mouse arrow is accurately pointing at the target point image and that pupil and CR recognition is good when the left mouse button is clicked. The system assumes that the subject is fixating the spot that is clicked.

4. **If the data is accepted by the system a green cross will appear** at the indicated spot on the scene image, as well as on the Data display. The current point will advance, and the new point will appear as a yellow cross on the data display.
5. **If data is not accepted** (no green cross), it means that either the pupil or the CR was not recognized or recognition was too noisy. Either repeat the mouse click, move the “Data Acceptance” slider towards “More Tolerant” and repeat the mouse click, or click “Skip” to calibrate without using that point.
6. **Repeat the above steps 2 through 6 for all target points.**
7. After all points have been entered, ask the subject to look at all the points again to be verify accuracy. The point of gaze cursor, on the scene video image, and the cursor on the Data display window should accurately indicate the subject’s point-of-gaze.
8. If desired, **re-enter data for any calibration point** by setting the “Current Point” value to the desired point and repeating steps 3-5.
9. When satisfied with the result, **click “Finish”**. Once “Finish” is clicked, points cannot be re-entered without repeating the entire process from step 1.
10. **Click OK to close the Subject Calibration dialog.**

It is very important to note that the point of gaze displayed on the head mounted scene camera image 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.

At right is a screen shot of the *Scene Image Screen*. It shows the head mounted scene camera image, after all 9 points have been entered (green crosses), but before “Finish” was clicked. (Note that some of the green crosses appear slightly offset from the target points. This is because the subject’s head has moved since those points were entered, and is perfectly OK as long as they were accurately on the fixation point when entered.)



6.2 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.

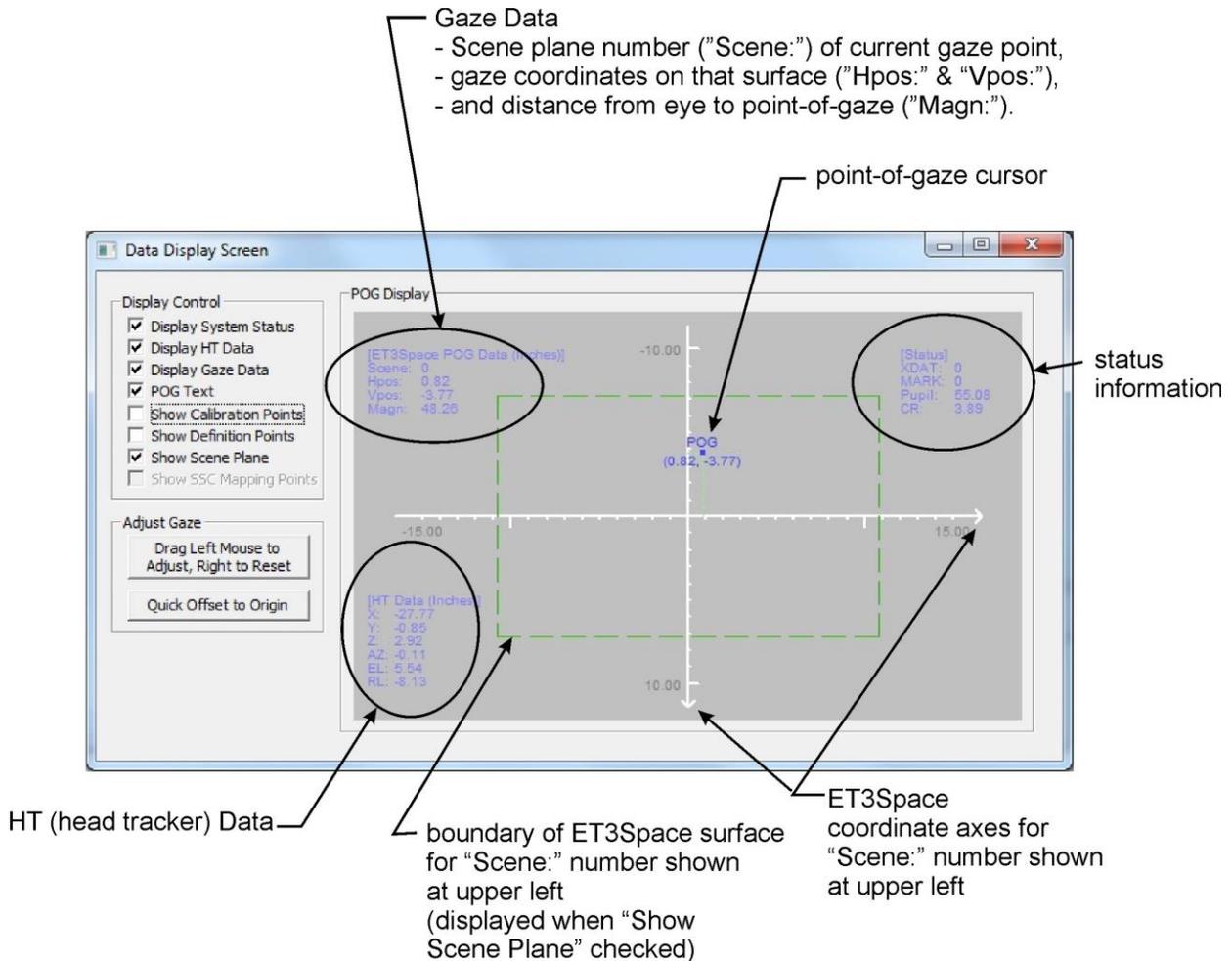
If one or more target points are not correctly indicated repeat the calibration procedure.

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

Any error caused by poor subject calibration will show up when the subject looks at the plane 0 calibration points. If the gaze measurement is accurate on plane 0 but has more error on other scene planes, this is will not be improved by repeating the subject calibration. Large errors only on scene planes other than plane 0 may indicate some error or inaccuracy in *ET3Space* environment set-up. Some variation in offset error between scene planes is expected and can be quickly corrected as described in section 9.1.1.

7. Data Display Screen

The *Data 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 *Data Display Screen* determine display content. In addition, the *Data Display Screen* contains controls for entering manual offset corrections to the point-of-gaze data.



For description of the *Data Display Screen* when not using *ET3Space* see the *ETServer Head Mounted Optics* manual.

7.1 Data Display Screen "Display Control" Group

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

The first 4 items are digital text displays which are superimposed on POG Display area. “System Status” values appear at the upper right corner of the POG Display area. “HT Data” is available only if a head tracker (HT) is communicating with the ETServer, and appears in the lower left corner of the POG Display area. “Gaze Data” is displayed in the upper left corner of the POG Display area. If *ET3Space* is 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.

7.2 Data 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.

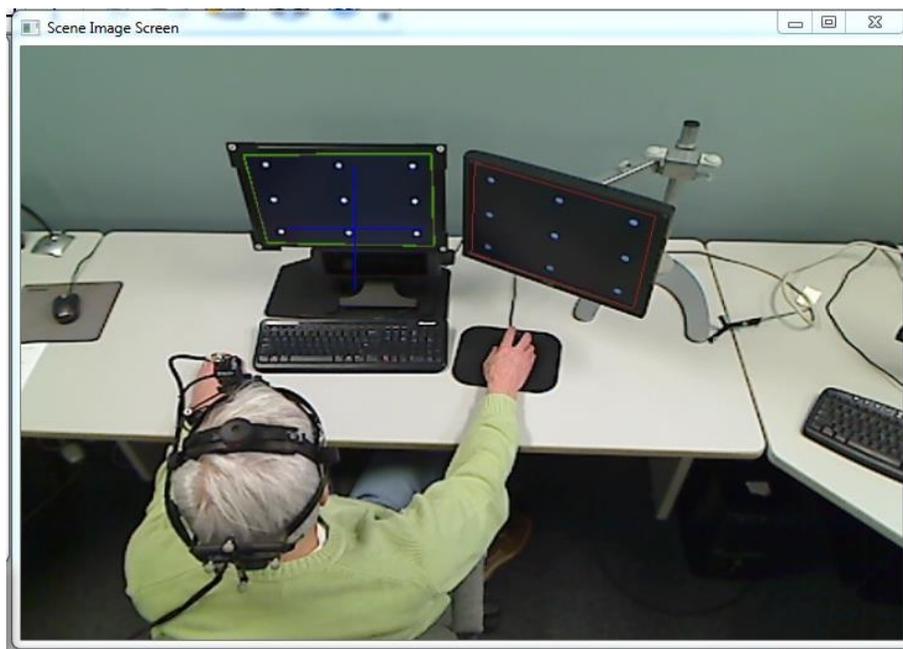
If *ET3Space* is enabled, the POG positions represent the gaze position on the scene plane surface specified by the current scene plane number. The units are inches or centimeters from the scene plane origin, along the scene plane y (“horizontal”) and z (“vertical”) axes. These axis lines are shown on 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), the mouse can be used to left drag the axes display origin to different positions on the display area. The mouse wheel can be used to zoom in or out. Right dragging the mouse in the area restores default origin position and zoom.

8. Scene Image Screen

The *Scene Image Screen* shows the image from either the stationary scene camera or head mounted scene camera. A stationary scene camera image may either be the image from either a USB Web Cam, or the image from a stimulus computer screen sent via a network connection. Instructions for configuring the system to show either type of Stationary Scene Camera image are in section 3 of this manual and in the *ETServer Head Mounted Optics Manual*. Instructions for configuring the system to show the head mounted scene camera image are in the *ETServer Head Mounted Optics Manual*.

In either case, and assuming calibration instructions for the corresponding type of scene image have been followed, point of gaze should be shown as a moving blue cross superimposed on the scene image. If a stationary scene camera image, outlines showing the scene plane boundaries, location of scene plane definition points or scene camera mapping points may be shown on the image by checking the appropriate box on the *Data Display Screen* “Display Control” box (see previous section). For either stationary or head mounted scene image, the most recent calibration point positions can also be shown. If a stationary scene camera image, these points should be in the proper place with respect to scene plane zero. If a head mounted camera image, the position of the calibration points will be shown with respect to the head mounted scene camera field of view; but remember that the camera may no longer be pointed towards the same place in the environment.



Stationary Scene Camera image with scene plane outlines and Point of gaze cursor (blue cross)

9. 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.

9.1.1 Correcting Gaze with respect to EyeHead Integration scene planes

ET3Space has a separate manual offset correction capability for each scene plane. There is a quick offset capability that requires the subject to look at the origin of a scene plane, 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 *Data Display Screen* will show the number of the scene plane on which gaze is currently detected, and the point-of-gaze with respect to that scene plane. Point of gaze will also be displayed on the *Scene Image Screen* if a Stationary Scene camera is enabled. If point of gaze on any particular scene plane appears to have an offset error (error of about the same amount and direction over whole surface), it can be corrected by the following methods.

To correct an offset with a single mouse click, have the subject look at the origin point on the scene plane in question; verify, on the *Data Display Screen*, that the system is detecting gaze on that scene plane; and click the *Data Display Screen* button labeled “Quick Offset to Origin”. The appropriate data offset will automatically be entered to place gaze at the scene plane origin. The cursor on both the *Data Display Screen* and *Scene Image Screen* (if showing a stationary scene camera image) should snap to the scene plane origin.

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

To correct an offset by dragging the POG, click the button labeled “Drag Left Mouse Button to Adjust” and left drag in the “POG Display” area. 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 accidentally 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 *Data Display Screen* are offset from the known point of gaze coordinate by a given amount, type in the negative of that amount. For example, if the subject has been asked to look at a scene plane origin point (0,0) and the horizontal point of gaze coordinate is showing 5.0 on that scene plane, rather than 0, type in -5.0 as the horizontal offset correction for the scene plane in question.

Note that if *ET3Space* is enabled, all of the above methods affect only the scene plane on which the system currently detects point of gaze, and affects only *ET3Space* data. If the *Scene Image Screen* is showing the image from a head mounted scene camera, the POG cursor on this image will not be affected.

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

9.1.2 Correcting Gaze with respect to Head Mounted Scene Camera

This section assumes that *ET3Space* is being used with a head mounted, rather than stationary, scene camera.

If, after subject calibration, the point-of-gaze (POG) cursor on the head mounted scene camera image appears to be offset (in error) in a similar direction and by a similar amount over the entire field, this can be corrected quickly, without repeating the calibration, just as for the *ET3Space* data. However, *ET3Space* must be temporarily disabled to make offset adjustments to the head mounted scene camera cursor. Uncheck the “ET3Space Enabled” box on the *System Control Table, System Configuration* tab,

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

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 is turned off.

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

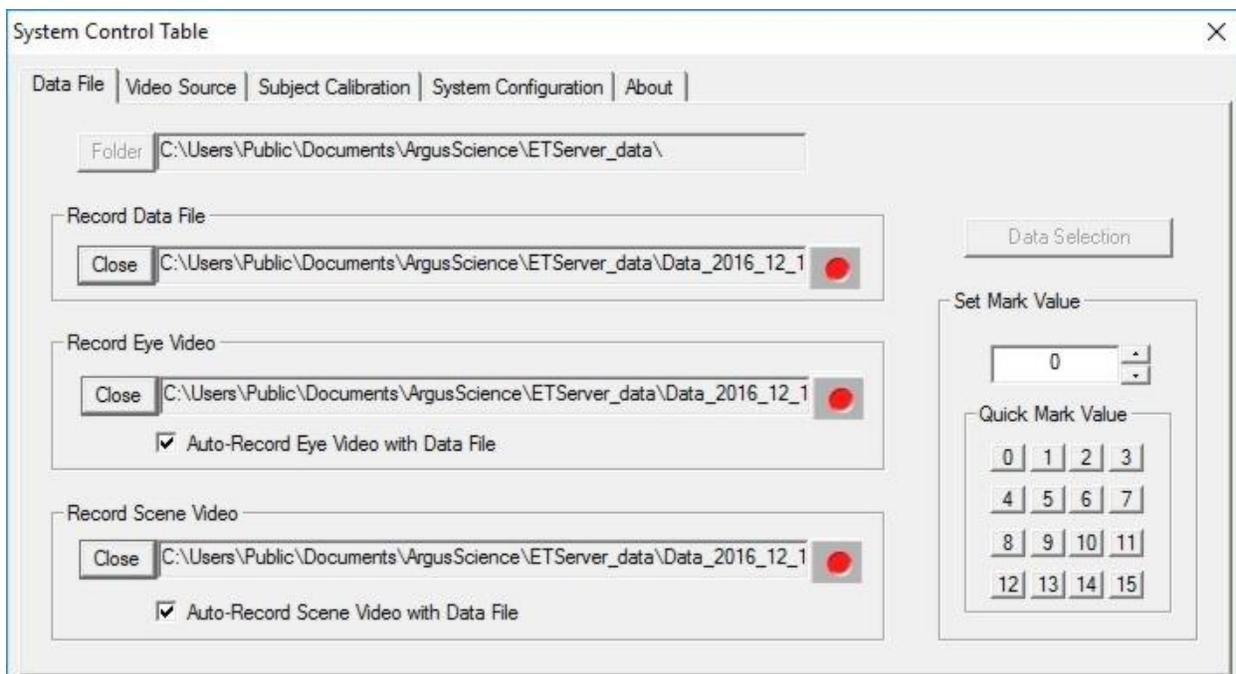
Once the offset adjustment has made, re-enable *ET3Space* by checking the “ET3Space Integration Enabled” box on the *System Control Table, System Configuration* tab. Note that the offset adjustment to the head mounted image cursor will have no affect on the *ET3Space* data. To make an offset adjustment to *ET3Space* data, use the “Quick Offset to Origin” or “Drag Left Mouse Button to Adjust” buttons with *ET3Space* enabled (as described in the previous section).

10. Collecting Data with ET3Space

It is strongly advised that the subject calibration be done before opening a data file. This will ensure that information about the calibration is included on the file header. If recording data for the first time, be sure that data file is configured to record the desired data set. See instructions in the *ETServer Head Mounted Optics* manual, in the section titled “Configure Data File”.

To automatically record the *eye or scene video along with digital data use the check boxes on the System Control Table, Data File* tab. Open a file either from the *Data File* tab dialog, or the “New Data File” selection on the *File* menu. If *ET3Space* is enabled, the file will be given an “ehd” extension and the *ET3Space* data set will be recorded.

Start recording either from the *Data File* dialog (red “record” symbol to the right of the file name), or by selecting “Record” from the *File* menu. Click the Pause symbol (two vertical bars) on the *Data File* dialog, or select “Stop” from the *File* menu to stop recording. Close the data file by clicking “Close” on the *Data File* dialog, or by selecting “Close” from the *File* menu.



See the *ETServer Head Mounted Optics* manual for more detail.

A list of data items available for recording and an explanation of each can be found in the *ETServer Head Mounted Optics* manual.

11. Communication with External Devices

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

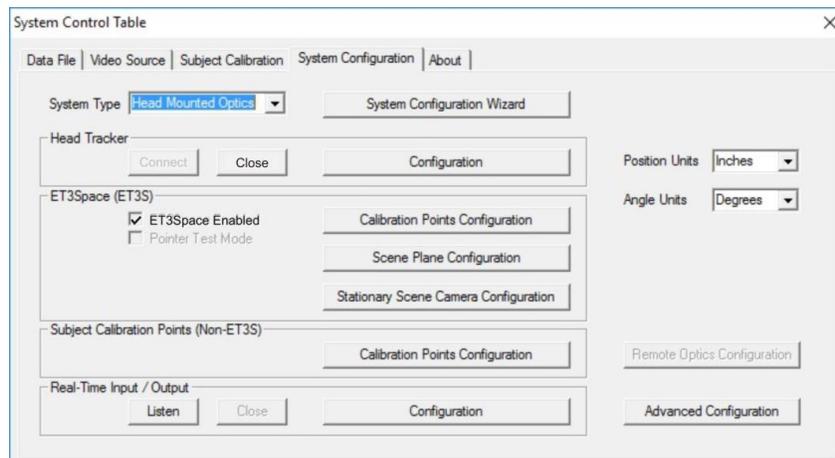
- Devices connected to the LAN can receive real time digital gaze and pupil diameter data, as well as the scene or eye video images. All of the data items that can be recorded by *ETServer* can also be sent, in real-time, to an external device. Detailed instructions for sending real-time data are in the *ETServer Head Mounted Optics* manual.
- A device connected to the LAN can send a channel of data to be recorded by *ETServer* along with gaze data, and can remotely open and close data files, and start and pause data recording on the *ETServer*. Detailed instructions are in the *ETServer Head Mounted Optics* manual.
- If the primary scene image being viewed by the subject is a computer display screen, and the computer is running Microsoft Windows 7 or Windows 10, the display screen image can be sent to the *ETServer* via LAN connection for use as the “Stationary Scene Camera” image. Instructions are in section 3.2 of this manual and in the *ETServer Head Mounted Optics* manual.

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

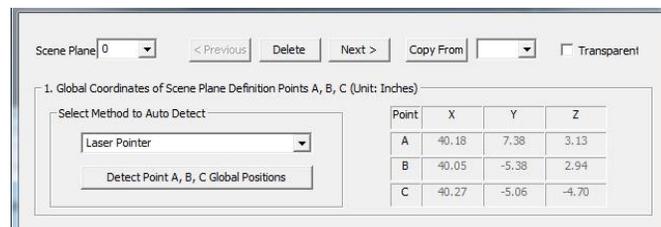
As part of the environment setup procedure, it is necessary to specify “definition points” for scene plane in the global coordinate system. There are several possible methods for doing this, and they were all described briefly in section 4.4.2.1. Each method is described in more detail below.

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 discussed in section 4.4, 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 4.4.1.



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.

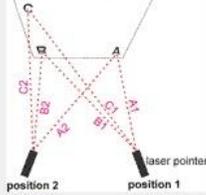
On the version shown below, the laser is activated with a button on the bottom of the alignment tube. An opening in the top of the alignment tube allows access to the laser battery compartment for battery replacement. Other versions of the laser pointer may look slightly different, but basic operation is the same. CAUTION: The laser is a class II laser. Do not look directly at the laser source or its mirror reflection.

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”.

Point A, B, C with Laser Pointer



Laser Direction in Sensor Coordinate System (Unit: Inches)

X Y Z

Point Auto Advance

Aim laser at Scene Plane Definition Point (A, B, or C) from designated position (1 or 2), click "Enter Data" button. Be sure to enter data for all three points.

Sensor Data Entered (Unit: Inches)

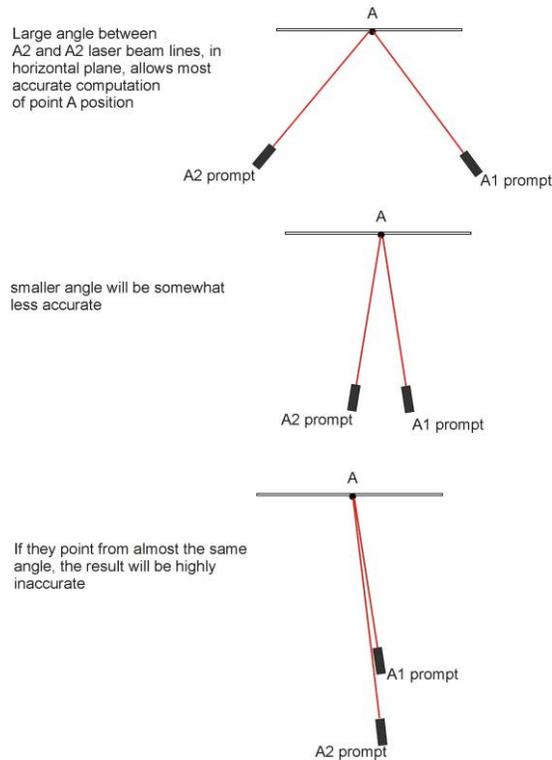
Point	X	Y	Z	AZ	EL	RL
A1	12.22	15.53	-2.40	163.75	10.33	-2.59
B1	11.25	13.13	-2.58	147.27	8.44	-1.98
C1	10.96	13.48	-3.84	147.68	-1.93	-1.80
A2	10.11	-8.76	-2.81	-151.77	10.24	-3.12
B2	11.02	-10.93	-2.58	-169.17	11.40	-2.77
C2	10.61	-11.10	-4.28	-168.49	-0.20	-2.53

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, be sure that the sensor is being properly recognized by the head tracker system, 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 sensor 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.

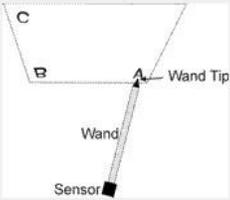
12.2 Pointer Wand Method

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”.

Point A, B, C with Wand Tip



Position of Wand Tip in Sensor Coordinates (Unit: Inches)

X Y Z

Point Auto Advance

Touch Wand Tip to Scene Plane Definition Point (A, B, or C) and click "Enter Data" button. Be sure to enter data for all three points.

Sensor Data Entered (Unit: Inches)

Point	X	Y	Z	AZ	EL	RL
A	14.21	16.23	-2.20	159.13	10.61	-1.54
B	12.92	14.33	-2.46	142.30	8.90	-1.19
C	12.66	14.80	-3.84	142.58	-1.65	-1.01

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 head gear, 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.

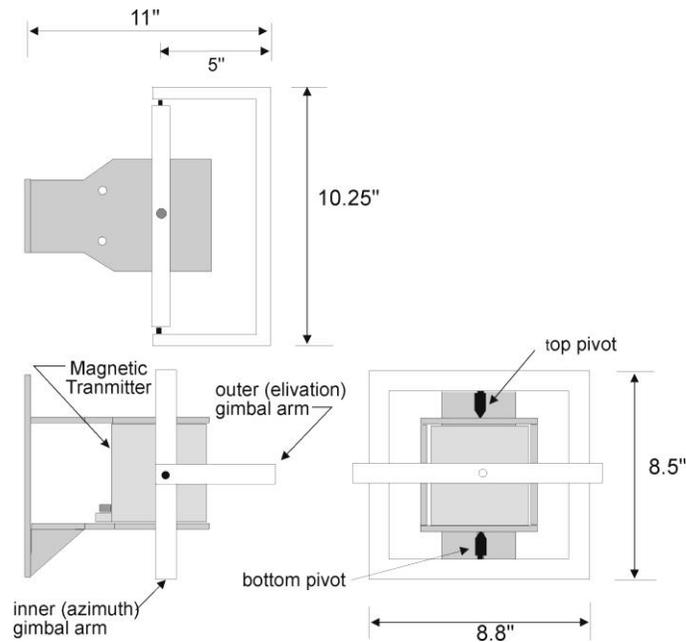
Note that the values that appear in the table at the bottom of the dialog are the position of the sensor when data was entered, not the position of point A, B, or C. The values in the table can be checked to make sure that they are sensible. For example if an optical tracker was blocked when one point 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.

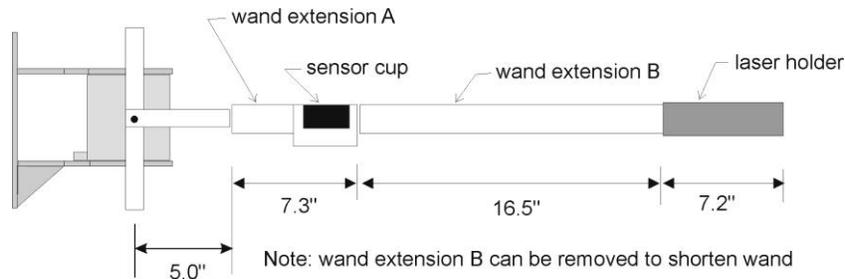
12.3 Gimbal Laser Pointer Method

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



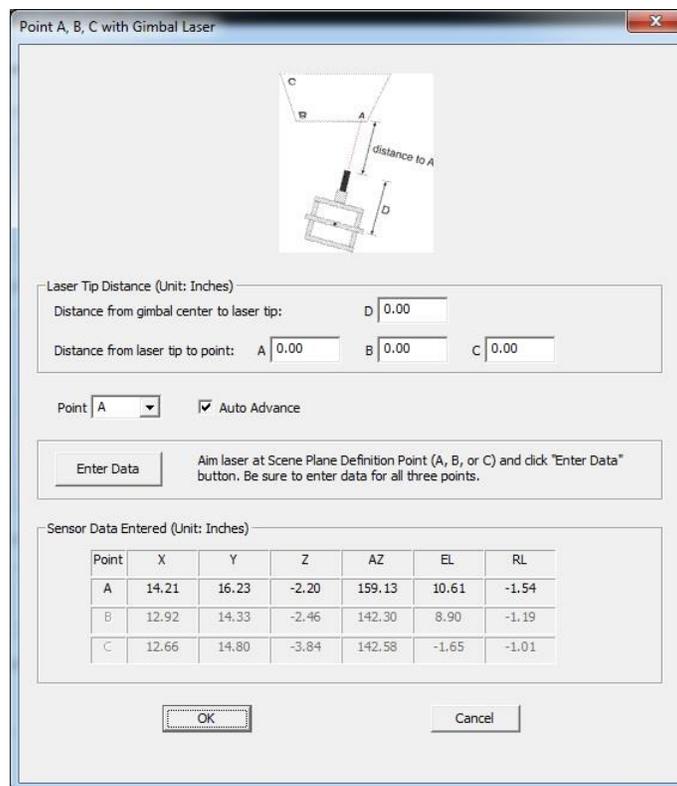
Side view of transmitter mount and Gimbal assembly with laser wand attached to outer gimbal

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.

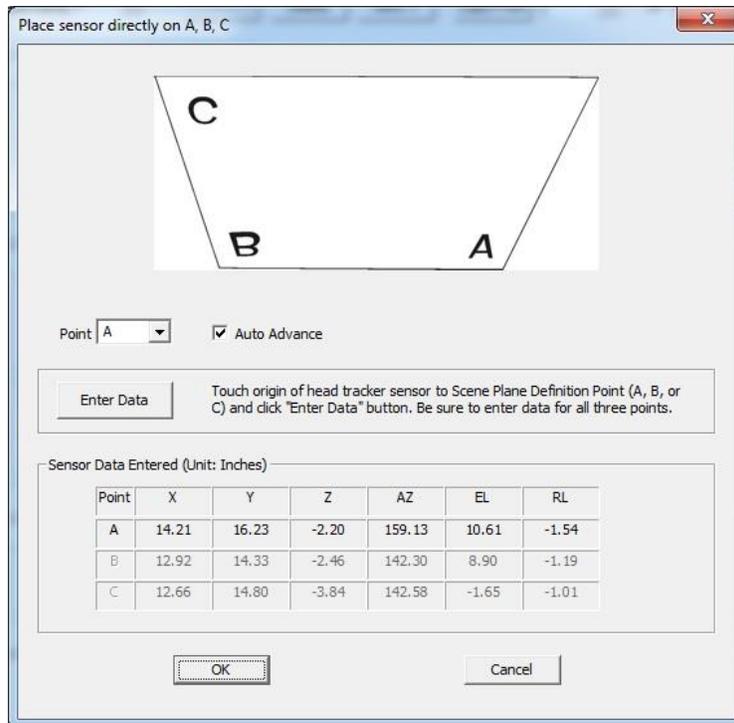
Each time data is entered the sensor position and orientation measured by the tracking system will be entered in the table at the bottom of the dialog, and the “Point” prompt will advance. To enter data out of order, use the drop down menu to select a point before entering data. Note that the values 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.