EQASCOM Alignment

Introduction

This document will attempt to explain how EQASCOM implements its alignment routines to achieve the highest possible GOTO Accuracy. We shall present the different alignment configurations possible and explain what type of mount/OTA errors can be corrected.

Points v Stars

Its quite likely that whilst reading EQMOD documentation and/or forum postings you will come across references to “Alignment Stars” and N-Star alignment. Certainly until recently this was the terminology we used, however, with version EQASCOM V1.17 we have re-worked our user interfaces to use refer to Alignment Points, N-Point etc. Whilst it is certainly the case that most folks will use stars as handy reference points when performing alignment we found that new users were often confused about there relevance to the pointing model. The term Point is preferred because:

- Stars do not hold a fixed position with respect to the observer, they are constantly moving. The alignment model dos not move and holds true irrespective of the subsequent position of the stars used to create it.
- Alignment can be archived using plate solving which does not require centring the telescope on a specific target star.

Pointing Correction Transformations

EQASCOM has two basic telescope pointing correction methods used in computing for the location of a target object based on a number of reference points.

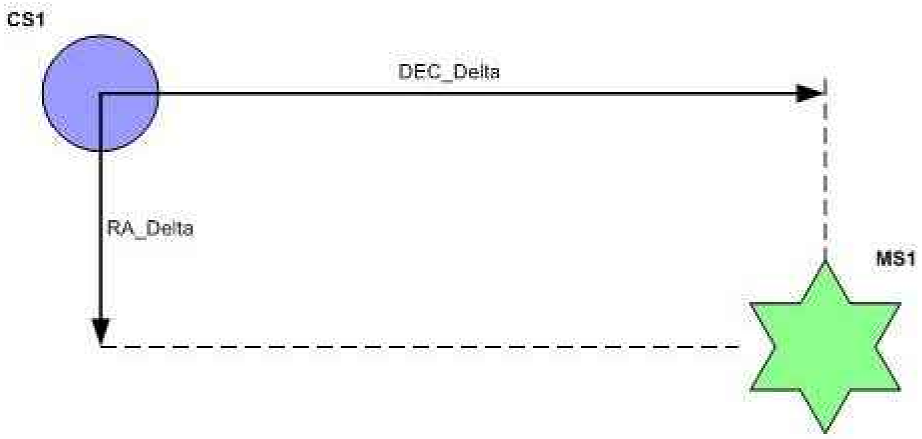
Nearest Point Transformation

This uses a Delta mapping method (Delta-RA, Delta-DEC) where simple coordinate transformation is used based on the distance (in RA and in DEC units) between the known Catalog Coordinate of an alignment point and the actual location of the point. The actual location of the point is measured by a user using a reticle eyepiece.

3–Point Transformation

The second method uses the AFFINE/TAKI Coordinate transformation process based on three reference points and their respective measured locations using a reticle eyepiece.

Nearest Point Transformation Model



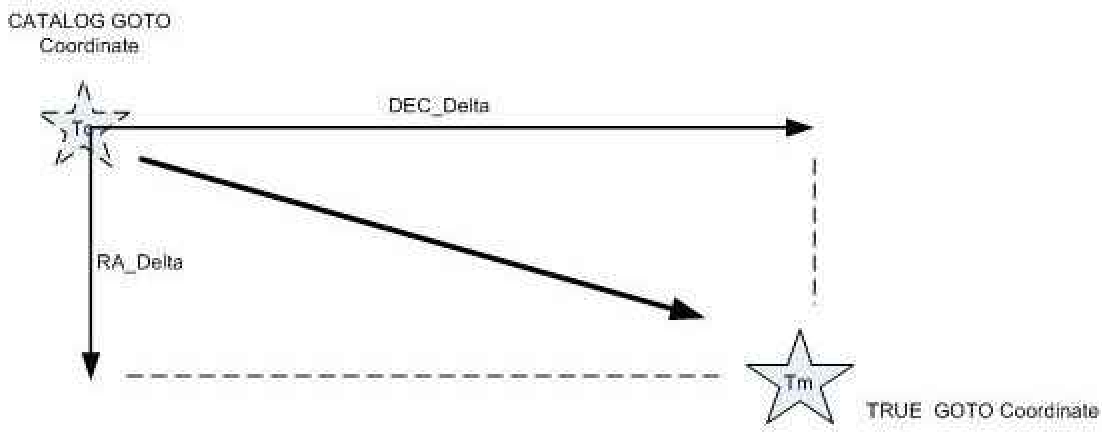


FIGURE 1: EQMOD Nearest Point Transformation method using the basic Delta-RA and Delta-DEC Distance mapping technique

In the 1 Point model, EQASCOM simply gets the location of the measured point and records the RA and DEC distance between the Planetarium Database RA and DEC coordinates (Catalog Coordinates) of the point/star (CS1) and the mount's reported RA and DEC coordinates of the measured point (MS1) as captured during the alignment procedure. The RA_delta and DEC_delta (distance) values are then used to compute for the location of any target object (Tm) based on the object's Planetarium Database Catalog coordinates (Tc).

The 3-Point Transformation Model

For the 3-Point transformation method, the AFFINE/TAKI coordinate transformation matrix operation is used to compute for the apparent location of an object (Tm) based on the RA/DEC coordinates three reference Catalog point (CS1,CS2, CS3) and the measured RA/DEC coordinate of these points (MS1,MS2,MS3) as captured during the alignment process. The target object's coordinates (Tm) is then computed by AFFINE coordinate transformation on the Catalog (CS1-3), Measured (MS1-3), and Catalog Coordinates of the target object (Tc).

The most accurate gotos are obtained INSIDE the triangle bounded by the three alignment points. For locations outside the triangle EQASCOM automatically switches to use the Nearest Point (1-Point) model.

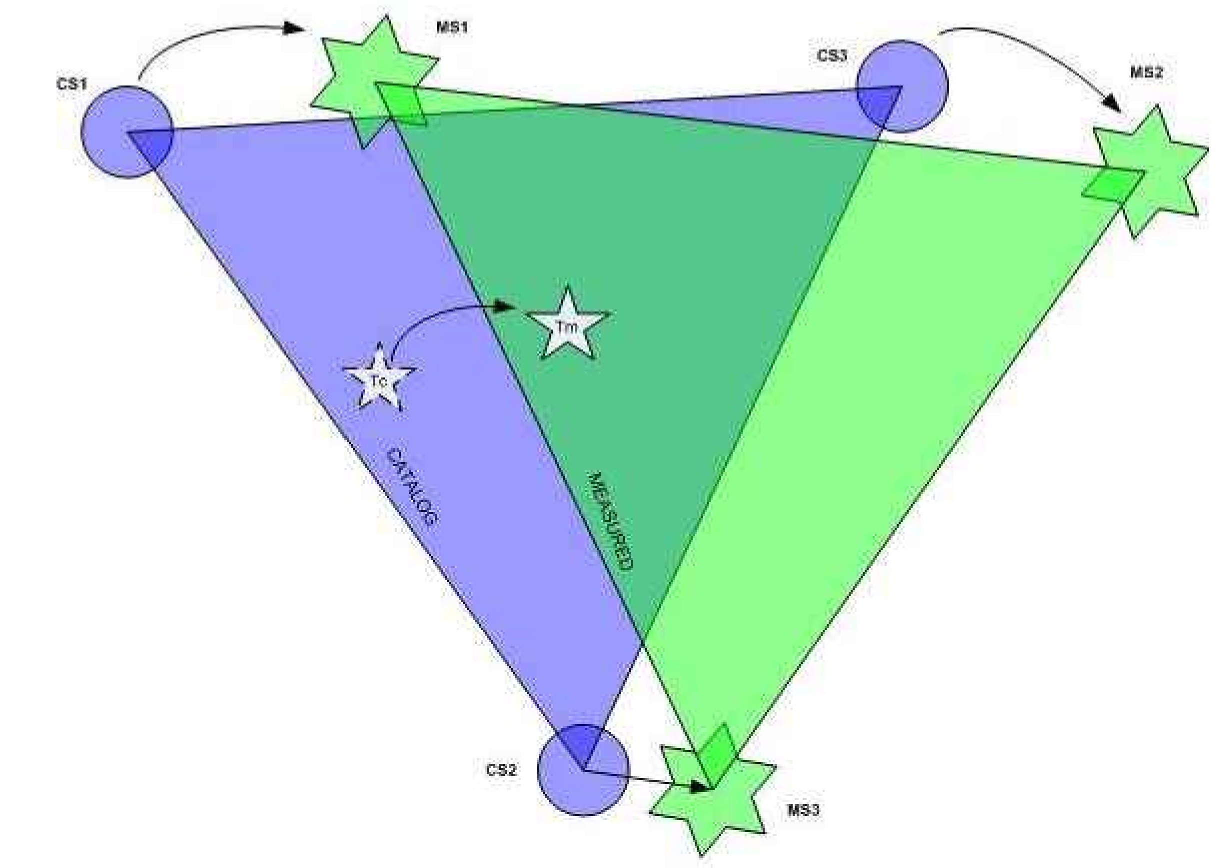


FIGURE 2: EQMOD 3-Point Transformation Method using the 3-point AFFINE Coordinate Transformation

Mount/OTA Error Modelling using Nearest Point and 3-Point Coordinate Transformation

EQASCOM's mount error modelling scheme uses a coordinate transformation process between the celestial sphere and the mount's stepper coordinate space. This basically is a point-to-point (mount-to-sky) mapping for any errors such as X-Y shifts, rotation, magnification, reduction, and one-sided skews which translate to polar alignment, cone errors, OTA axis alignment errors, RA and DEC axis errors, etc.

With Nearest Point error modelling, only the RA coordinate and DEC coordinate shifts (X-Y shifts) are accounted for. It does not account for rotations, magnification, reduction, and coordinate skews where most of the mount errors are present.

With 3-point error modelling, X-Y coordinate shifts, rotations, magnification, reduction, one-side skews are being accounted such that most of the alignment errors present on the mount and the OTA's optical axis are being compensated. The following figures illustrate all kinds of scope 3-point modelling errors that can be present on any setup.

3-Point X-Y Shifts Errors

Figure 3 and 4 shows a sample measured X and Y shift errors on all three stars with respect to the Catalog Points. If such errors are measured on one side of the meridian for example (Figure 5), the mount could have exhibited a misalignment from the true RA home position and DEC home position which is commonly present on manually aligned Mount to OTA Home positions (Counter weights shaft pointed down, OTA pointing north or south). This is basically normal as we typically start from a "manually home positioned" mount.

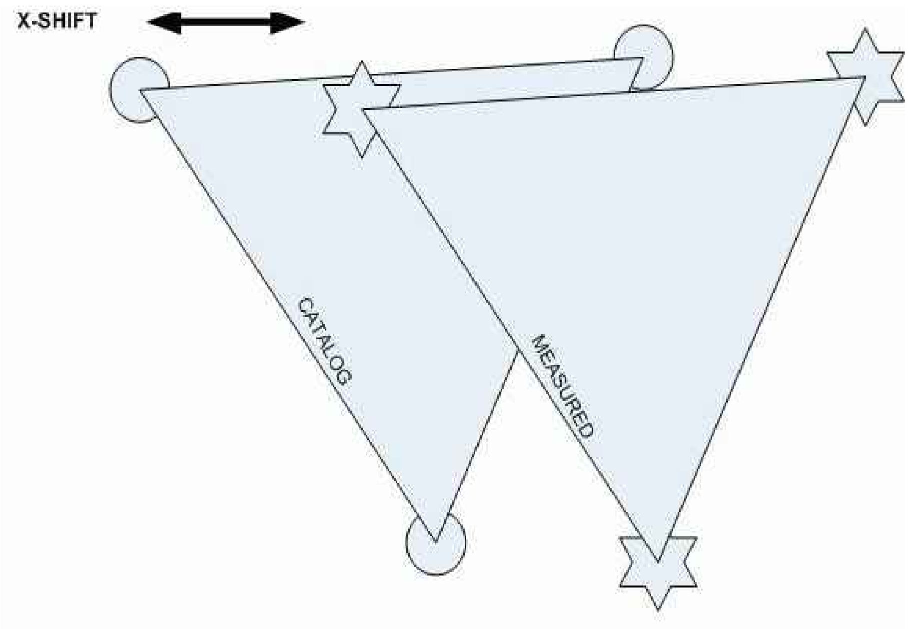


FIGURE 3: Three-Point X-Shift error representation

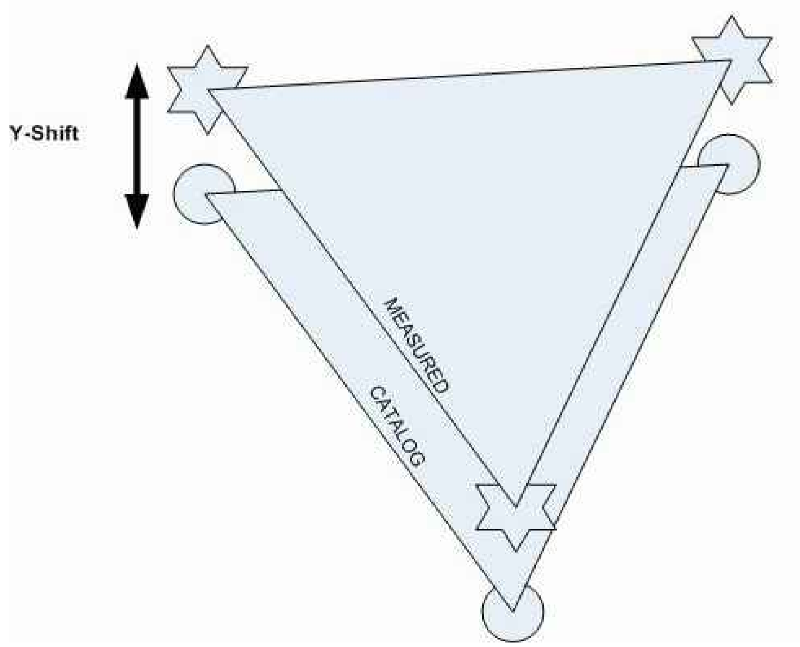


FIGURE 4: Three-Point Y-Shift error representation

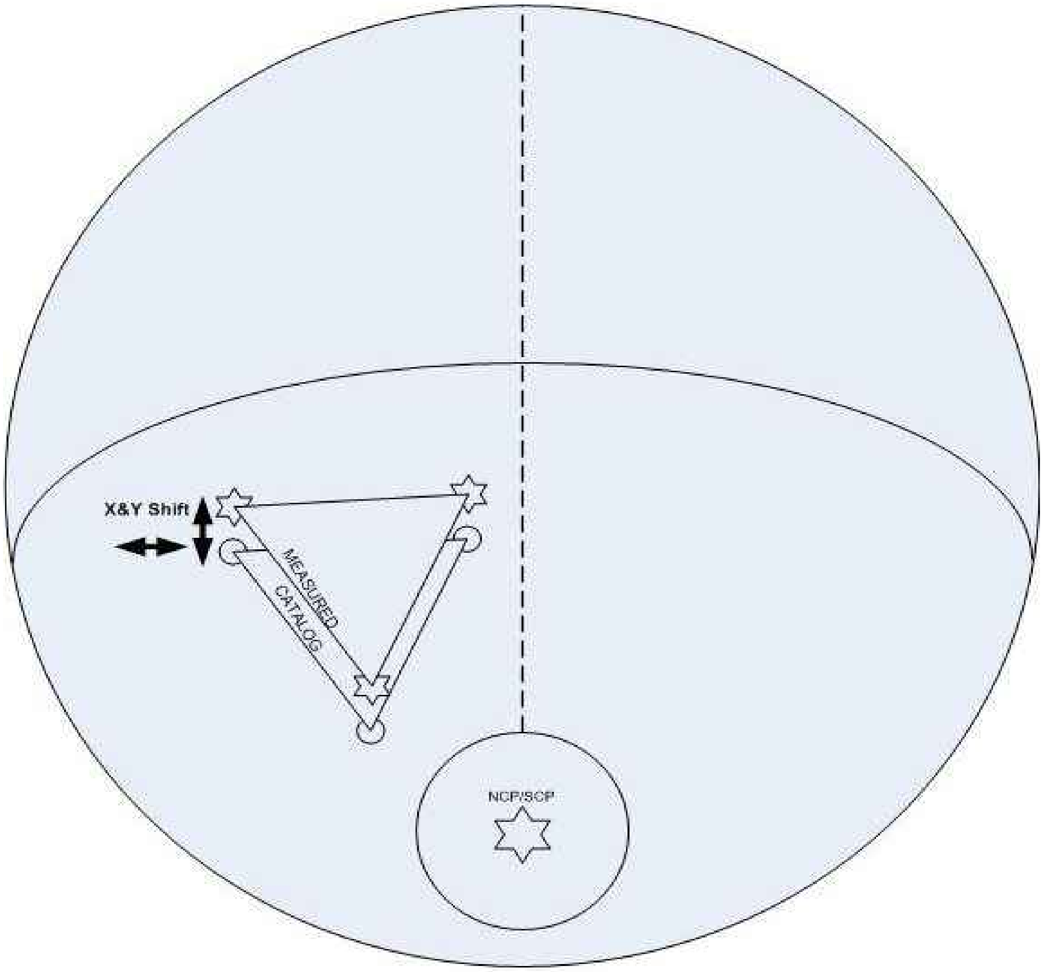


FIGURE 5: Three-Point X-Y Shift error on a Mount Coordinate space to Celestial Sphere Coordinate space

Three-Point Rotation Errors

In Figure 6 the measured stars exhibit a rotation with respect to the Catalog coordinates. If such rotation is measured for example at the meridian side (figure 7), the mount has exhibited an error shift on the Azimuth to NCP/SCP. If a rotation is present for example on the horizon side (Figure 8), the mount has exhibited an error shift on the Altitude to NCP/SCP. The angle of rotation is actually the measured drift slope on EQASCOM's Polar alignment computations. The higher the angle of rotation, the higher the drift slope will be, which basically translates to Polar Alignment shift errors. Three-point rotation errors is a clear indication of the mount's RA axis not being parallel to the Earth's axis.

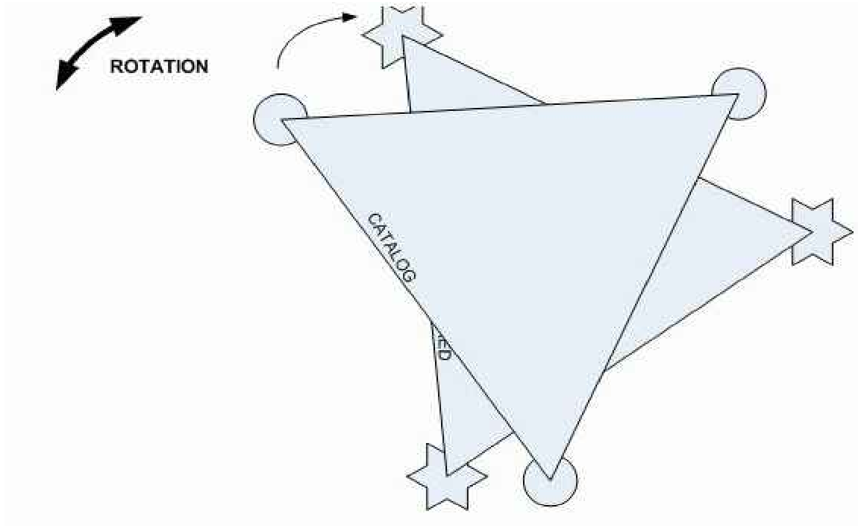


FIGURE 6: Three-Point Rotation error representation

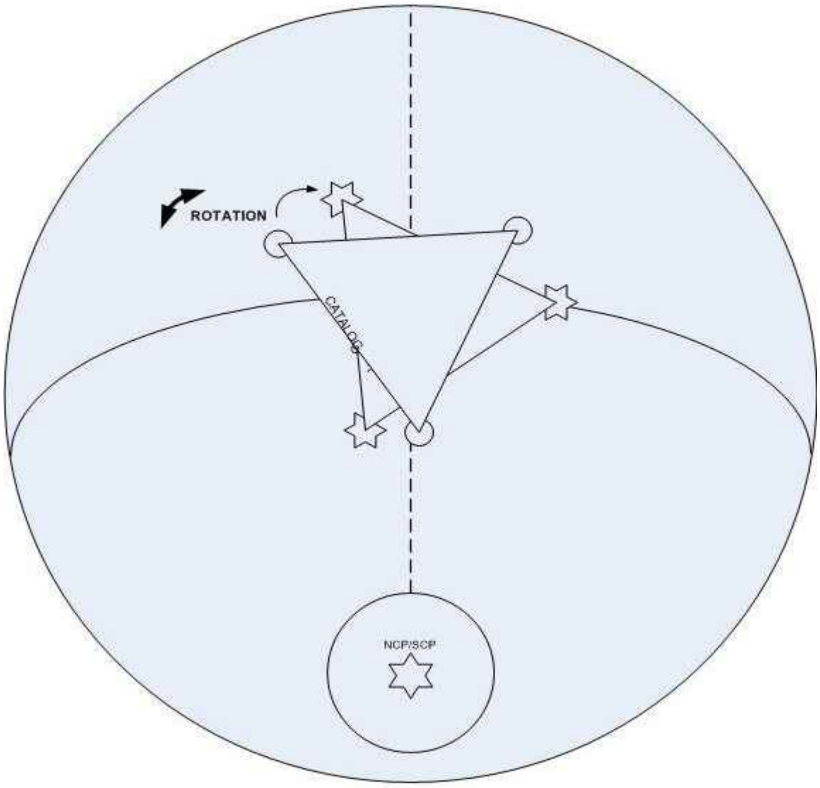


FIGURE 7: Three-Point Rotation error on a Mount Coordinate space to Celestial Sphere Coordinate space as Measured from the Meridian Side

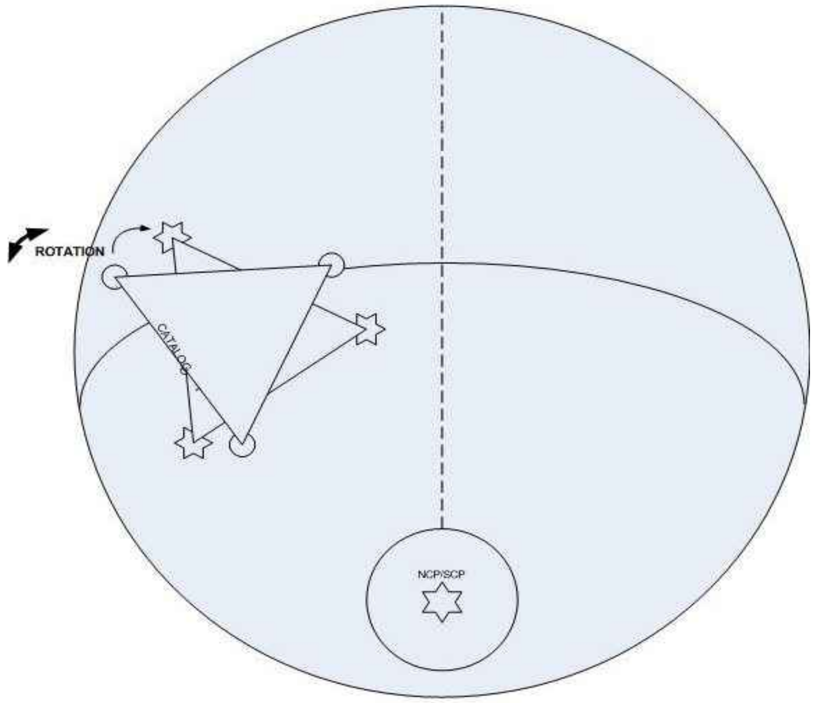


FIGURE 8: Three-Point Rotation error on a Mount Coordinate space to Celestial Sphere Coordinate space as Measured from the Horizon Side

Three-Point Magnification-Reduction Errors

In Figure 9, the area of the triangle formed by the measured points is greater or less than the area of the triangle formed by the 3 Catalog points. If such errors are measured for example at the meridian (Figure 10), then the mount could have exhibited the classic case of CONE errors. The shift is usually away from the meridian and towards or away from the horizon. This basically means that the OTA's optical axis is NOT perpendicular to the mount's DEC Axis.

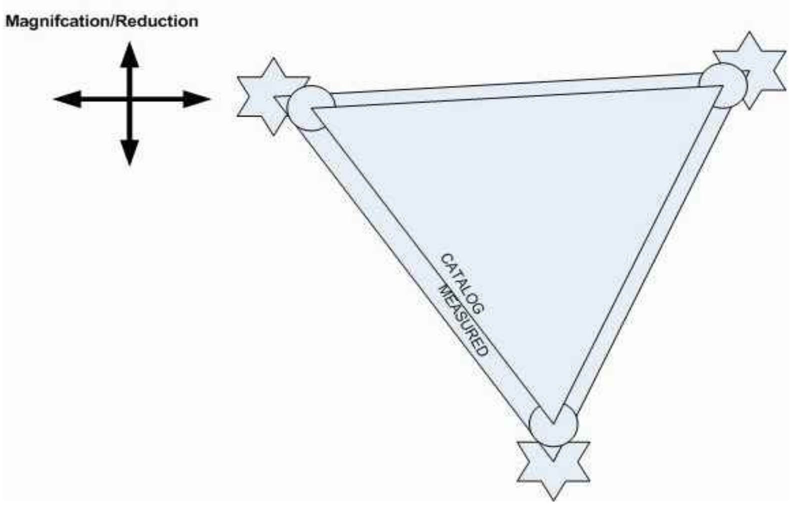


FIGURE 9: Three-Point Magnification-Reduction error representation

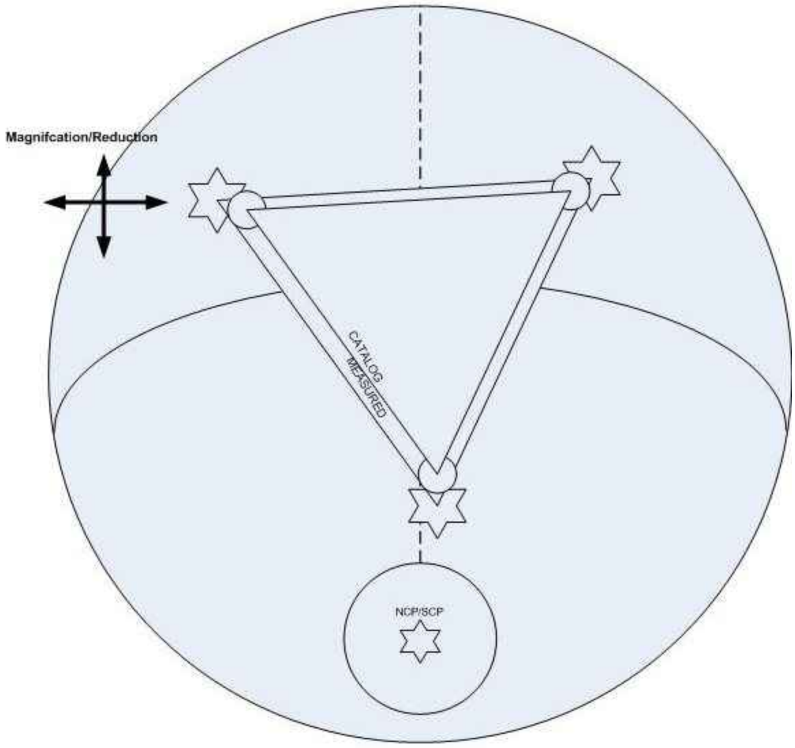


FIGURE 10: Three-Point Magnification-Reduction error on a Mount Coordinate space to Celestial Sphere Coordinate space

Three-Point 1 Side Skew Errors

Ideally, the AREA of the triangle formed by the three Catalog Points should be identical to the triangle formed by the three measured Points. If one of the points has exhibited a shift (Figure 11) and there are no rotation or magnification errors, then there is a skew and the AREA of both triangles will not be equal. Such skew when measured for example at any part of the sky (Figure 12), then there is the classic case of mount to OTA flexures. Mechanical flexures are typically isolated and OTA position angle specific and the influence on the three alignment stars are not constant thus creating a skew on the alignment stars.

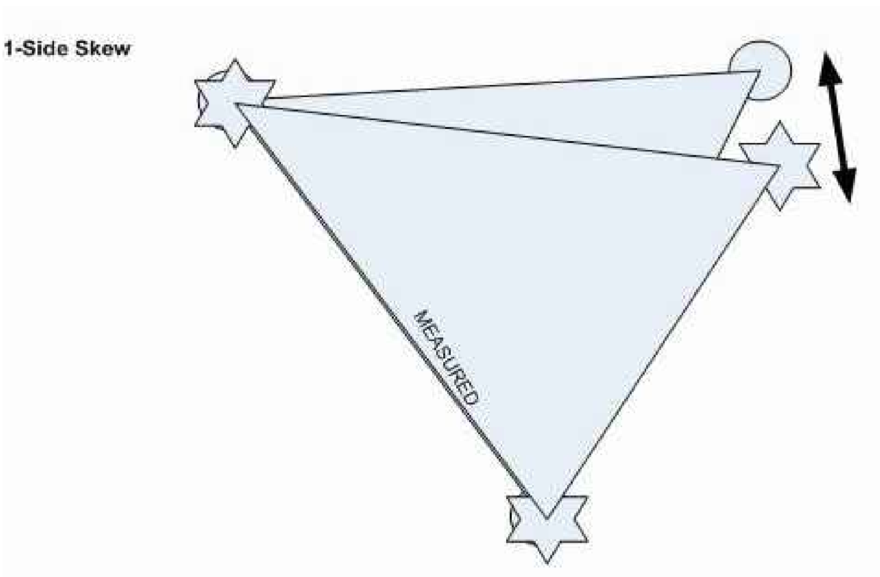


FIGURE 11: Three-Point 1 sided skew error representation

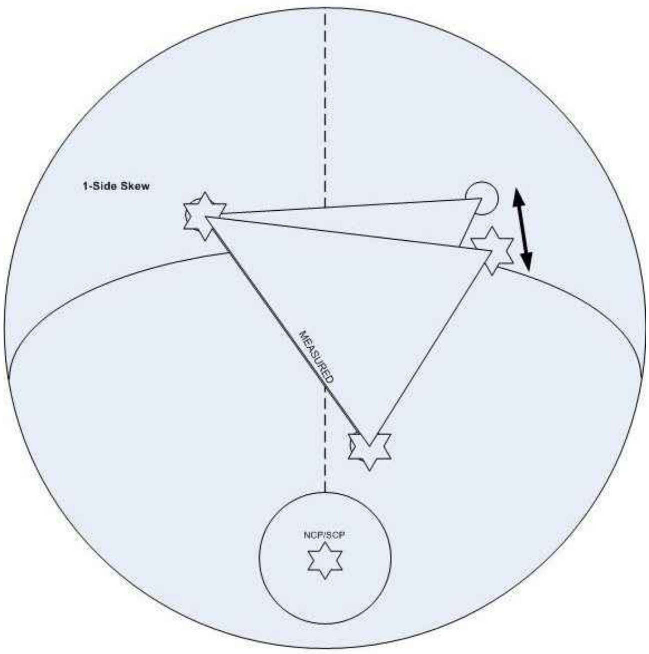


FIGURE 12: Three-Point One-Sided skew error on a Mount Coordinate space to Celestial Sphere Coordinate space

Three-Point Combination Errors

With a Three-Point combination (Figure 13 - X-Y Shift, Rotation, Magnification-Reduction, 1sided skews), the algorithm basically models most of the mount's misalignment errors. As the mount+OTA sees it on the sky (Figure 14), the algorithm practically compensates for these errors and should easily provide you the most accurate GOTO pointing model for your mount.

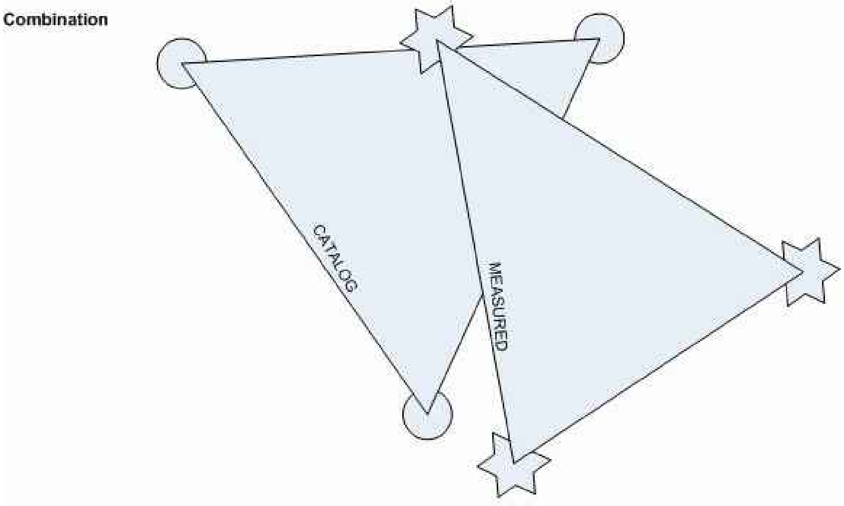


FIGURE 13: Three-Point Combnination X-Y Shift, Rotation, Magnification-Reduction, 1Sided Skew error representation

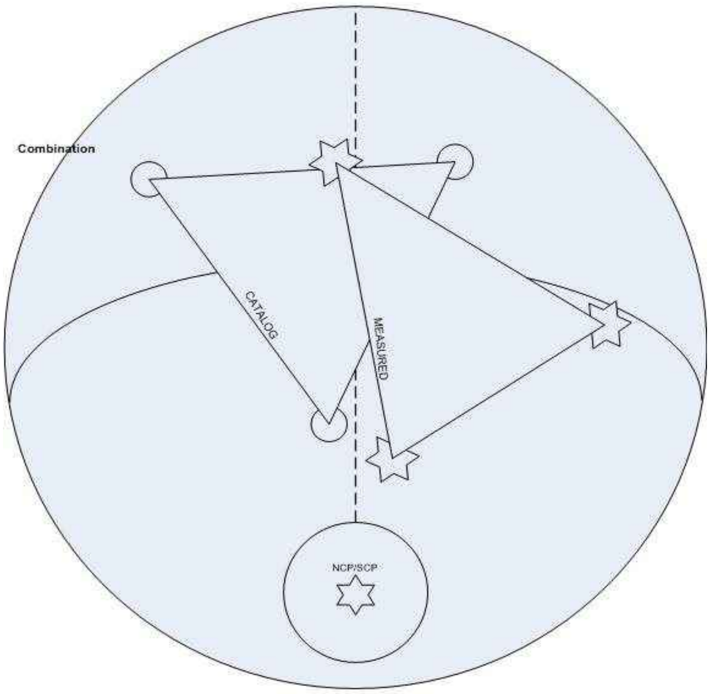


FIGURE 14: Three-Point Combnination X-Y Shift, Rotation, Magnification-Reduction, 1Sided Skew error on a Mount Coordinate space to Celestial Sphere Coordinate space

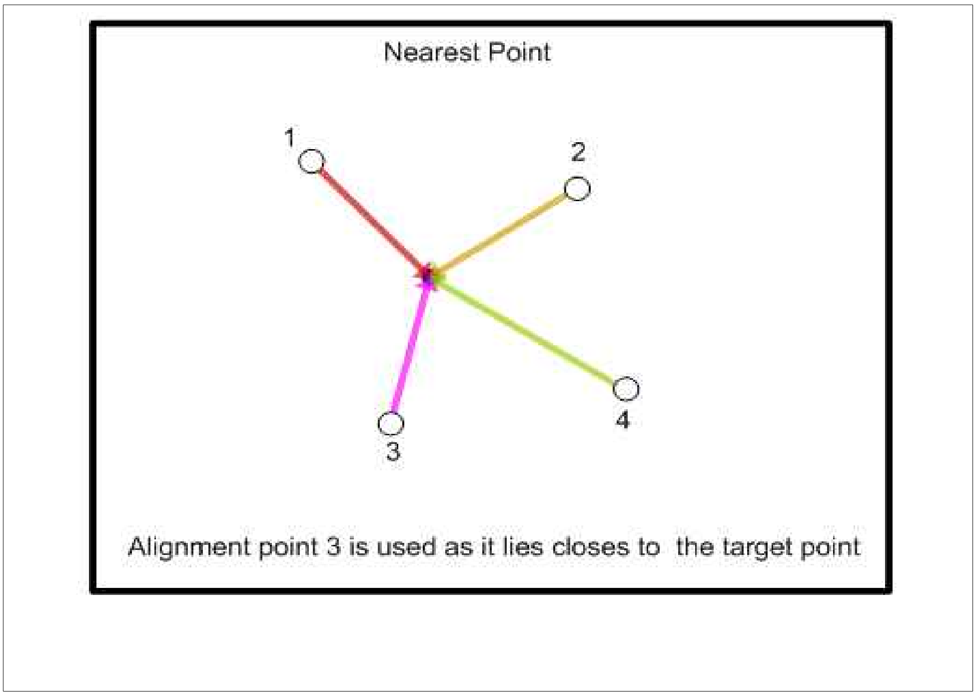
EQASCOM Pointing Models

So far we've looked at the pointing transformations that EQASCOM has at its disposal. How and when EQASCOM uses these transformations is the key to the Pointing Model.

EQASCOM provides a N-Point pointing model. Users can define pretty much as many alignment points as they wish (up to 1000 maximum). The user also has some control over which pointing transformation algorithms are used.

Nearest Point

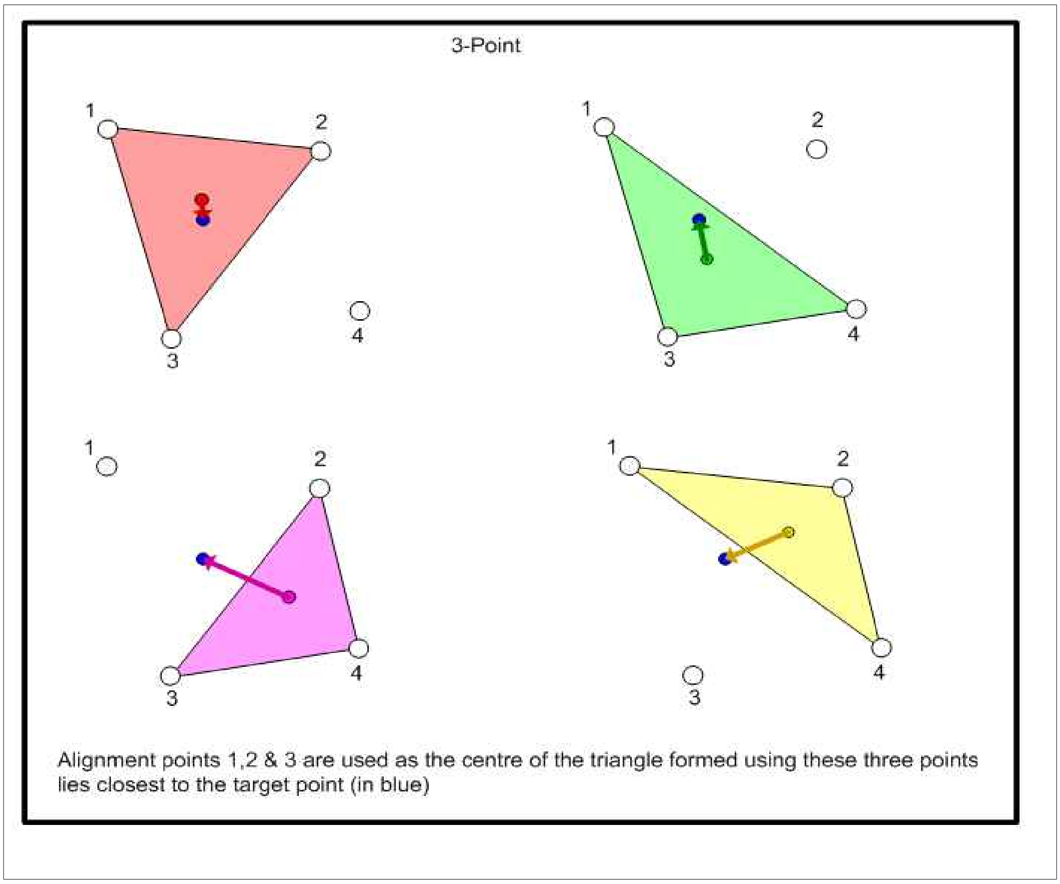
Nearest Point simply searches through the current alignment list to find the alignment point nearest to target position. Once the nearest star is found a transformation is preformed based upon the data associated with that point.



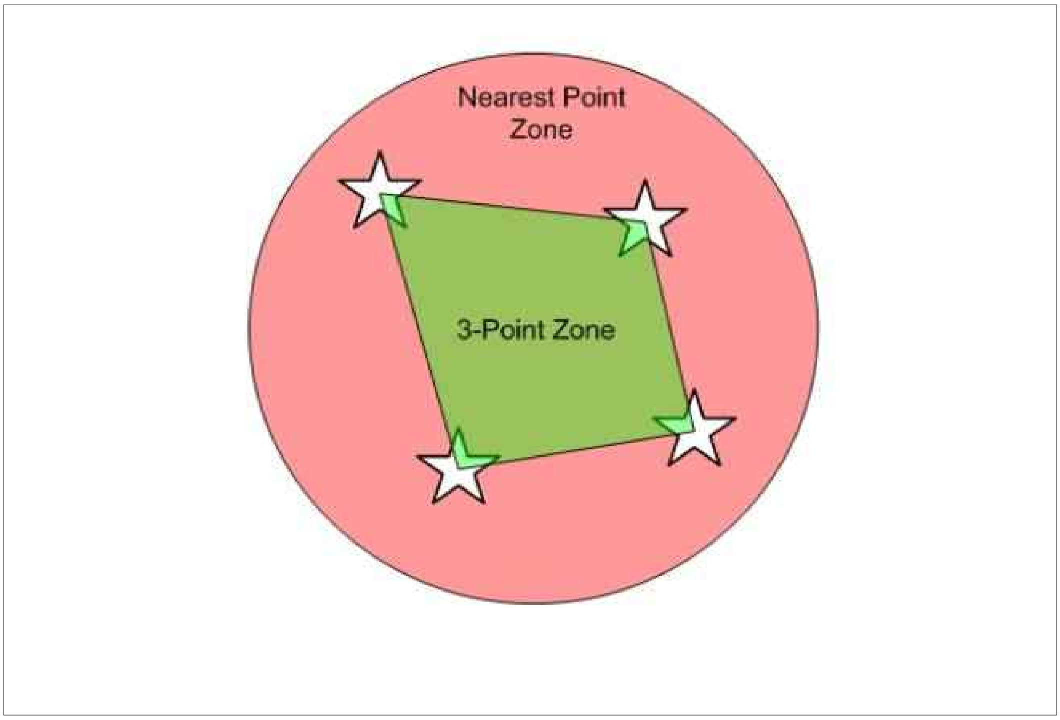
3-Point

EQASCOM will automatically choose the best Transformation method.

- If less than 3 points have be defined it will use a Nearest Point transformation
- If 3 or more points are defined then EQASCOM iterates through all triangle combinations possible using the 50 nearest alignment points to establish which triangle has its centre closest to the target position. The three alignment points that make up that triangle are then used for pointing correction. The diagram below illustrates this process. There are four stars in the alignment list and as a result there are four possible alignment triangles.

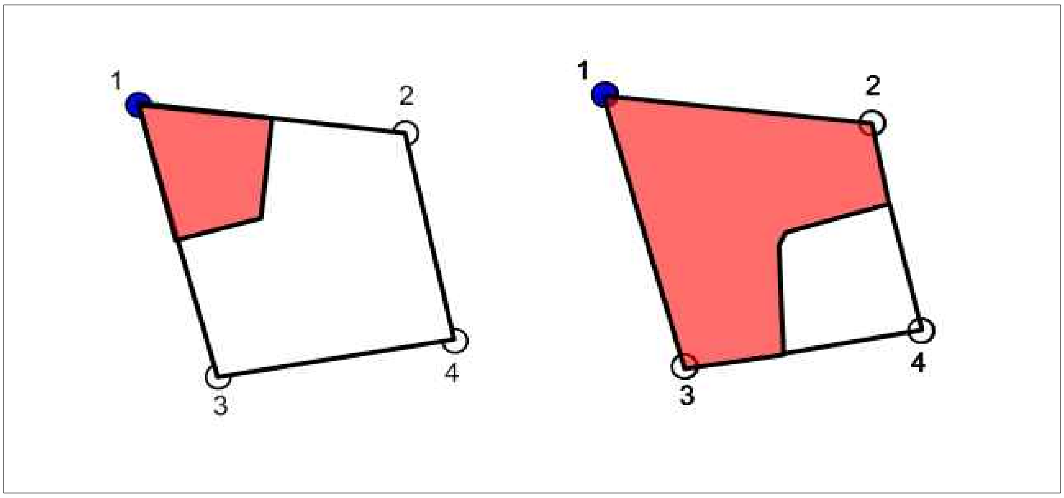


- Where a target falls outside of the bounds of a 3-Point triangle EQASCOM will automatically switch to using the Nearest Point transformation.



- A potential problem occurs where where 3-Point triangles span the meridian, particularly if you have a reflecting telescope where mirror flop many be significant factor. EQASCOM has a “Pierside Points Only” checkbox which will ensure that only points on the same side of the meridian as the target point to be used in transformation calculations.

- When using a three point transform it is clearly important that all three alignment points used have been accurately calibrated. One badly calibrated point can have an impact over a large area of sky. The digram below compares the the area of influence the blue alignment point has for both Nearest Star (left) and Three Star (right) transformations.



- As the number of alignment points increase the areas of influence of each individual point become increasingly more complicated to visualise. If you have any doubts about the accuracy of any alignment points within a MultiPoint model you may find better pointing is achieved by switching to using a Nearest Point algorithm which limits thee areas of influence of badly calibrated points.

Choosing which Alignment method to use

The following sections will give you some basic guidelines on choosing which alignment method to use. EQMOD provides all of these alignment methods at the disposal of the user so that the system can easily adapt for any mount+OTA alignment conditions,

1 Point Alignment

When fewer than three points are present EQASCOM will automatically apply a Nearest Point transform. A One Point alignment (Figure 15) only compensates for X-Y shift errors and should work with the following:

- User has opted for 1 star sync for quick alignment/imaging/observing session. This works best if the target object is situated near the alignment star

- 1 Point alignment would only be suitable for "all sky" pointing if :

    - The mount is accurately polar aligned
    - There are no CONE ERRORS and the OTA's optical axis is always perpendicular with the DEC axis
    - Minimized Flexure errors
    - No (or minimized) mechanical slop on both RA and DEC gears

It is best to choose the alignment point to be near the celestial equator and at least 30 to 45 degrees from the horizon to minimize any light refraction shifts which are prominent near the horizon.

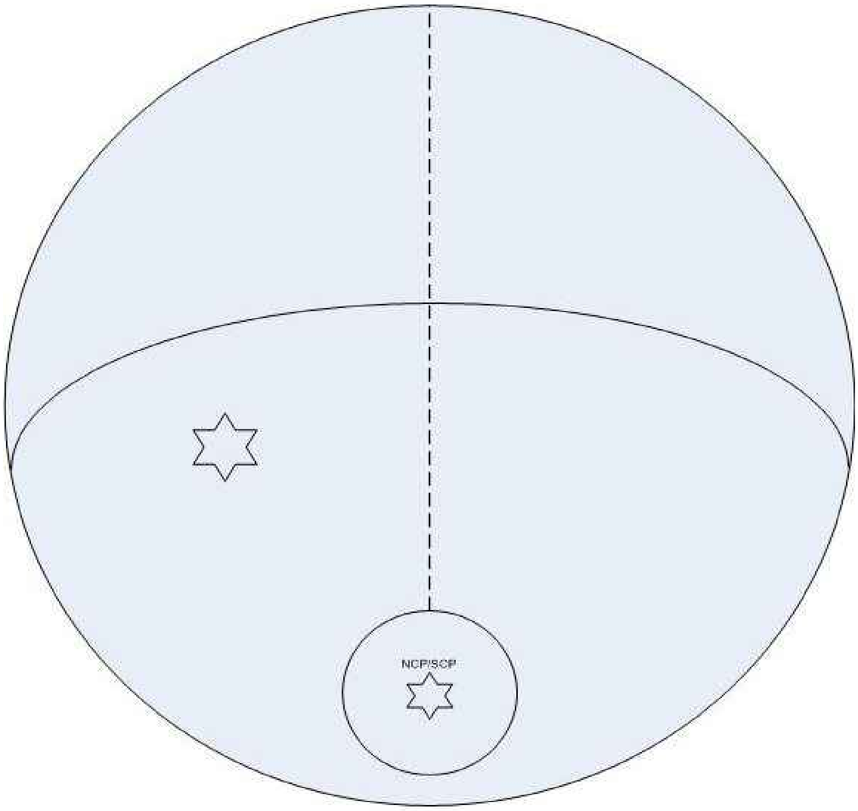


Figure 15: One Point Alignment as measured on one side of the Meridian

2 Point Alignment

When fewer than three points are present EQASCOM will automatically apply a Nearest Point transform2-Point alignment is basically a dual 1-Point modelling scheme. This works best if one of the alignment points is situated on one side of the meridian with the second alignment point on the other side of the meridian (Figure 16).

- Mount should be accurately polar aligned as the 1-Point model does not account for Rotation Errors.
- There should be minimal or no MOUNT+OTA FLEXURES as the 1-Point model only accounts for flexures near the alignment stars. Actually a flexure error on where the alignment point is located could easily influence the entire meridian side amplifying the GOTO pointing error.
- CONE Errors are meridian side specific and can be compensated by a dual 1-point model although GOTO errors due to CONE issues
- tend to increase as you target objects near the north our south part of the sky.
- It would be best to choose points near the celestial equator to even out the errors induced by cone and flexure errors.

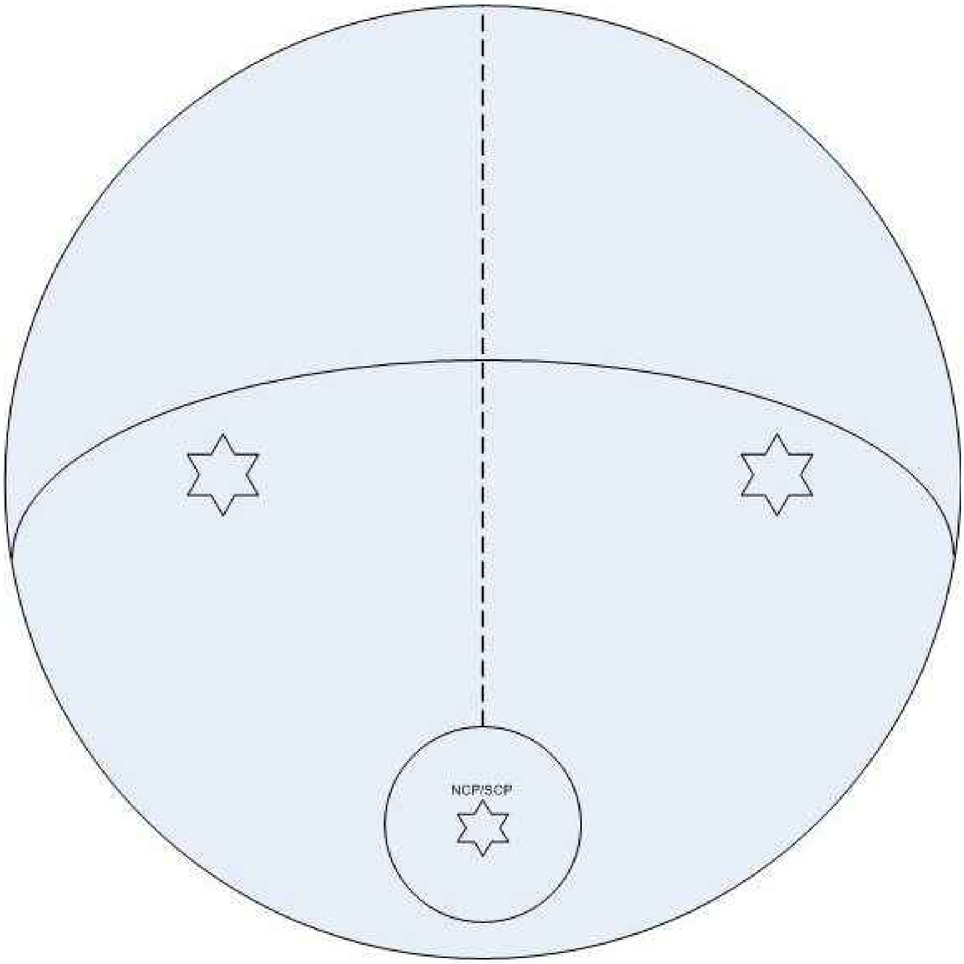


Figure 16: Two Point Alignment as measured on both sides of the Meridian

There must be a serious question as to whether folks should bother with two point alignment in practice particularly given that three point alignment provides much better correction.

3 Point Alignment (3-Point+Nearest Transform)

Three Point alignment (Figure 17) is the basic implementation of the 3-point model pointing scheme. It accounts for all error (shifts, rotations, etc) however only up to a certain extent;

- The three points should be widely spaced as you are averaging out the errors induced on the four corners of the sky.
- Very sensitive to meridian flips as the flexure errors on one side of the meridian can easily influence the pointing accuracy of the other side of the meridian

To recover from this issue the user can switch to EQASCOM's "Nearest Point" mode and the driver will revert to a 1-point model pointing scheme disabling the affine triangle and re-using the three alignment points as a TRIPLE 1-point pointing model. EQMOD will simply choose the nearest point based on the target GOTO object and apply the usual X-Y shift modelling compensation.

- GOTOs are mostly accurate within the triangle formed by the three alignment point. GOTO accuracy tend to decrease as you put your target objects OUTSIDE the triangle
- Obviously, two of the three points are always situated on one side of the meridian and GOTOs are likely to be more accurate on this side.

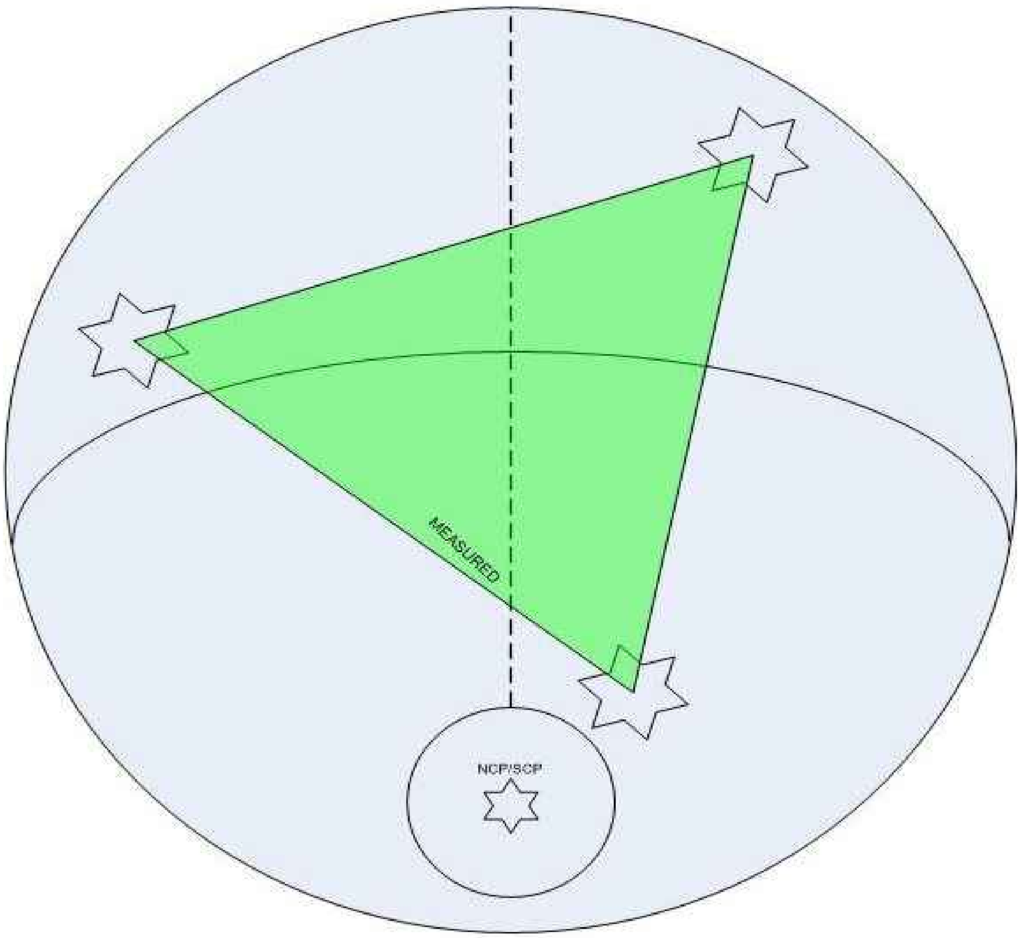


Figure 17: Three Point Alignment as measured on most part of the sky

4 Point Alignment (3-Point+Nearest)

Four point alignment still uses the 3-Point model pointing scheme as driver dynamically chooses the three of the four nearest alignment points to process the AFFINE/TAKI transformation. The four star alignment accuracy is almost identical with the 3-star alignment except that with four stars (Figure 18), you balance the number of alignment stars on both sides of the meridian. This will make the pointing accuracy consistent on both sides of the meridian unlike with the 3-point, accuracy is higher on the side of the meridian where two of the three points are located.

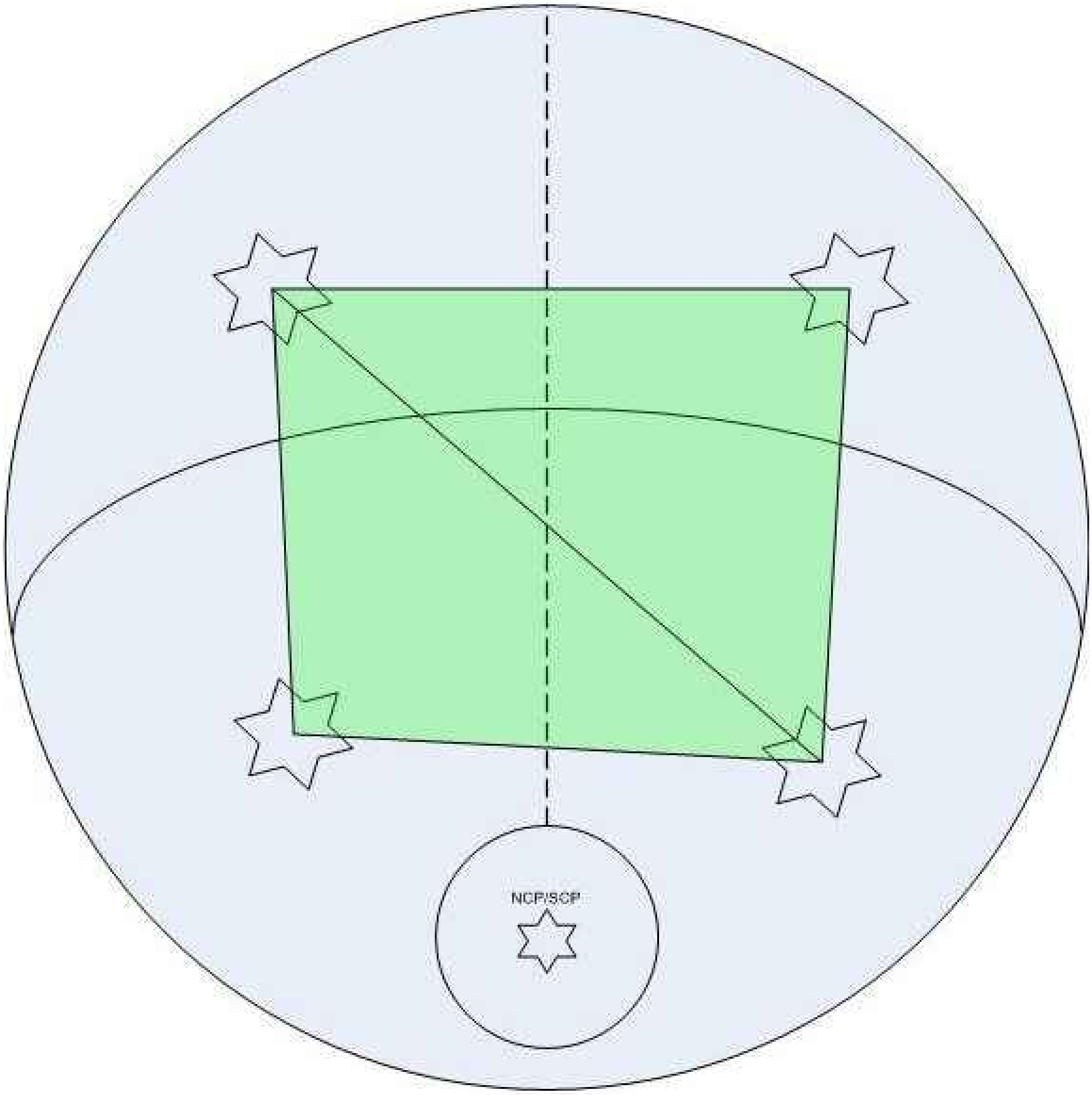


Figure 18: Four Star Alignment as measured on four corners of the sky

6 Point Alignment (3-Point+Nearest Transform)

A Six point alignment layout (Figure 19) provides better pointing accuracy than the three or four points as it "ISOLATES" any "INTER-MERIDIAN" dependency errors. EQASCOM will still apply the 3-point model scheme but dynamically choose the three nearest alignment points from the six available to implement the AFFINE/TAKI transformation. Each side of the meridian will then have its own independent 3-point model scheme isolating any flexure influence on the other side of the meridian providing the user close to arcseconds of pointing accuracy specifically within the area covered by the triangles on each side of the meridian. This method is also best for measuring the Polar Alignment of your mount.

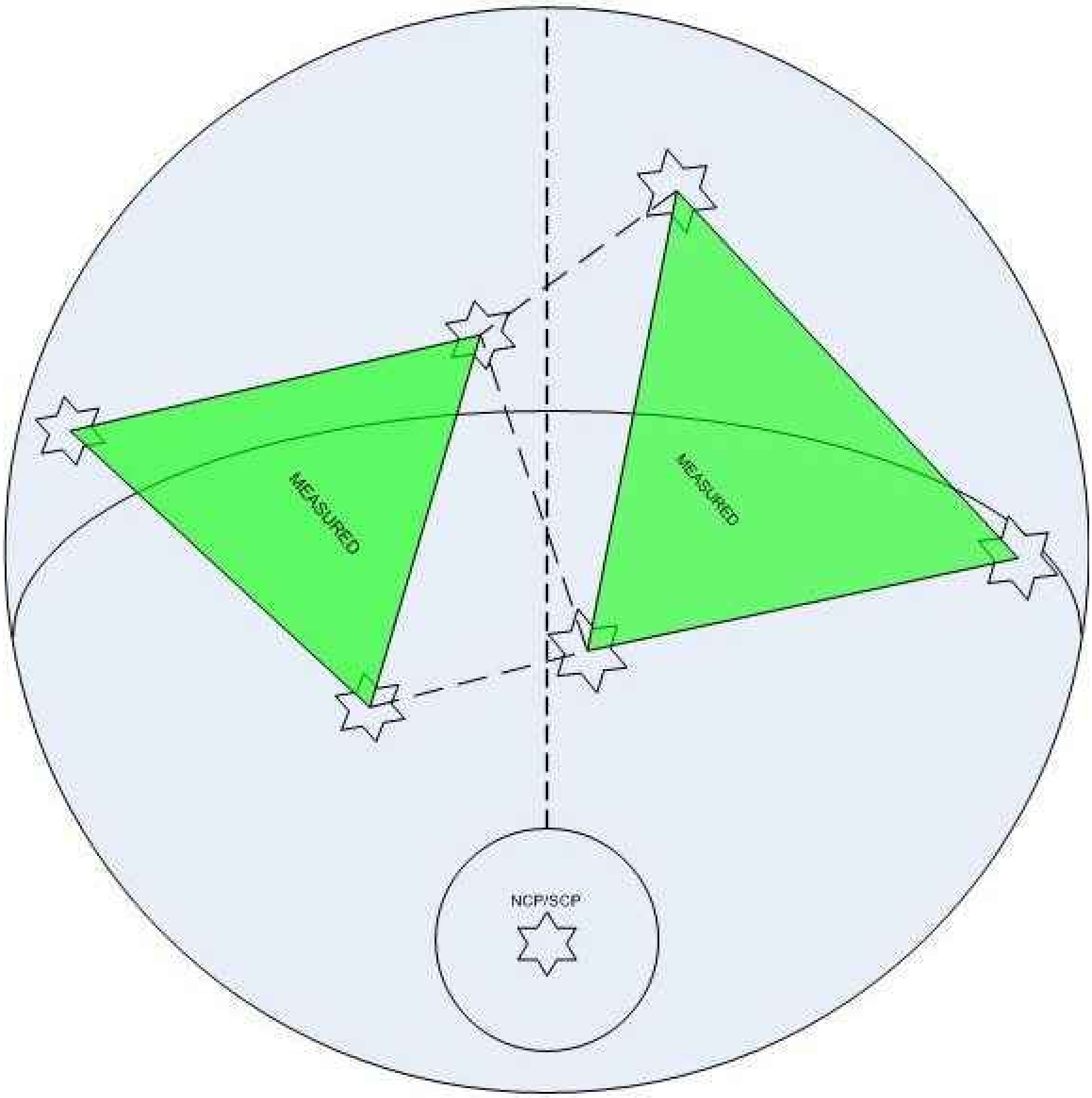


Figure 19: Six Point Alignment as implemented with 3 points on one side of the Meridian and another 3 on the other side

12 Point Alignment (3-Point+Nearest Transform)

A twelve point alignment method provides MULTIPLE 3-point modelling on four corners of the sky (Figure 21) which minimizes BOTH the inter-meridian dependency errors AND North to South dependency errors. This addresses mostly FLEXURE error isolations on the four corners of the sky aside from the usual polar, shift, cone, etc.

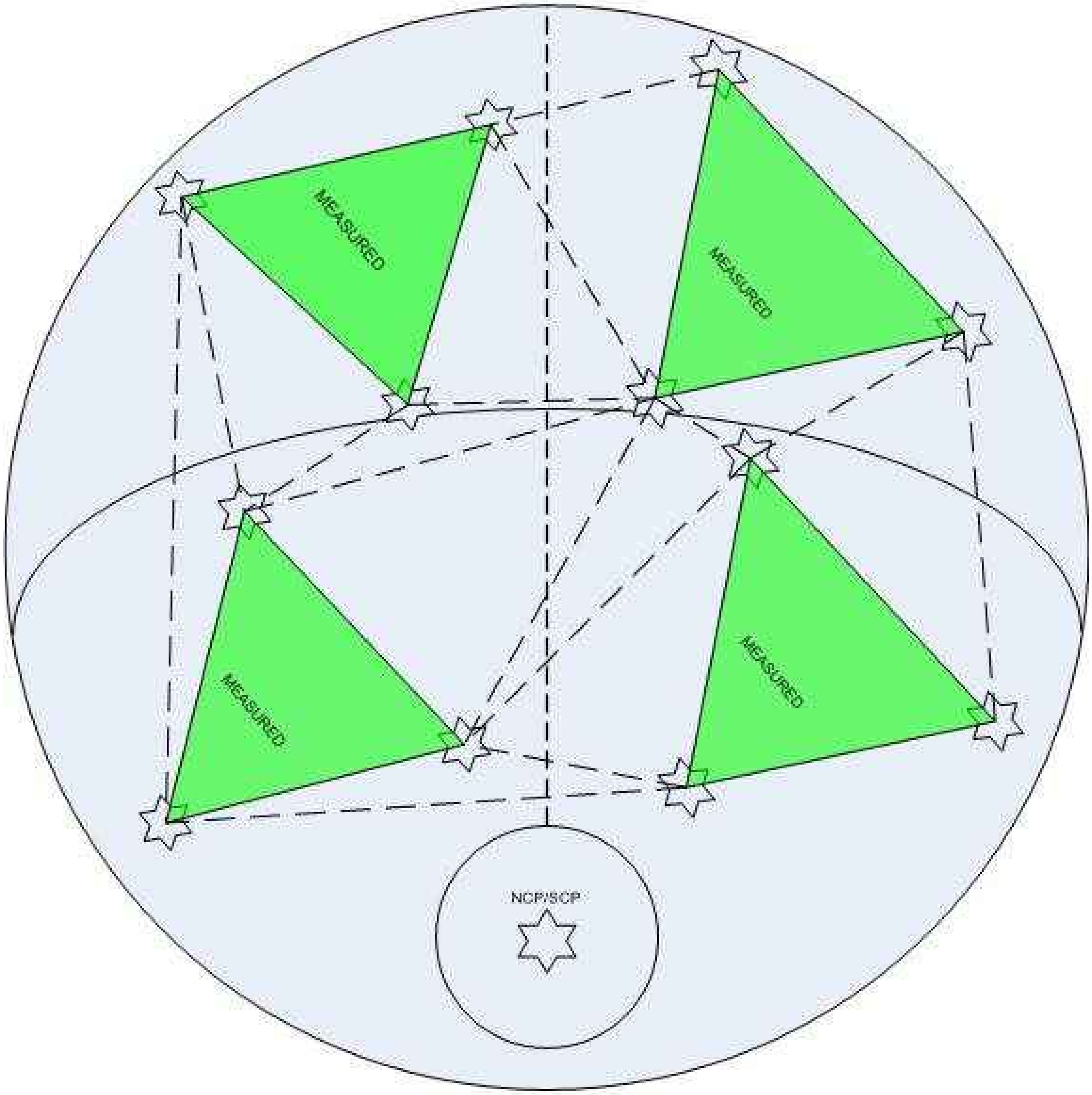


Figure 20: Twelve Point Alignment as implemented with 3 Point measured on each four corners of the sky

N-Point Alignment (3-Point+Nearest Transform)

The N-Point is the ultimate in arcsecond (or sub arcseconds) pointing accuracy as you are already painting the entire sky (Figure 21) with mapping data to your mount's stepper coordinate space. EQASCOM still applies the 3-point model scheme but dynamically chooses the three nearest alignment points form the N-Point List to implement the AFFINE/TAKI transformation.

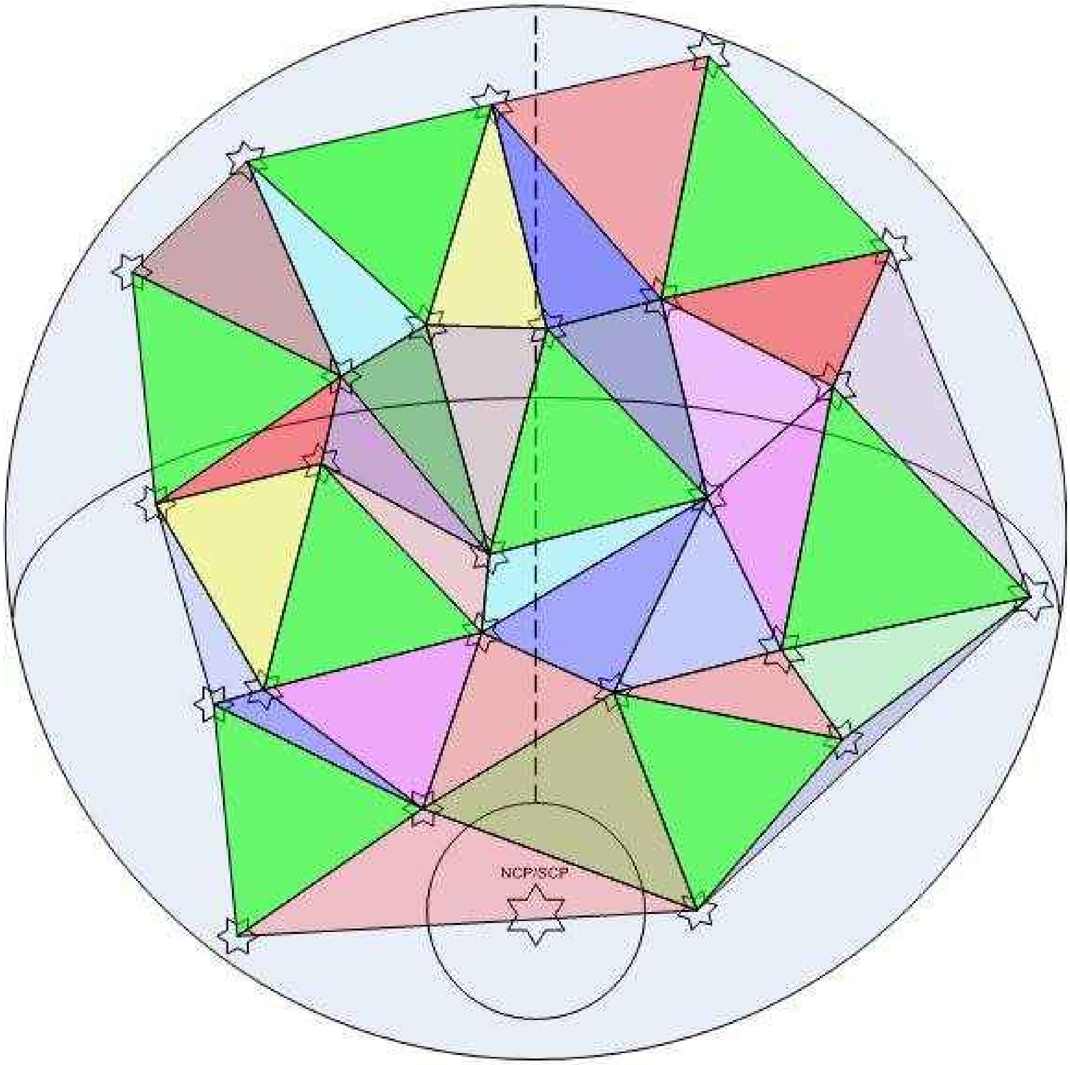


Figure 21: Multiple Point Alignment as measured on almost the entire sky

N-Point Alignment (Nearest Point Transform)

You could view this alignment model as being multiple 1-point. You might decide to evenly spread alignment points over the sky or may choose to locate them only nearby objects of interest to act as a local sync point. Whilst using the nearest point transform is potentially not a accurate as a 3-point approach it does have the advantage that if at any point you feel the pointing accuracy is suffering you can simply add a new point local to your intended target confident that pointing will improve (with 3-Point there is no guarantee that the best available alignment triangle obtained using local points)

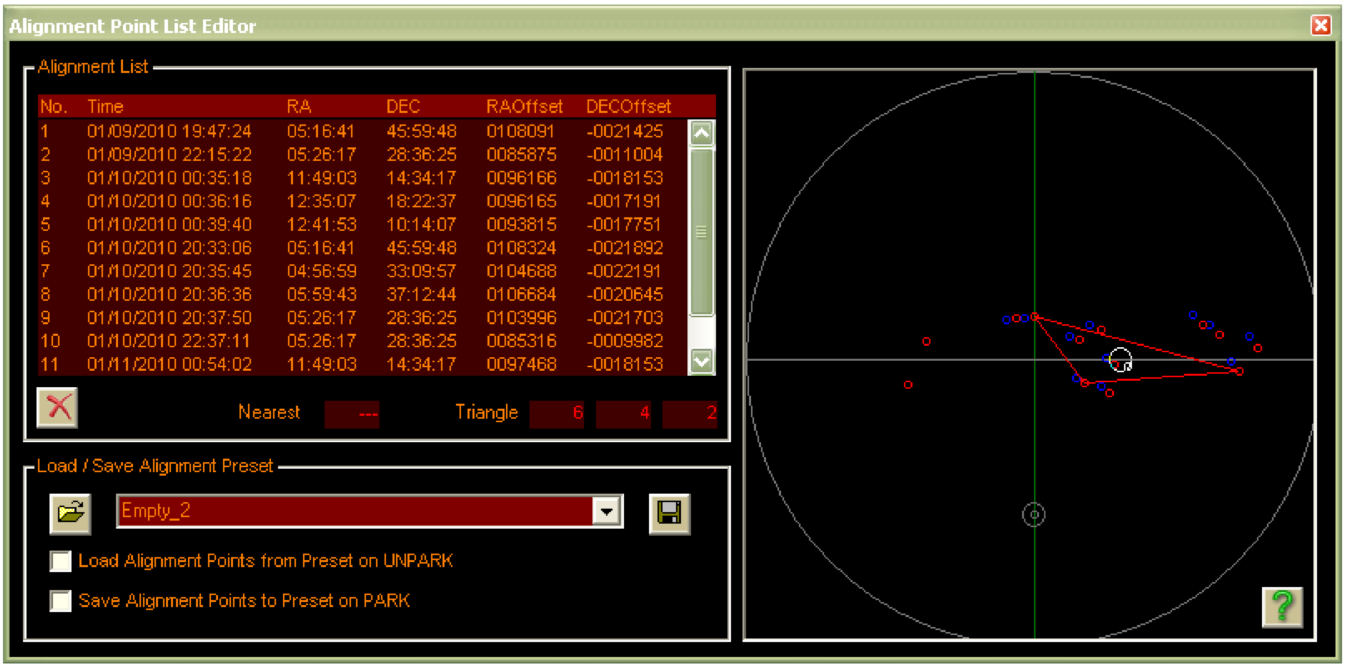
Getting most out of the N-Point

EQASCOM's N-Point Model gives the user enough flexibility in mapping out the Sky's coordinate space with your system's coordinate space. However N-Point in itself may be a time-consuming activity for some, especially if they are required to add more alignment stars in the driver's database to drive up the pointing accuracy of the mount. Here are a couple of steps to follow to make the N-Point experience an enjoyable one;

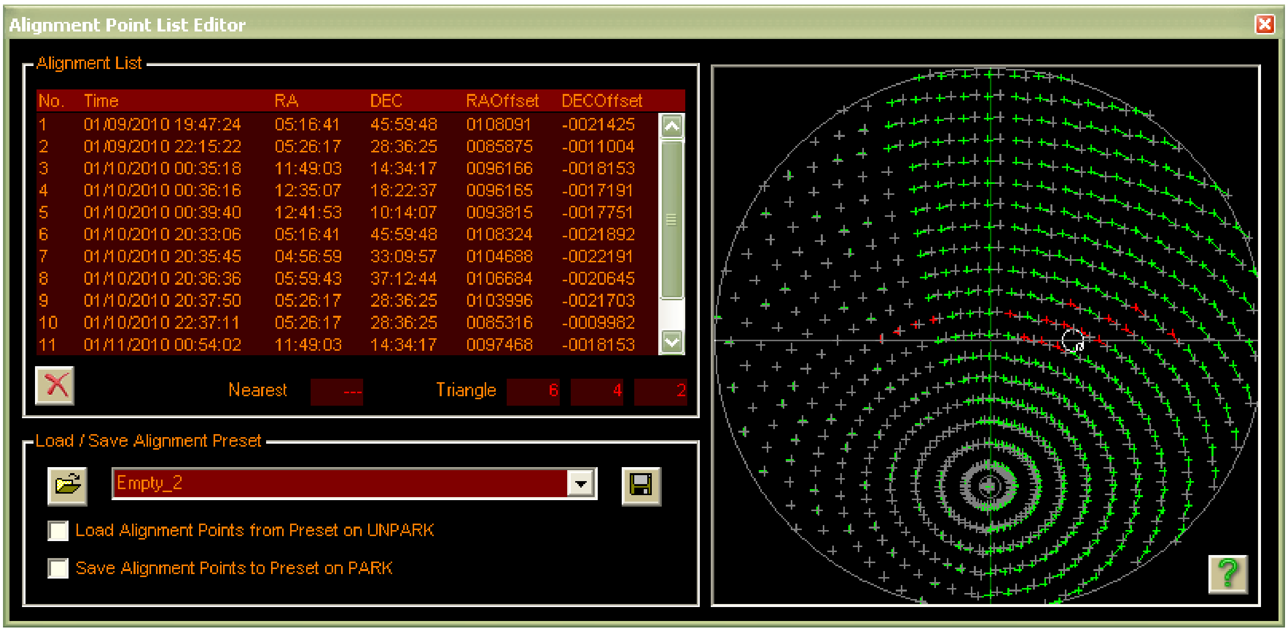
- EQASCOM provides a facility to save the N-Point data and allows the user to re-use the same data even days after the star alignment activity. This means you can always re-use the same database on succeeding sessions.
- To be able to re-use the N-Point data and to maintain its level accuracy, the PC has to by synchronized always to an accurate time referencing system such as a GPS or an internet based atomic clock prior to a N-Point alignment session and before an observing or imaging session.
- Mount has to be parked at the end of any observing session, OTA should not be moved. RA/DEC clutches should be kept tight.
- Any accessory mounted on the OTA can contribute to flexure. If one wishes to maintaining the same level of arcseconds of accuracy, the same accessory configuration should be maintained before and after any alignment (N-Point table population procedure) activity.
- GOTO accuracy should be OK mostly for 3 to 4 alignment stars in "N-Point+Nearest" configuration.
- Accuracy should be OK even with 1 Point or 2 Point provided that the mount is accurately polar aligned and have minimal Cone errors
- You can use EQASCOM's "Append On Synch" mode to populate the N-Point table by simply SYNCING on nearby stars with the Planetarium Program Sync function. Adding more alignment point in its database means MORE 3-Point Triangles are added and would mean a wider triangle area for landing accurate target GOTO objects.
- You can initially start with a 3-Point alignment configuration during your observing session and do a nearby star SYNC (while in Append on Synch mode) as you move from one object to the next object. This way you can "interleave" your observing session with the N-Point alignment session and further increase the pointing accuracy as you go along the way.
- Use the EQASCOM “proximity range” slider to prevent clusters of closely packed alignment points. When adding a new alignment point a search is made of the existing points and any that fall within "range" of the new point are automatically removed from the list. The allowable range is 0-15 degrees in 1 degree steps. So if set to a maximum then any point within a 15 degree movement of either the RA or DEC axis would be removed.
- Use the Points List window to monitor the distribution of points in your model and to see which points are currently being used to apply pointing correction.
- If you mount/telescope exhibits significant flexure or mirror shift then Nearest Star transformation may deliver better performance due to the fact correction is always based upon a local point.

N-Point Mapper

The N-Point mapper allows users to view the coordinate transformation map of the entire sky based on the current N-Point data.



Using the same N-Point data as shown above, a coordinate transformation map of the entire sky is drawn showing the actual coordinate shift from the Catalog location going to the apparent location (transformed coordinates) as represented by a line with the transformed coordinates portion marked by a grey cross. (See figure below)



The transformations marked with a red line are coordinate data that falls within the 3-point triangle. This is where the gotos are most accurate. The ones marked with green lines are those transformed coordinates using the nearest star method.

You can see how the driver dynamically chooses the alignment method across the sky based on the stored N-Point data arrangement.

FAQs

Q: My Synscan provides 1-Star, 2-Star and 3-Star alignment. What modes does EQASCOM provide?
A: EQASCOM provides MultiPoint Alignment. Its up to you how many alignment points you want to use. If you want the equivalent of "1-Star" the you simply clear the alignment data and add a single point to the alignment list.

Q: Can I change between Sync and Dialog based alignment methods once an alignment list has been started?
A: Yes, you can change the alignment method/interface at any time.

Q: Can I switch between "Nearest Point" and "3-Point+Nearest" at any time.
A: Yes.

Q: I use an external program to provide pointing correction. What settings should I apply in EQASCOM?
A: Set the alignment interface method to "Dialog". Clear any existing alignment and sync data. Ensure that alignment data isn't being automatically loaded on unpark or saved on park (these are options on the Edit Points List screen). EQASCOM will then only provide a sync correction to pointing if it receives ASCOM Syncs command.