Automapper II Documentation

Automapper works with TheSky, CCDSoft, and TPoint to help you automate the process of mapping points. “Mapping points” refers to the process of moving the telescope around the sky and measuring how far off your pointing is. TPoint uses this information to build a model of your telescope’s pointing errors. It is commonly referred to as a pointing model. TPoint and TheSky then work together to correct for pointing errors. If you are using a Paramount ME with ProTrack, the model is also applied during tracking. For best results with ProTrack, use a high-density model with lots of points (200 or more). See Appendix A for advice on working with TPoint.

Setting up

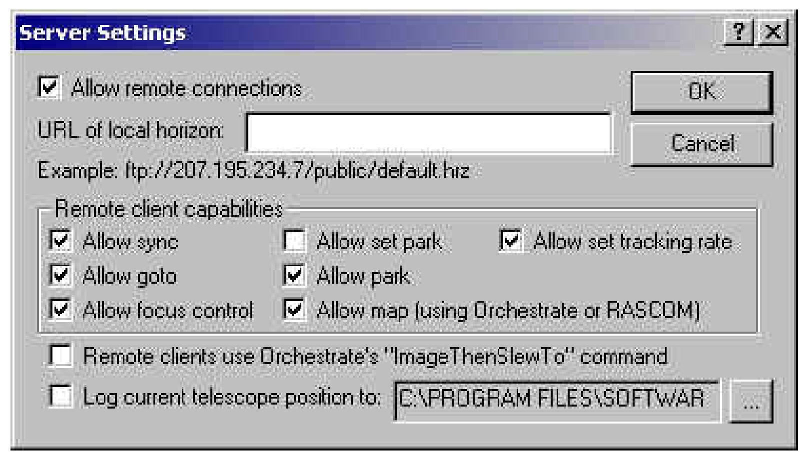
Before you can use Automapper II, you need to configure TheSky and CCDSoft to allow an external program to control them. Use the Server Settings dialogs in each product to set them up for use with Automapper II. **Please note that you will need the latest version of Orchestrate installed in order to use Automapper II.** Orchestrate installs a required file for accessing TheSky with external programs.

Server Settings for TheSky

The Server Settings dialog for TheSky is shown at right. Be sure to check “Allow remote connections” at upper left. In the “Remote client capabilities” section, please check:

- *Allow sync*
- *Allow goto*
- *Allow map*

You can check other settings if required, but the above are required for Automapper II to function.



Server Settings for CCDSoft

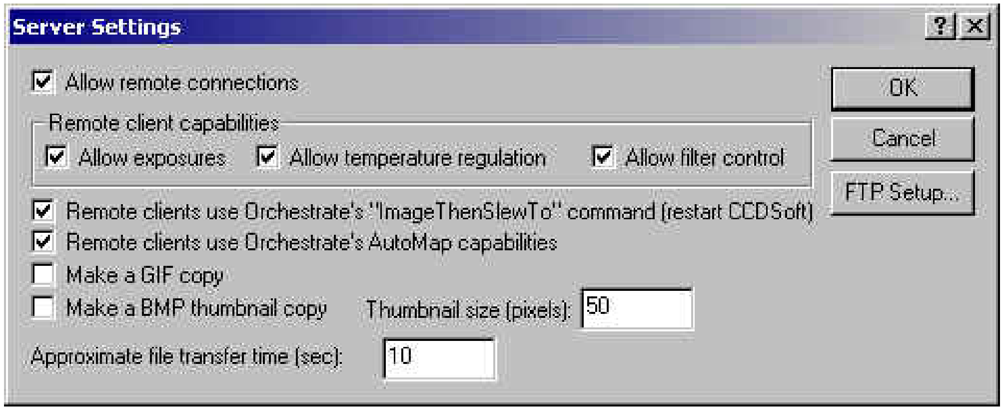
The Server Settings dialog for CCDSoft is shown at right. Be sure to check "Allow remote connections" at upper left. In the Remote client capabilities section, please check:

- *Allow exposures*
- *Allow filter control*

Please also check:

Remote clients use Orchestrate's AutoMap capabilities

IMPORTANT! *Make sure that you* ***uncheck*** *GIF and BMP copies!*



Using Automapper II

Automapper II brings everything you need to map points successfully into one program. You can create lists of points across the sky, set limits showing where points are to be mapped, and make an automated mapping run with Automapper II. Here is a list of the key features in Automapper II:

- Import a list of mapping points from TheSky (File | Select Input File) (See Appendix B for how to create a list in TheSky)
- Generate a list of points in Automapper II (Tools | Make Points List)
- Set up altitude and azimuth limits so that you map only the available portions of the sky (Tools | Set Limits)
- Save and reload lists of points that have not yet been mapped
- Generate a tight cluster of points near the first point to assist in getting the TPoint model active quickly during mapping.
- Generate noise-free synthetic periodic error correction for a Paramount mount (Tools | Paramount PEC Utility)
- Go to a specific point in the list of points ("Go to point" button)
- Map the current point ("Map Cur" button)
- Start a mapping run ("GO" button)

Note: Before you use Automapper II for the first time, you need to set the Server Settings in TheSky and CCDSoft (see earlier in this chapter). You must also review the Automapper II defaults (Options | Set Defaults) to make sure that they are correct for your equipment.

Note: Before you use Automapper II, make sure you remember to insert a TPoint object into TheSky (Edit | Insert New Object).

A Typical Automapper II Session

A typical Automapper II session contains the following steps. If you have never done a manual mapping run, we suggest you give it a try. Knowing how a manual run operates will help you get the most out of Automapper II.

1. Verify that you have the most recent versions of TheSky 5 or 6, CCDSoft v5, and TPoint installed. Orchestrate is no longer required.
2. Open TheSky and CCDSoft. If necessary, set/verify the Server Settings for both programs.
3. Insert a new TPoint model into TheSky, slew to a star, center it and perform a Sync.
4. If you are working at a high magnification or if you are using a small chip (small for mapping purposes being anything under 15x20 arcminutes of sky coverage), you should:

- Consider using the USNO database so you have enough stars for mapping. For more info, go to this web page: http://www.bisque.com/thesky/tom/usno.asp
- Try starting with a 6- to 10-point manual mapping run just to get a rough TPoint model in operation. This will make sure that slews are close enough to the desired target for success. **TIP:** Slew to the first point in the mapping run with the Go to Point button, and then do your 6-10 point mapping run in that area. Start with a bright star, and make small moves that put the next 6-10 stars somewhere on the chip so you can easily center them and map them.

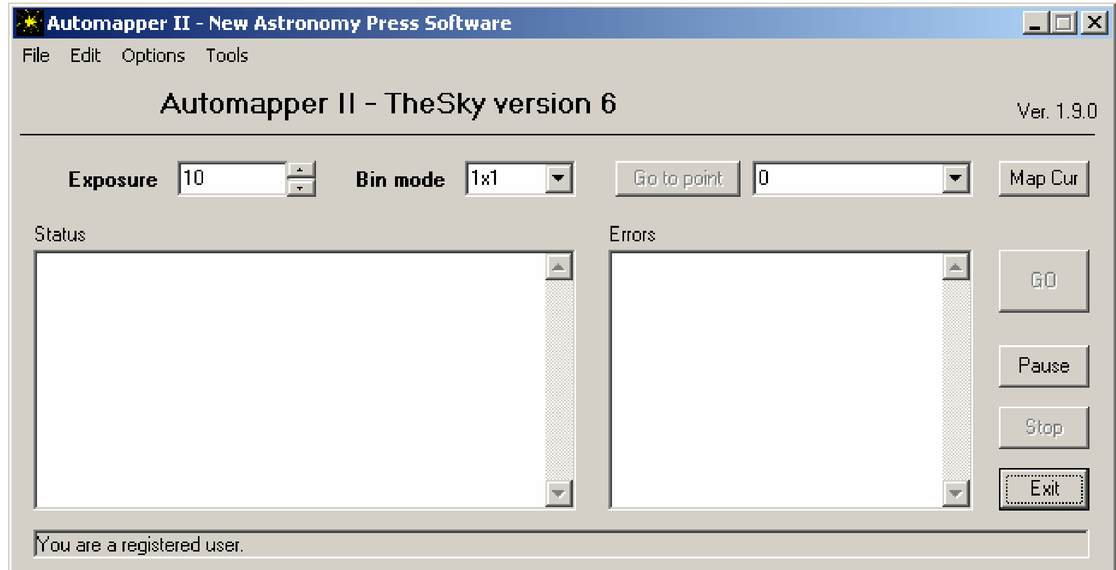
5. Run Automapper II, and set options if this is the first time you are using Automapper II. Critical point: make sure you enter an accurate value for image scale and North angle on the Options | Set Defaults menu item. An incorrect image scale will prevent Automapper II from doing its job, and an incorrect North angle will reject good images. You can get both of these numbers by taking an image and using Research | Insert WCS in CCDSoft. (See step #8)
6. Create a list of points, or read in a list of points you created earlier with TheSky or Automapper II.
7. Set limits as appropriate (Tools | Set Limits).
8. Take an image in CCDSoft, and then use the Research | Insert WCS menu item. This will synchronize things, and give you accurate values for North angle and image scale. You'll have best success if you do this near the first point in the mapping run. The longer your focal length, the more useful this will be. See note #4 above regarding a small manual mapping run to get TPoint oriented. See note below about image scale - **the image scale must be entered for the unbinned mode!**
9. Start your mapping run. Monitor the run; if you aren't getting at least 80-90% success, something is not right and you need to check your settings, or maybe you missed a key step.

Mapping is simple and complex at the same time. You need to have every piece of the puzzle installed and configured correctly for mapping to work. Automapper II will allow you to use a large number of mapping points by stepping through them automatically. But you will still need to know enough about mapping to get everything set up so that Automapper II can do its part of the job.

Note: Version 1.6.11 introduced a new way of working with image scale. You need only enter the unbinned image scale. Automapper II will calculate the image scale for the various bin modes.

Automapper II Main Window

The program window is shown at right. This is your home base for working with Automapper II. Additional settings and features are available using the menus at upper left. Key settings and operational feedback are provided here in the main window



The main window contains the most frequently used controls:

Register This button only appears if you have not yet paid for and registered the program. Click it to enter your username and password, and remove the 30-day limitation.

Exposure This is the exposure time in seconds for the images taken during the mapping run. The exposure time should be long enough to get a good, clean image. The best time will depend on your camera, telescope, and sky conditions. Generally, and exposure of 10-90 seconds will do a good job. Faster scopes under dark skies with large-pixel cameras will require the shortest times; slow focal ratios, bright skies, and small-pixel cameras will require longer exposure times.

Bin mode The bin mode to use for taking the images. 1x1 will give you the highest accuracy, but if the images are very large it could slow things down. Consider binning 2x2, or using just the central portion of the CCD chip if it is taking too long to take and download images.

Status/Errors These windows display the current progress of Automapper II, and any errors that occur. Many types of errors are normal. For example, if there is an obstruction where an image is taken, there won't be any stars in the image and mapping will fail and generate an error. Don't be alarmed; only errors that clearly indicate a problem are of any concern. For example, if the errors tell you that Automapper II can't communicate with TheSky, you should check your Server Settings in TheSky to make sure they are correct.

Go to Point The list to the right of this button includes every point in the current list of points. You can select a point, and then click this button to slew the telescope to the point. This is often useful at the start of a mapping run. You can slew to the first point, and then sync TheSky on a bright star before mapping some points manually prior to the automated run. If your pointing isn't accurate without TPoint, this will increase the likelihood of a successful mapping run. TPoint won't kick in until at least 6 points have been mapped. If you are having trouble with accuracy before TPoint kicks in, you can use the Initial Radius feature on the Points dialog, or try manually mapping six or more stars manually before using Automapper II. If your polar alignment is good, and your mount is very accurate, these steps will not be necessary. You could also do a preliminary mapping run with Automapper in a small area of the sky (use Set Limits), to get TPoint started. Then do a high-density all-sky run in the normal manner. It is OK to mix manual and automatic points in the TPoint model, as long as you are careful to make the manual points reasonably accurate.

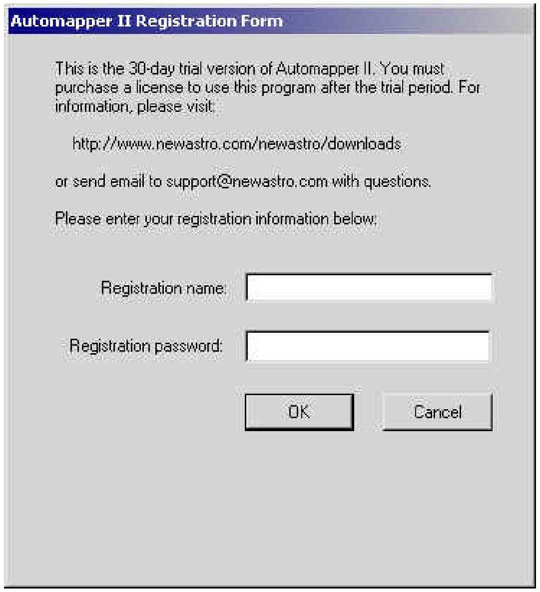
Map Cur Maps at the current location by taking an image and mapping it to TheSky

GO Starts an automated mapping run. Make sure that all parameters are set and ready to go before you hit the GO button!

Pause Pauses an automated mapping run. When paused, the text on the button changes to "Resume".

Stop Stops a mapping run. Since Automapper II is running TheSky and CCDSoft by remote control, there will be times when those programs have control of the computer. Under those conditions, you will have to wait for TheSky or CCDSoft to finish an action before Automapper II will actually stop.

Exit Exit Automapper II



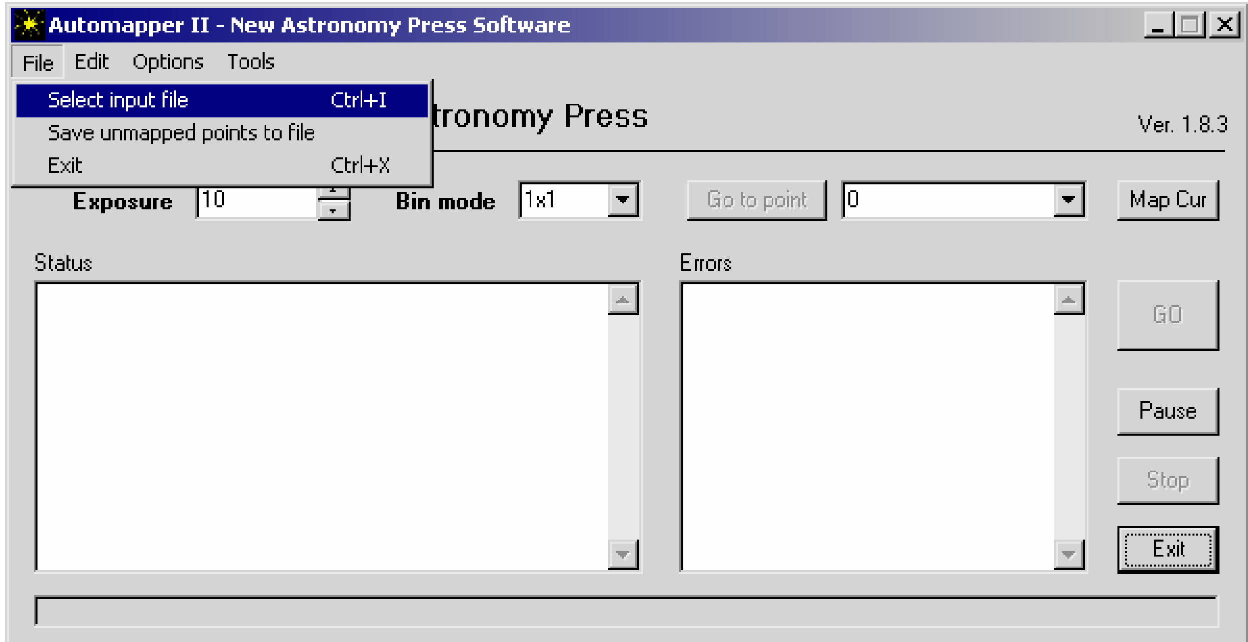
Registration Dialog

If you have paid for registration, click the Register button, and fill in your username and password as shown at right. Be sure to type both the username and the password exactly as you received them. Click OK, and the registration information will be saved. You can download and install future upgrades without needing to re-register, but we suggest you keep your registration information handy in case you need to re-install Automapper II on a different computer at some future time.

Loading a List of Points Created in TheSky

Use the File | Select Input File menu item to load a list of mapping points that you have previously created in TheSky or Automapper II. Automapper II can generate much larger lists of points than TheSky can. See Appendix B for instructions on how to create lists in TheSky.

***Note:** Version 1.6.11 introduced a new File menu item: Save unmapped points to file. If you stop a mapping run, and want to save just the points that have not been mapped, you can use this menu item to do that.*



Setting Defaults

Before you use Automapper II for the first time, make sure you use the Options | Set Defaults menu item to set up the program for your specific equipment. **In particular, the image scale of your camera/telescope combination must be set accurately!** An incorrect image scale will prevent Automapper II from mapping points.

Note: Because Automapper II uses Insert WCS to improve accuracy of mapping, all images taken during the mapping run must be saved to disk. Automapper II turns on AutoSave, and sets the AutoSave prefix to “MAP” so it’s easy to identify which images are related to the mapping run. The number of each image is reported in the Status area. You can use the Edit | Copy menu item to copy the status and error reports, paste them into Notebook, and save them to a file. You can then compare the status results and errors to specific images if necessary. When you are done analyzing the images, you can safely remove them from your hard disk.

Setting Defaults

Note: *Versions 1.6.11 and 1.8.3 introduced a number of new default settings.*

North angle *- Tells Automapper II the angle of your camera with respect to North. A critical setting! Your best protection against false matches. Use Active checkbox to turn ON.*

North angle tolerance *- The amount by which the North angle can vary. For example, if set to 3, then the North Angle can vary by +/- 1.5 degrees. Values of 2-5 are practical.*

Min/Max. number of stars *- The minimum/maximum number of stars allowed for a map to occur. Images with too few/too many stars will not be mapped, even if there is an astrometric solution.*

Passes *- The maximum number of passes for retrying failed points*

Max errors *- The maximum number of errors that Automapper II will tolerate before aborting.*

Settling time *- Time, in seconds, between the end of the slew and the start of the exposure.*

Image scale *- The image scale of your camera/telescope combination. You can do Research | Insert WCS in CCDSoft/TheSky to determine image scale accurately, or use CCDCalc.*
NOTE: Must be the unbinned image scale.

Median clearance *- Size of a zone of avoidance near the meridian, in degrees.*

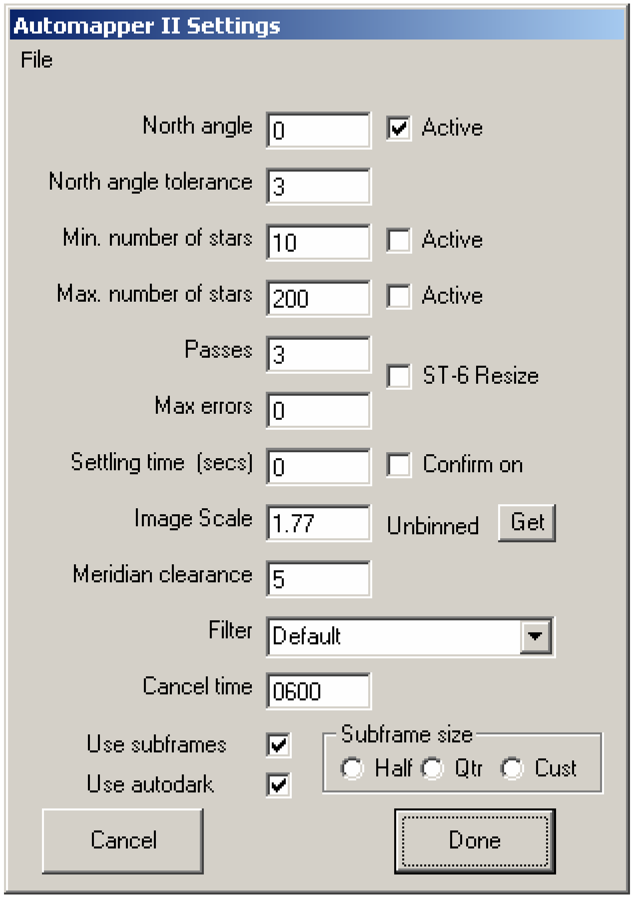
Filter *- The filter to use when mapping (usually Clear or Luminance).*

Use subframes *- If your telescope has a very wide field of view, the number of stars could overwhelm the mapping process. Check this if you must use subframes to limit the number of stars.*

Use Autodark *- Turns on Autodark (should normally always be checked)*

Accurate image scale and North angle are essential to success!

Confirm on *- When checked, Automapper II will wait before taking at image at each point*



Here are some additional details about each of the default settings:

North angle Must be the actual North angle of your camera. To determine the North angle, take an image and use Research | Insert WCS in CCDSoft. The astrometric solution will report the North angle (and the image scale) which can then be inserted into this dialog. Or you can make sure that TheSky and CCDSoft are running and configured, and simply click the Get button. This runs a script that takes an image, Inserts WCS, and gets the North angle value and enters it here. **DO NOT** use Image Link information to determine North angle, as this works differently (can be 180 degrees out of phase!).

Active box Determines if North angle is used to avoid mis-matches when mapping.

Tolerance The amount by which the North angle can vary from one image to the next. There will be small variations in North angle from one image to the next because there are small errors in the star positions in the catalog. The Tolerance value can be made larger or smaller to meet your requirements. Values of 2-5 are good, with smaller values forcing tighter tolerance.

Num. Stars Sets the minimum and maximum number of stars required in an astrometric solution. If there aren't enough stars, the image is not mapped. Likewise, if there are too many stars, the image will not be mapped. When there are too few stars, the WCS solution can be unreliable. When there are too many stars, false matches are possible because there are different ways to arrange the stars into a solution, or there may be so many stars that no solution can be found. The range of values allowed for these settings is from 5 to 1500 stars. The smaller your field of view, the smaller the number of minimum stars must be. If your field of view is very small, you should consider using the USNO database to supplement the star databases supplied with TheSky.

Active boxes Determines if Minimum/Maximum Number of Stars used to avoid mis-matches when mapping.

Passes The maximum number of passes. If points are not successfully mapped in the first pass, Automapper II will make additional passes to map failed points. **TIP:** If a point hasn't mapped in three passes, it probably isn't going to map.

ST6 Resize The ST-6 camera has non-square pixels. Check here to force Automapper to square them up before matching.

Max errors The maximum number of errors that Automapper II will tolerate before aborting the mapping run. In most cases, you can leave this at zero, which means Automapper II will tolerate all errors. If you are testing to make sure everything is OK, you can set a smaller number.

Settling time Time, in seconds, between the end of the slew and the start of the exposure.

Confirm on When checked, Automapper II will wait before taking at image at each point for you to confirm that it is OK to continue. This is intended for users who have a manually operated dome. After you move the dome to match the telescope, you can confirm that you are ready to map the next point.

Image scale The image scale of your **unbinned** camera/telescope combination. To determine image scale, take an image and use Research | Insert WCS in CCDSoft. Users of older versions should make note of the change to **unbinned** image scale; earlier versions required you to re-enter image scale if binning changed. You now only need to enter the image scale once for a given camera/telescope combination. Note: Use the Get button only if you saved image scale in the CCD Calculator.

Accurate unbinned image scale is critical to success!

Meridian Cl. Meridian clearance. This is a zone on both sides of the meridian that is avoided when making lists of points. Generally, we recommend a setting of 5 degrees as a starting value.

Filter Determines which filter is used during mapping if a filter wheel is present. To keep exposure time short, you will generally need to select the Clear/Luminance filter, but you can use any filter you like.

Cancel time The time, using 24-hour military format, when you want to force Automapper II to end the mapping run. For example, you might want to force an end to the mapping run prior to sunrise, or prior to some other use of the telescope. If you do force an early end, and want to continue later, you must leave the telescope running. Do not park the scope; just turn off tracking if it will be a long time (such as the next night) until you continue the mapping run.

Subframes When checked, Automapper will use pre-defined subframes instead of the full frame. As a convenience, Automapper II normally turns off subframes automatically for a mapping run. If this box is checked, either a half-chip or quarter-chip subframe will be used, or you can click “Cust” to force Automapper to use whatever subframe size you have already set manually in CCDSoft. Your should use subframes for mapping when you have a very wide field of view, or when you want to reduce the amount of time required for image downloads. If the subframe is too small, too few stars will be found and that could lead to difficulty in mapping. Generally speaking, an image size of about 20x20 arcminutes is about right for mapping. Larger and smaller fields of view can be made to work, but you may have to tweak the Scale Tolerance % and Required Match % numbers in The Sky (Tools | Image Link | Setup dialog). Tip: Try binning before you try subframes.

Autodark When checked, CCDSoft will use an Autodark frame when taking images for mapping. An Autodark reduces speckling from hot and cold pixels, and results in better astrometric solutions, so you would normally always leave this checked.

Making Lists of Points

The heart and soul of Automapper II is the list of points that you use to map. The list can be generated by TheSky or by Automapper II. TheSky can make lists with up to about 200 points. This sounds like a lot, but at long focal lengths, more points are better. Automapper II can create very high numbers of mapping points which will give you greater pointing accuracy.

If you are using a Paramount with ProTrack, a large list of points is even more important. ProTrack is an excellent tool, but it is only as accurate as the data you feed it. If you have a low-density model with large spaces between points, ProTrack can't track accurately between the points. If you want to use ProTrack for long, unguided images, your starting point for a good number of points is about 250.

To load a list of points you created in TheSky, use the File | Select Input File menu item.

To make a list of points with Automapper II, use the Tools | Make Points List menu item. If you don't like the results you get after making a list of points, adjust the input values at the top of the "Make a list of points" dialog and click the Make List button to try again.

Making a List of Points

The dialog at right allows you to create high-density point models with Automapper II. The dialog contains the following settings:

***Density factor** - Valid settings: from 5 to 50. An all-sky model with a setting of 5 will generate about 20 points. At a setting of 50, you will get a LOT of points - about 1500 of them! I have my doubts about the practicality of such large models, but you are welcome to experiment.*
***Note:** If your model generates more than 1200 points, all points may not show up in the window. They are still saved internally.*

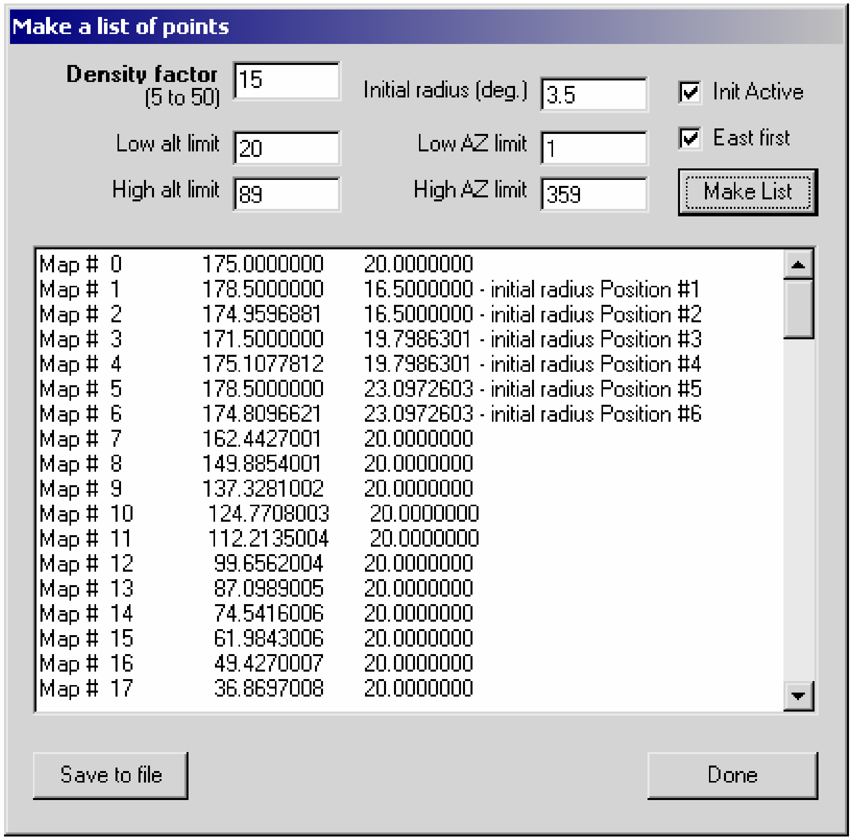
***Initial radius** - Expressed in degrees. A radius around the first point within which 6 closely-spaced points are mapped. (The TPoint model starts operating when there are six points.) By mapping 6 closely-spaced points, you can get TPoint active before you range too far from the first point. The "Init Active" checkbox must be checked for the 6 initial points to be added.*

***Low/High alt limits** - The lowest and highest altitude for points. Mapping points lower than about 10-15 degrees may not add much useful information to your model.*

***Low/High AZ limits** - The azimuth limits are set to 1 and 359 by default. If you need to stay further away from North for some reason, you can specify that here.*

The limits are fairly coarse. For finer control over limits in both altitude and azimuth, use the Options | Set Limits menu item.

***Init Active** - Check this box to have Automapper II add 6 or 7 extra points to the start of the list. These extra points will be*



clustered around the first point, with a spacing determined by the Initial Radius setting. Why 6 points? TPoint "kicks in" once you have 6 points. But clustering 6 points closely together, the chance of missing a point due to uncorrected pointing error is greatly reduced. The longer your focal length, the more likely you are to need this feature.

***East first** - When checked, the points for the mapping run will start in the southeast. When unchecked, the points start in the southwest.*

***Make List** - Click this button to generate a list of points.*

***Save to file** - Click this button to save the list of points to a file. Load it again using the File | Select Input File menu item.*

***Done** - Click this button when you are done generating points and are ready to use them in a mapping run.*

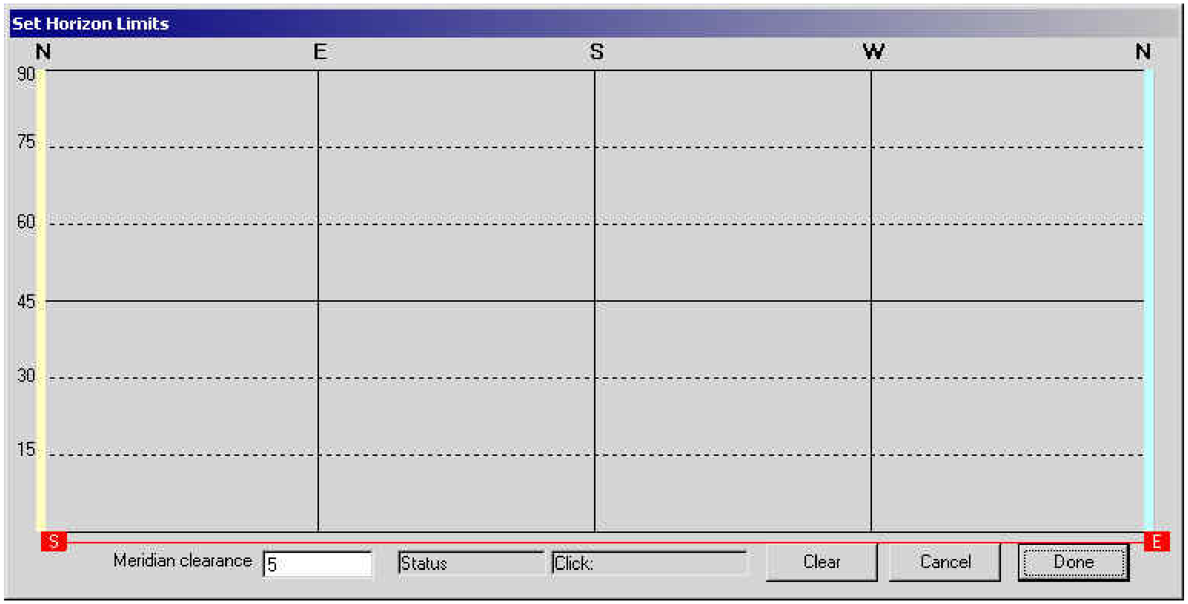
Setting Limits

You may have portions of the sky that you do not want to use for mapping. There might be trees, a roofline or some other obstruction in the way. Or perhaps you never image in certain directions or at certain elevations because of light domes. Whatever the reason, you can use the Limits features of Automapper II to define areas of the sky where mapping points will not be used.

Note: If mapping points exist in the areas outside the limits, they will be ignored during a mapping run. Automapper II compares each point to the limits, and if the point is outside the limits, it is not used.

Setting Limits Dialog

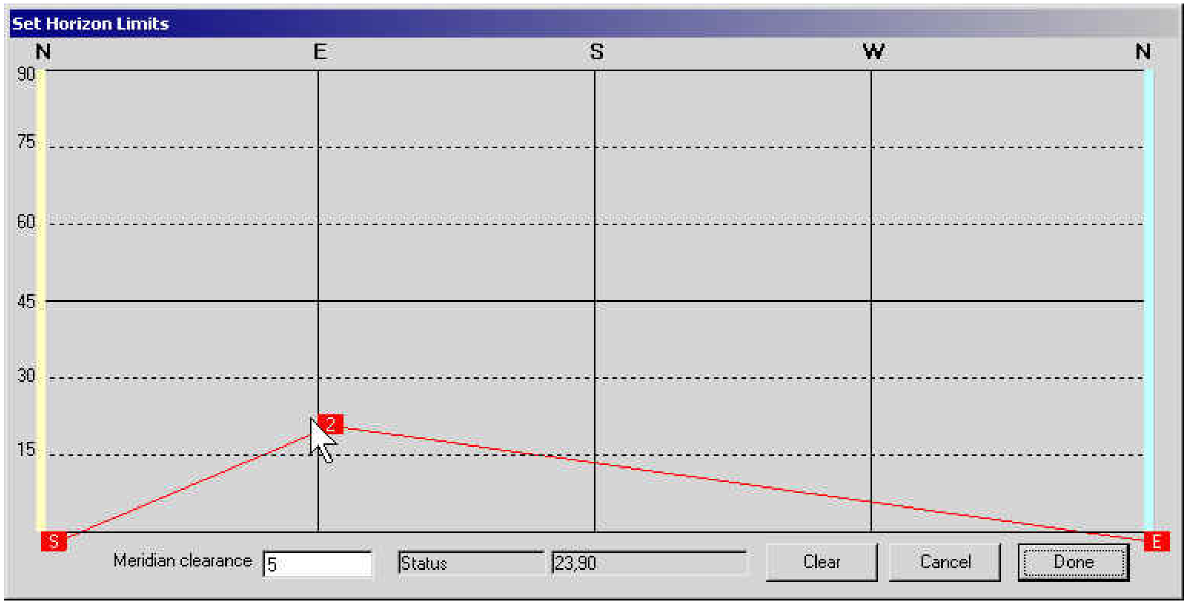
The Tools | Set Limits menu item opens the Setting Limits dialog shown at right. The yellow and blue vertical bars can be dragged to set azimuth limits. Right-click to add points that define the lower altitude limit. The meridian clearance defines how far away from the meridian you want the telescope to stay.



Adding Altitude Limits

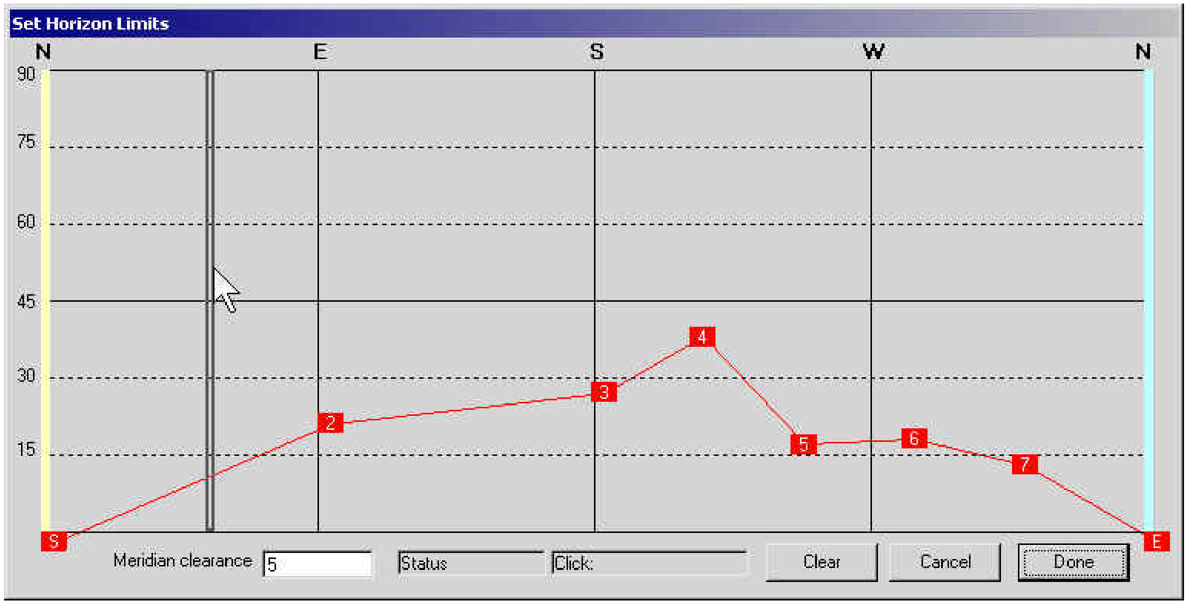
You can define the lower altitude limit by adding additional points. To add a new point, right click at the appropriate azimuth. The vertical lines are labeled at the top, from north at the left through south in the center and back to north at right, making a full circle. Once you have added a point, you can click and drag to position it where you want it. The starting and ending points can also be repositioned, but they only move up and down.

TIP: *Hold down the Shift key and click on a point to activate it. Now you can use the "+" and "-" keys on the keypad to move the point up and down. This allows you to define the altitude for a point more precisely than by dragging. Hold down the Shift key while using the "+" and "-" keys to move left/right. The regular "+" and "-" keys won't work; only the keypad keys will work.*



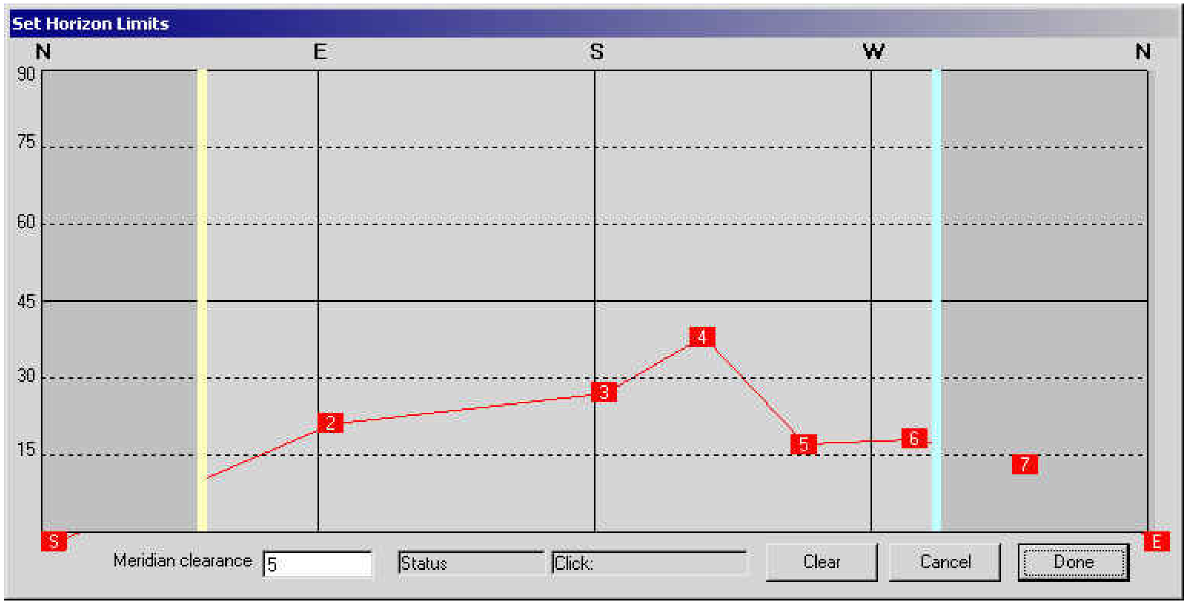
Setting Azimuth limits

You can define azimuth limits using the vertical bars at far left and right. Click and drag the limit bar away from the edge. Release the mouse button to set the bar at the new location.



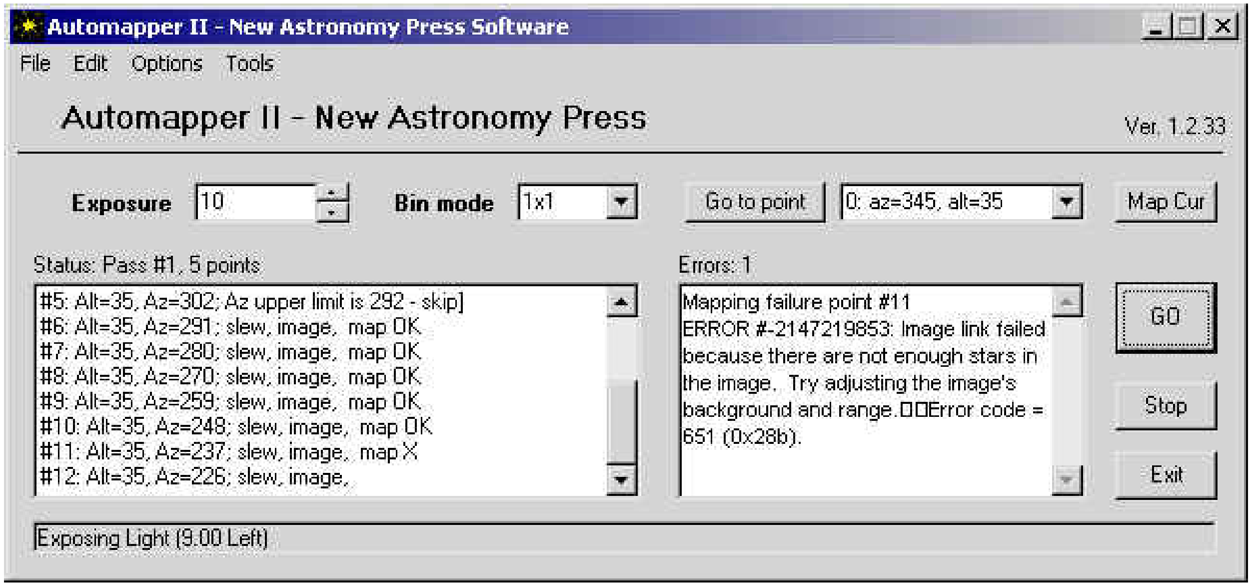
Limits Example

The example at right shows both altitude and azimuth limits set. The red line defines the lower limit of points that will be used. If points exist outside this zone, they will be skipped. The yellow and blue vertical lines define the azimuth limits.



Running Automapper II

The image at right shows the start of a typical Automapper II run. (Display may look different as features change.) The points to be mapped are shown at left. Point #5 was skipped because it exceeds the azimuth limit. Point 11 failed; the reason is shown at right. The Insert WCS failed because there weren't enough stars in the image. A longer exposure might have found more stars, or a cloud or tree may have blocked the image. If it was a cloud, the point might well get mapped on the next pass.

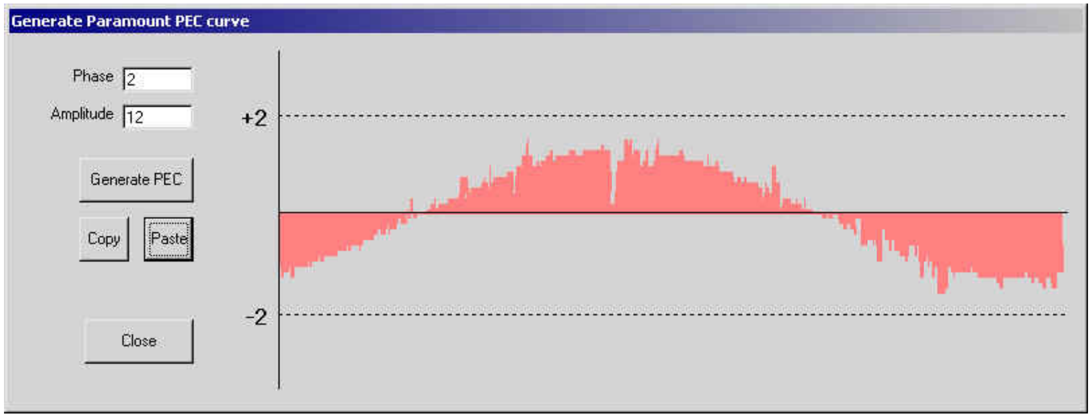


Using the PEC Utility

The Paramount ME has extremely low periodic error. It is so low, in fact, that it can be very challenging to get a clean recording of it. You need a really calm night to get a good recording - but a calm night with good seeing is better spent imaging. The PEC utility allows you to record PE on an average night, and then create a matching sine wave pattern with the same amplitude and phase. You can then paste the sine curve into TheSky, and upload the result to the mount.

Using the PEC Utility

The PEC utility is designed to help you get very accurate PEC correction with a Paramount ME. Follow the instructions below to make use of this feature. The image at right shows the result of clicking the "Paste" button to paste valid PE data from a Paramount PE recording run.



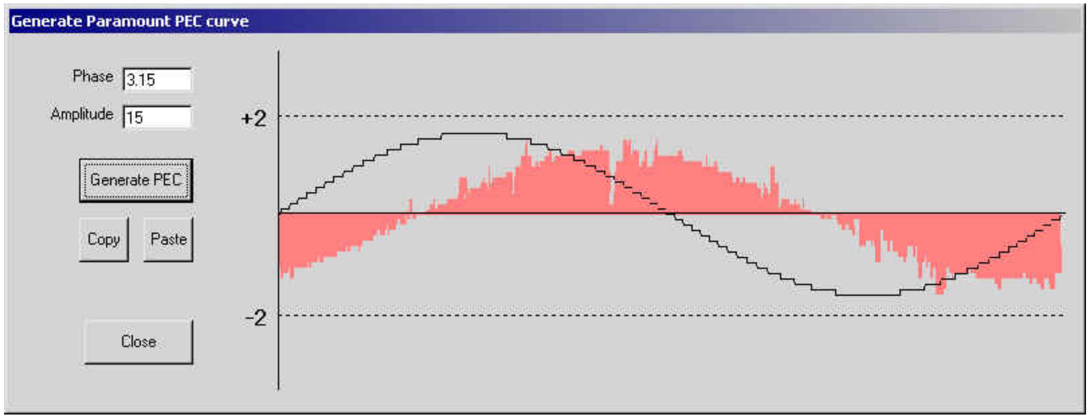
Why a sine curve? The Paramount ME is so precise that the periodic error is nearly a perfect sine wave. Although a sine wave won't match exactly, it will typically be a better fit that the noisy data you collect. Even the Curve Fitting tool in TheSky won't give you as good a result. Worse, the curve-fitting tool often does not match up the left and right edges properly. A sine wave of the correct period, by definition, matches up perfectly at the left and right edges. There is no way to vary the period, so you are guaranteed proper left/right edge connection.

Note: If you have superb seeing, don't use the PEC Utility. It is meant only for smoothing out PE when seeing isn't good enough to get a really accurate set of data. In superb seeing, non-sinewave variations are probably valid, reflecting small periodic errors in the two belts internal to the Paramount drive mechanism.

- Start by doing a conventional PE recording in TheSky. (For best results, turn off Dec corrections and make sure the camera is square to the mount's axes.) Use the Telescope | Options | More Settings menu item, then the Periodic Error Correction tab. Click the Record button, and allow the guide camera to make corrections to the mount. Use Direct Guide for best results.
- When you are done, click done, and then click the Copy button to copy the raw data to the clipboard.
- Click the Paste button to insert the raw data into the PEC utility (see figure above). The pasted data is plotted in red.
- Click the "Generate PEC" button to generate a PEC curve using the Phase and Amplitude settings (see figure below). This will likely not match your raw data. Vary the Phase and Amplitude settings until the generated curve matches the phase and amplitude of the data (see second figure below). You can use decimals to get a close match.

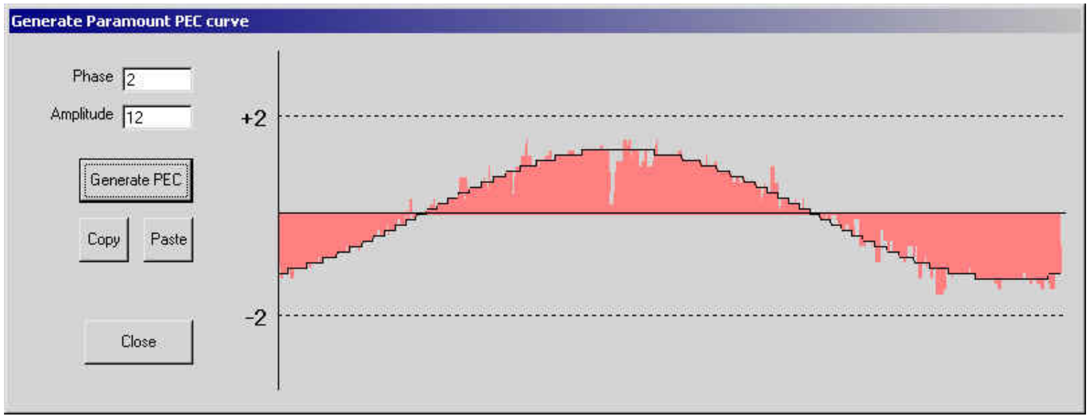
Generating a PEC curve

Clicking the "Generate PEC" button generates a PEC curve using the numeric values in the Phase and Amplitude boxes. Adjust the values to shift the phase and increase/decrease the amplitude until the generated curve matches the raw data as closely as possible.



Matching PEC Curve

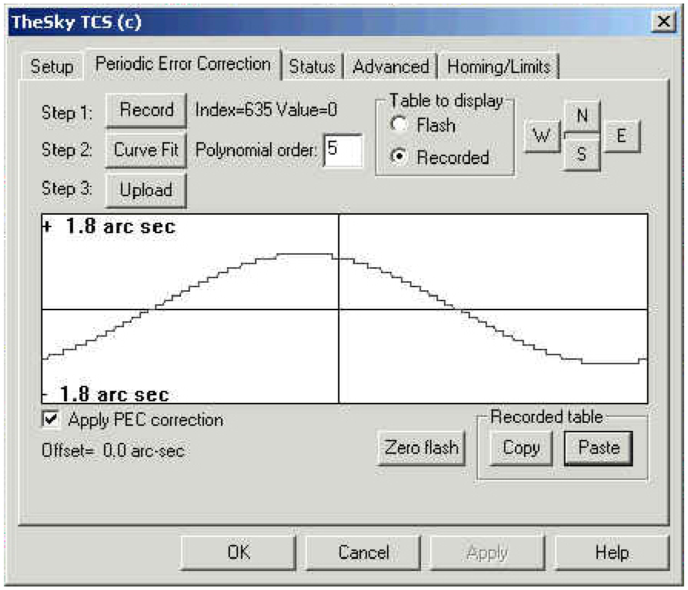
In this example, the Phase and Amplitude settings have been adjusted so that the generated curve is a good fit for the raw data. The raw data is actually pretty clean in this example; under typical seeing conditions, you may be faced with much rougher data than this. You can still match phase and amplitude fairly closely.



- **Click the Copy button to copy the generated PEC curve to the clipboard.** This is an important step! You must put the generated data on the clipboard before you can paste it into TheSky.
- Go to TheSky and Paste the data into TheSky. Use the Paste button on the Periodic Error Correction tab. The image below shows what you should expect to see - except of course it will be your generated PEC curve, not the one shown!
- **Click the Curve Fit button.** This is another mandatory step. TheSky can't just upload your clipboard data to the mount; it must massage the data and the Curve Fit button will make that happen. The fitted curve should be very close to your pasted data.
- **Last step!** Click the Upload button to upload the fitted data to the mount.

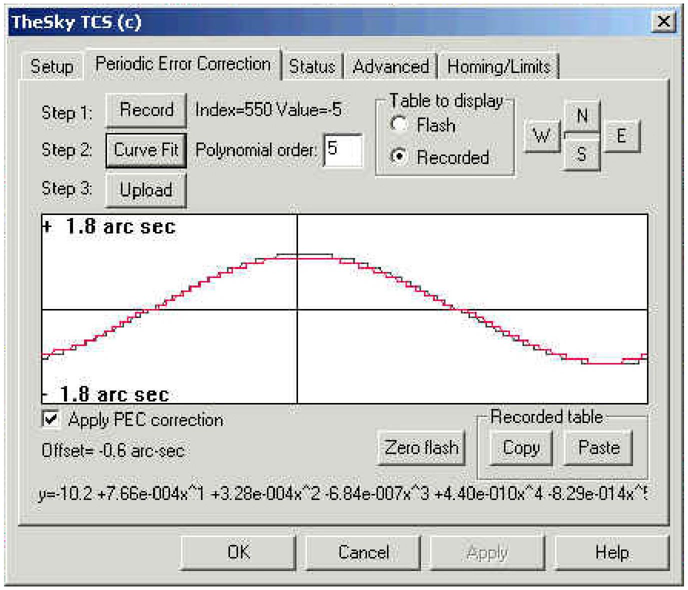
Note: The current version of the Paramount's firmware requires that the mount be turned off, then back on, before you can use a new PEC table. So we suggest that you park the mount near home, turn it off, turn the mount back on, and then reconnect. Now you can enable the PEC table/recording and you should get excellent results.

Pasting the Generated PEC into TheSky



Make sure that the "Table to display" is set to "Recorded." Click the Paste button to paste the generated PEC curve into the graph. You should see a smooth curve with small steps like you see here if you have done everything correctly.

Fitting the Curve



You must now click the "Curve Fit" button (step 2). This causes TheSky to generate a curve (shown in red) based on the data you pasted. Even though the red curve doesn't look different, it is! It is very important that you fit a curve; otherwise, the data will not be set up properly and junk will get uploaded to the mount! This is very important. If you get a corrupt PEC in the mount, no harm done - just paste again, click the Curve Fit button, and then click the upload button.

Note: Starting with version 1.8.3, there is an Offset button on the PEC dialog. You can use this to shift the curve up or down if necessary.

Appendix A: TPoint/ProTrack Tips

Here is a copy of a message I posted on the SoftBisqueUser Yahoo group on how to get the most out of TPoint and ProTrack.

Note: For the Paramount ME, I recommend that you use version 043 or later of TheSky. In general, please use the latest versions of TheSky, CCDSoft, TPoint, and Orchestrate to make sure your installation supports all features of Automapper II.

With a large number of points in your TPoint model (think 250 at least), and adding the right terms for your equipment, ProTrack will do some amazing things. ProTrack's algorithm works, but to get good results you have to nail the TPoint model precisely. GIGO applies: garbage in, garbage out.

Here are some general guidelines for getting the most out of TPoint, the ME, and ProTrack:

- Refine your polar alignment to one arcminute or better. This should only take 2-3 iterations with TPoint, but you can do more if you like. You can get by with small models for rough alignment (around 5 arcminute error), but you need an accurate ruler to get accurate measurements. Plan on 150 or more points to get down to one arcminute _reliably_. You need enough points to overcome measurement error. Also, you must add terms (and the right ones) in order to get high accuracy. More about that in a moment.
- Once you have your desired accuracy in polar alignment, make a high-density TPoint model. Experience suggests that about 250 points is the baseline for high accuracy with ProTrack. The weight, lever arm, off-center components, mirror movement, etc. of your system will dictate what you can actually achieve. The points for the model need to be set with the highest accuracy you can muster. Use your regular camera, not a video camera, for high-density, high-precision modeling. (You might consider purchasing my product Automapper II for this step.)
- Next step is to add terms to your model. TPoint automatically adds the first six terms for you. Unless you have a demonstrated reason to remove them, keep them. Here is a list of the automatic equatorial terms:

  IH - Index error in RA

  ID - Index error in Dec

  NP - Non-perpendicularity in RA/Dec

  CH - Non-perpendicularity of the OTA in Dec

  ME - Error in polar axis elevation

  MA - Error in polar axis azimuth

- Do not just go to "Suggest terms" and let it add terms; those are **suggested** terms, after all, and they have to be analyzed and evaluated before you can trust them. Before you start looking at suggested terms, add the following terms one at a time, evaluating each for its effect on the model:

  TX - Tangent tube flexure. I am finding that this is generally better to use than TF; it combines for greater accuracy with the other terms. Compare the effect of this setting and TF to decide which is better for your setup. Occasionally, you may need both.

  HCES and **HCEC** - Centering errors in the RA gear

  DCES and **DCEC** - Centering errors in the Dec gear

- The above terms are almost always beneficial. Next step is to evaluate the other named terms (except those with "AAT" in the name; those are for a specific telescope, not the ME). You are looking for terms that, when used, will significantly reduce the Sky RMS and PSD values. (RMS = root mean square error; PSD = population standard deviation.) Never use a term that increases the PSD, no matter if it also reduces the RMS. Terms that provide only minimal improvement (less than 10% better RMS) should not be used. Terms that do not provide at least 2-3 units improvement in RMS should not be used. I have found that the following terms are commonly useful for me; your results may vary - check every term's impact on your model!

  Terms I find useful: HDSD4, HHCH4, HHSH4

- At this point, you can now try Suggest terms. Use the same rules for suggested terms as for named terms: make sure they show enough of an improvement in your point to be included. However, when suggesting terms, you should always take an additional step: test the term in practice. Suggested terms can be very useful; they can be completely bogus. The name says it all: these are ***suggested*** terms. They have been found to be of ***possible*** statistical significance; you need to verify that by seeing how they affect real pointing, not just the RMS and PSD. Having a low RMS is NOT the same as having great pointing!!! (Strictly speaking, even the named terms you add should be verified, but they are named terms because they are so commonly helpful, so there is less risk in simply using the named terms.)

NOTE: Adding and evaluating terms is a non-trivial exercise. The more you know about math, and statistics in particular, the more effective you can be at selecting, analyzing, and evaluating terms. Read up on TPoint and the math and concepts behind it if you can - it will make you more effective at selecting terms. Also, be patient. It takes time and effort to learn TPoint and the vast logic behind it. The good news is that the more time you invest in TPoint, the more you will get out of it.

I am able to get <15 arcseconds RMS error reliably using the approach outlined here. I have left out the steps needed to actually add terms; I'm assuming the reader is already familiar with the TPoint interface.

If you experience problems with ProTrack, the first place to look is at the terms you added to your model. Terms must be evaluated by how they improve or hurt your pointing/tracking accuracy. Next step is to verify that you cleaned out bad data from the list of points. Look for outliers and mistakes, and mark them so they are ignored. Next, be aware that when you are closer to the edges of the model, modeling is less accurate. If you want to image at 45 degrees of elevation with ProTrack, for example, go well below that when mapping points. How low you can go depends on the point where atmospheric refraction starts to elongate stationary stars for your focal length/pixel size combination.

I have tested ProTrack with various TPoint models, and the better the model and term selection, the better ProTrack works, so I think ProTrack itself is really solid. The keys to getting good results:

- Density of the model
- Accuracy and precision of mapping (a complex subject itself; use the imaging camera for mapping)
- Cleanup of bad points, if any
- Selection of terms (correct terms; terms that add real improvements; read up on TPoint)
- Evaluation of terms based on pointing results

Appendix B: Creating mapping lists in TheSky

[The following material is from an email I sent to the Paramount Yahoo group. It explains the logic behind working to perfect a TPoint model. I think you will find it useful when you are working on the terms for your TPoint model. Please see the TPoint documentation from Software Bisque for background information.]

I started out by removing all terms, then adding the Equatorial terms back in (Equatorial button).

Point 33 was an error. If you look at the scatter diagram, there is a single point WAY out away from the rest. Such severe outliers should be marked as do not use (highlight the point's row, then click the radio button with a slash through it). Don't overdo this; only use it for severe outliers. Minor outliers often contain useful information about the system.

This gives us an RMS of about 47 arcseconds.

Next, I added the flexure and gear terms: TF, TX, NCES, HCEC, DCES, DCEC, DAF, DNP. One does not know which ones are valid and which are noisy yet; we just add them in at this stage so we can evaluate them. This yields an RMS value of approx. 25 arcseconds.

Click the Fit Information button, and look at the second instance of the following table (the first instance is raw; this is the adjusted numbers):

	coeff	change	value	sigma
1	IH	+0.743	+1110.05	3.704
2	ID	-0.700	+177.10	3.029
3	NP	+0.727	-710.88	8.060
4	CH	+2.493	-8.60	28.933
5	ME	-2.085	-104.74	13.736
6	MA	+0.357	-53.22	3.925
7	TF	-4.153	+98.00	55.027
8	TX	+0.644	-93.62	44.312
9	HCES	-2.113	-33.38	8.932
10	HCEC	-1.281	-32.53	15.754
11	DCES	+5.239	-30.59	5.230
12	DCEC	+0.125	+23.85	16.244
13	DAF	+0.611	+421.94	15.334
14	DNP	+6.039	+130.78	19.503

Sky RMS = 24.83
Popn SD = 25.48

What we want to look at are the last two columns; value and sigma. Value is signal; sigma is noise. We want to NOT use any term where the S/N (signal to noise ratio) is lower than 3. For example, the S/N for ID (Index error in hour angle) is 177/3, or 59. That's great. The S/N for TF (tube flexure) is 98/55, or not quite 2:1 - too low, got to go. The following terms have S/N < 3, with the lowest S/N at the top:

4	CH	+2.493	-8.60	28.933
12	DCEC	+0.125	+23.85	16.244
10	HCEC	-1.281	-32.53	15.754
7	TF	-4.153	+98.00	55.027
8	TX	+0.644	-93.62	44.312

Start by removing the term CH (non-perpendicularity of the OTA in Dec). Observe what this does to the other terms - remember, the CH term is so small that the noise is larger than the signal, so removing it might remove noise in other terms, and improve their S/N enough that we might wish to keep them. TF improves a little, but not enough to keep it, so let's get rid of that one next. TX gets close to 3:1, and is worth keeping an eye on. not much change in DCEC, but HCEC improves considerably:

9	HCEC	+0.057	-37.11	3.460

So let's get rid of TF next. This has negligible impact on RMS error (24.8 to 25.0). TX improves to 2.5:1, so I'll let it in for now. DCEC is really bad at 13:15, or less than one. That is the next one to go. We have 11 terms left:

	coeff	change	value	sigma
1	IH	+0.871	+1110.67	3.720
2	ID	-0.596	+176.96	3.036
3	NP	+0.581	-711.58	6.454
4	ME	-1.965	-84.80	1.758
5	MA	+0.384	-53.22	3.962
6	TX	-2.816	-22.85	3.918
7	HCES	-2.511	-34.56	8.982
8	HCEC	+0.180	-35.40	3.131
9	DCES	+5.108	-30.26	5.260
10	DAF	-0.528	+424.70	1.651
11	DNP	+8.085	+114.48	14.779

Sky RMS = 25.07
Popn SD = 25.58

Note how, by removing the worst (noisiest) terms, we have gotten really good sigma on the remaining terms. The general rule here is a simple one: start by removing the noisiest terms, and observe what that does to the remaining terms. Some terms may go from marginal to useful; some terms may go from useful to garbage. You need to check your work at every step, removing ONE noisy term at a time and evaluating. Continue until, as above, all terms have a S/N of no worse than 3:1.

(At this point, polar alignment shows as too high by 85 arcseconds (not bad, considering your best bet is to align to the refracted pole; might be hard to improve upon), and off by 53 seconds in azimuth (just under one arcminute; can probably get better with a Paramount ME).)

With 280 points, it's possible that you might find useful benefits from looking at suggested terms. I usually don't bother with suggested terms if I have less than 150 points.

However, adding one suggested term provides only a marginal improvement:

```
 12     HHCH5      -0.512     -9.71    3.423

Sky RMS =  24.71
Popn SD =  25.26
```

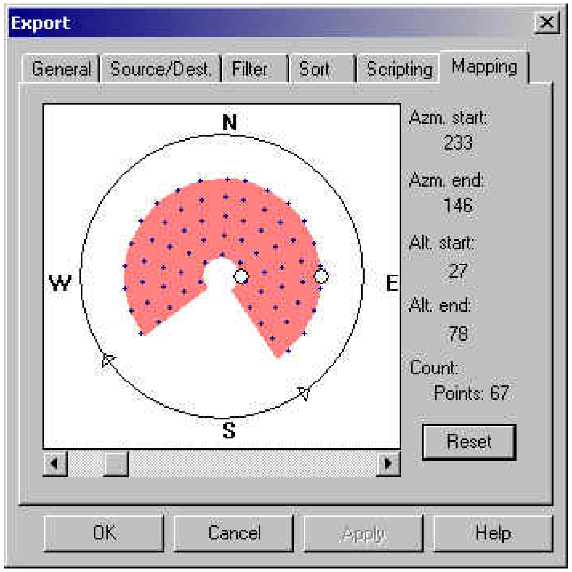
The S/N of HHCH5 is nearly 3:1, but if you look at the effect of adding this term on the existing terms, it adds noise to some of the other terms - a result that suggests we are on the wrong track. So I would not use any suggested terms at all with this model - I would want to see a S/N of 5:1 or more, and no serious negative impacts on the rest of the terms before I would even think of adding a suggested term.

So we're done - 11 terms is all that should be used, no suggested terms at all. I'll send you a copy of the revised .sky file privately.

Appendix C: Creating mapping lists in TheSky

Generating a File of Points

The process starts with the Data | Export menu item.

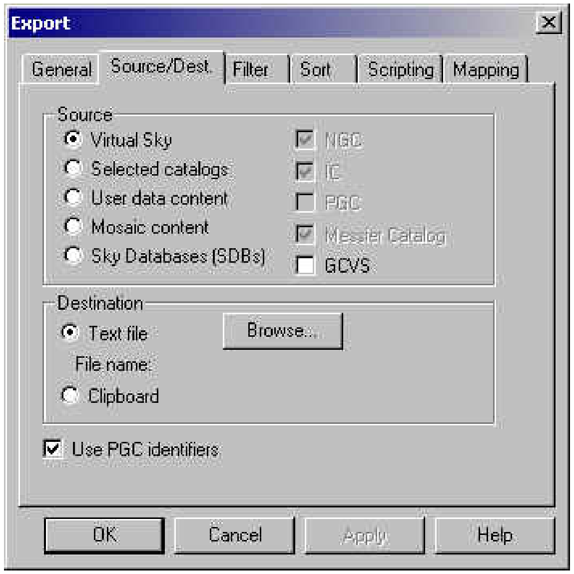


The Export Dialog, Mapping Tab

This opens the Export dialog. Click on the Mapping tab to activate it. You can manipulate the controls on the sky map to set limits, both in alt and az, for your points. The slider at the bottom controls the density of the points.

Setting the Output File

Once you have defined the limits and density on the Mapping tab, switch to the Source/Dest. tab and create the list. Duplicate the settings you see here. Click the Browse button to define the name and folder for the output file.



Saving the List of Points

Switch to the General tab and create the list. Duplicate the settings you see here. Click the Create List button to output the file with the name and location you set on the Source/Dest. tab.

Once you output the list of points, you can open the file in Automapper II and use it to do a mapping run. You can also use Automapper's own built-in ability to generate a list of points. Automapper II can generate lists that have a higher density of points.