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1. Introduction

2. Introduction

Basic and Professional Editions
Software Documentation

CCDAutoPilot is technically an "executive" program that issues commands to other programs, such as that for your camera, focuser, telescope, rotator, dome, etc. that you would routinely use to collect data during the course of an evening's observing session. If you were operating the system manually, you would have to take certain actions with one or more programs at certain times to achieve a successful imaging run. With CCDAutoPilot, you can set up the activities during the day or whenever convenient and CCDAutoPilot will execute those activities at the appropriate time and take appropriate corrective action if things don't go as planned.

CCDAutoPilot currently works with CCDSoft, MaxImDL, TheSky6, TheSkyX, ASCOM telescopes, focusers, rotators and domes, TAKometer, RCOS PIR, Optec Pyxis, Boltwood Cloud Sensor I, II and compatibles, DigitalDomeWorks, Automadome and FlipFlat/FlatMan artificial flat sources. Plate solving can be via CCDSoft/TheSky6, TheSkyX and PinPoint. Entry points are provided at key points during the course of a session to introduce external programs for specific needs. Thus, the entire observatory, regardless of size or complexity, can be automated from sunset to sunrise.

Assuming you have configured those programs you use in your observatory and are presently operating them successfully, you will need to Initialize CCDAutoPilot. This is the key process by which CCDAutoPilot learns about your system in order to achieve full automation. Once initialized, you can select one or more targets anywhere in the sky and CCDAutoPilot will slew your mount to that location within a few arc-sec., regardless of your mount's pointing accuracy, move your rotator (if you use one) to the correct position, automatically calibrate your guider and guide exposure and take whatever data you want for each target. It will do in process data assessment and move any data that doesn't meet your quality assessment to another folder. It will take any dark and/or bias frames you want either before or after your data frames, and take dusk and dawn flats if desired. If appropriate for your system, it will monitor weather conditions, open and close your dome end even send email or text messages concerning significant events. CCDAutoPilot can inter-operate with other observatory control systems, either commercial or of your design, by a powerful control file facility. (Some of the above features are not available in the Basic Edition.)

New in version 5 is complete, on-the-fly editing of a session in progress. Due to the Target Database structure as a relational database with referential integrity, coupled with an almost complete rewrite for flexible performance, you can change almost anything *while the session is running*. The only real exception is the current exposure in progress. Let's say you are in the process of taking a series of 5 red exposures of a target. Exposure number 3 is under way and you decide you want only 4. Then simply select 4 on the session page and you will get only 4. This flexibility extends throughout CCDAutoPilot and includes session options, calibration frames, focusing and guiding options.

CCDAutoPilot provides a number of tools and wizards to tune and optimize your imaging system, establish and measure progress against goals and evaluate data taken during the session.

Given the level of complexity of these systems, initialization and configuration setup is essential for successful operation. Through this help file and other instructional material, I hope to make the transition from manual to automatic imaging as painless and enjoyable as possible. Be sure to read the Introduction to Automation(See 4.6) as well as the rest of the Imaging Strategies(See 4.) topic to get the most out of automated imaging. Once you successfully make this transition, you will have a repeatable and reliable data acquisition protocol to operate your system to its greatest capability and get to sleep while all this is going on as a bonus!

If you are pleased with CCDAutoPilot5 and would like a graphic to include on your web site with your images, the below image (ap5_credit.gif) is located in the CCDAutoPilot5 program folder:

2.1 Version History

5.05.2 January 25, 2013

- Bug fix: Fixed error when using Darks Before or Darks Now from the Darks Before page
- Bug fix: Auto Date Correct now works with multiple targets that are after midnight.

5.05.1 January 22, 2013

- Bug fix: Add target manually, broken in 5.05.0, now works

5.05.0 January 21, 2013

- Add Feature: Tracking rates(See 8.4.1) are accepted from TheSky and used for non-sidereal rate objects (comets, satellites, etc.)
- Change: Target start times(See 8.4.1) will now be the time the first exposure starts, not when slewing and focusing start.
- Change: Improved responsiveness when editing a session.
- Change: CCDNavigator Session Import menu will open file dialog if no path to plan or no plan available for the current date.
- Change: Allow TheSkyX to start properly with slow computers when launched by Link to Software.
- Change: Active and inactive targets now shown when Delete All Targets is selected.
- Change: Prevent unrealistic download times being added if a long exposure is aborted.
- Change: Clarifed log for equinox used for ASCOM telescope slews.
- Bug fix: Check for update toggle now works properly
- Bug fix: Run First now properly implemented
- Bug fix: Email to and User addresses can now be different.
- Bug fix: Eliminate bogus guider cooler raise temperature report.
- Bug fix: Show exposure count in status bar for calibration frames.

NOTE: In the near future, CCDAutoPilot will **require** ASCOM platform version 6.

5.04.9 December 4, 2012

- Bug fix: SkyStar crossing the meridian for a focus star when it shouldn't.
- Bug fix: Late target being rescheduled until the next day.

5.04.8 December 2, 2012

- Add Enhanced Automation(See 4.9) Features
- Add Feature: CCDNavigator3 integration(See 4.9). Requires CCDNavigator 3.0.14 or later.
- Change: Increased SkyStar chosen focus star meridian margin to prevent meridian flip to focus star.
- Bug fix: Park properly for Weather Abort actions

5.04.7 November 12, 2012

- Add Feature: Added hardware section(See 12.) to Troubleshooting help topic.
- Add Feature: Initial support for CCDNavigator3.
- Change: Increase rotator timeout to 8 min. for slow rotators
- Change: Enhanced weather reporting during a weather abort

- Change: Cloudy delay/session abort operates at start of session and Focus before Target Start
- Bug fix: Proper abort after wait for cloud clearing timeout or worsening weather.
- Bug fix: Rotate to first target before precision slew.
- Bug fix: Summary reports now completes with either weather or user abort.
- Bug fix: Eliminate exception caused by some cameras with many binning options.

5.04.6 October 18, 2012

- Add Feature: Option to run Weather Abort upon slew failure with TheSky6 or TheSkyX. See here(See 8.14.5).
- Add Feature: Enhanced CCDNavigator support.
- Change: Improve weather abort logging.
- Bug fix: Re-enable Pause button after aborting a session.
- Bug fix: Pending focus at meridian will be executed after meridian flip.
- Bug fix: Speed/gain settings (Maxim) now preserved in system profile.
- Bug fix: Very cloudy condition not always resulting in session abort.

5.04.5 September 19, 2012

- Bug fix: Completely disable software version checking

5.04.4 September 18, 2012

- Add Feature: Path to Sky Quality Monitor can now be chosen by user.
- Add Feature: SQM mag. per square arc-sec. value now added to FITS header as MPSAS
- Change: Increased probability of successful launch of unopened server programs when Linking to Software(See 8.2).
- Change: trap error if RunApp is checked with an empty entry.
- Change: Eliminate pseudo-dark since Maxim passes a calibrated guider array if set in Maxim
- Change: Improve plate solve with TheSkyX
- Change: Eliminate server software version checking
- Change: Plate solve in Initialization routine now follows AutoDark selection in Settings/Plate Solve
- Change: Added information for using AO devices with Maxim. See here(See 12.4).
- Bug fix: Weather abort doesn't prevent acquisition of calibration frames and stops guider if running
- Bug fix: Imager temperature raised by 30° when specified.
- Bug fix: Allow focusing near meridian when sufficient time is available before transit.
- Bug fix: Correct guiding when target is near meridian and must wait for flip for first exposure to start.

5.04.3 August 7, 2012

- Bug fix: Enable flat bias control.

5.04.2 August 3, 2012

- Add Feature: Changed target context menus. Added Invert Active Selections and Duplicate Target functions. More...(See 8.4.1)
- Add Feature: Can enter average flat bias to improve exposure convergence under certain conditions. More...(See 8.14.3)
- Change: A weather abort will only abort flats is the sky is used as a light source.
- Change: Minimize spurious weather abort emails
- Change: Added warning if a RunApp is checked but the application is not found.

- Change: Do not close FlipFlat when aborting a session.
- Change: Don't connect to telescope until after observatory is open.

5.04.1 June 23, 2012

- Add Feature: Minimize probability of double stars being chosen for SkyStar focusing
- Add Feature: Added Run 0 to Options (See 8.6.1)page, Startup up tab.
- Add Feature: Enhanced session review on the Run(See 8.8) page to include exposure summaries and the ability to paste to notepad.
- Change: Prevent editing of current target during a running session.
- Change: Can now handle up to 20 filters in a filter wheel.
- Bug fix: Preserve panel sizing on Session Page, Light Frames tab.
- Documentation: Clarified %d as Position Angle, not Rotator position on Setting page, File Settings tab.

5.04.0 May 18, 2012

- Add Feature: Run 0 added on startup options tab.
- Add Feature: Support for PinPoint USNO B and USNO B (net) added
- Add Feature: Support for ISO speed (QSI gain) programming with Maxim. See Camera Options(See 8.14.9)
- Change: disabled menus and features that require software to be linked from the Setup page
- Change: Decrease min. sun angle for dawn flats to -20.
- Change: Weather will abort flats phase if flats are sky flats only
- Change: Wait for Maxim to turn on cooler(s) before querying cooler temperature(s)
- Change: Allow testing rain sensor during clear sky by applying water drops to sensor
- Change: Improved weather abort during various portions of session.
- Bug fix: Corrects AO Maxim AO bumping
- Some minor bug fixes on clipboard calls and initialization.

5.03.9 April 4, 2012

- Change: Improved hot pixel filter
- Change: Download estimates are now based on light frames only.
- Change: Link to Software *required* for target editing.
- Bug fix:: Move on if cooler is colder than set point temperature at session Startup
- Bug fix: Resolve date/time error with It(Italy) region setting
- Bug fix: Prevent error with short exposures and Insert WCS and/or Data Assessment

5.03.8 March 22, 2012

- Change: Target star focusing behavior change. See here(See 8.4.2)
- Change: Wait for clouds to clear active only during light frame acquisition. See here(See 8.14.5)
- Change: If cloudy during meridian flip, wait for clouds to clear (if checked) before doing precision slew.
- Change: Improved flat acquisition efficiency.
- Change: Exp. time increment decreased to 0.1 sec. for planetary imaging.
- Bug fix: "no row at position 1 error" resolved
- Bug fix: Unable to set target start time earlier than the end time of an inactive target.
- Bug fix: Negative ADU report during flat acquisition
- Bug fix: Correct guiding when using Maxim/Telescope

5.03.7 March 14, 2012

- Add Feature: Hide inactive targets. See here(See 8.4.1)
- Add Feature: Specify a target star for focusing. See here(See 8.4.2)
- Change: Cooler no longer turned on when CCDAutoPilot links to Maxim.
- Change: Dither/Guiding time factored into time estimates.
- Change: Focuser not needed for G2V measurements.
- Bug fix: Target ADU for sky flats not being met in some cases.
- Bug fix**:** Rotator adjustment after precision slew not being made in some cases.
- Bug fix: Italian/Swiss culture target add error corrected.
- Bug fix: Corrected occasional error in G2V measurement wizard

5.03.6 February 21, 2012

- Add Feature: Post Flip Delay added. See here(See 8.12.3)
- Change: Focus Offset Wizard enhanced. See here(See 8.14.7)
- Change: Linearity Wizard enhanced and user-specified tolerance added. See here(See 8.14.7)
- Bug fix: Use Autodark state for plate solving was being ignored.
- Bug fix: Eliminate "Command in Progress" error from TheSkyX
- Bug fix: Wrong series info being displayed for updated target after update.
- Bug fix: Inactive targets were being hidden during a sort.

5.03.5 January 6, 2012

- Bug fix: Prevent error when adding a new target via the Get button

5.03.4 January 4, 2012

- Add Feature: Target list can now be sorted in addition to drag/drop. See here(See 8.4.1)
- Add Feature: The light exposure mid-point is now shown to aid in meridian crossing planning. See here(See 8.4.1)
- Change: Default failed folder is now a sub-folder under the target name's folder
- Change: Duplicate FOVI check is more robust.
- Change: All comboboxes are read only to prevent problems with user-entered data
- Change: TAKometer target rotation angle now displays properly in status line
- Change: Prevent program error if a clipboard manager is used
- Change: Park while waiting/tracking off while waiting are operational at the very start of a session.
- Bug fix: Session window splitter bar position is now properly remembered.
- Bug fix: Eliminate occasional delay in getting Session Events when changing to Run page.
- Bug fix: Keep rotator target position in acceptable range.

5.03.3 November 27, 2011

- Add Feature: New wizard to measure camera linearity(See 8.14.7)
- Change: Improved light series editing responsiveness
- Change: Stay on the target being edited when updating
- Bug fix: Correct target add errors that sometimes occur

5.03.2 November 13, 2011

- Add Feature: Sky Quality Meter info is now entered into the ccdautopilot log. See Software.(See 8.2.1)
- Change: The Target name, when available, is appended to the default light frame folder name. See File Settings.(See 8.14.2)
- Change: The maximum flat frame exposure time is increased to 999 sec.
- Change: Run app folders can be cleared by hitting cancel after navigating to the existing file.
- Bug fix: Unable to navigate to mount slew program.

5.03.1 November 11, 2011

- Bug fix: Prevent error if last character after '%' is deleted in file name template
- Bug fix: Prevent series becoming unchecked when editing
- Bug fix: Modify dome park logic to prevent error.
- Add Feature: Dome homing to move shutter is now optional. See Control Settings(See 8.14.5)
- Add Feature: Can set Maxim readout modes for bias and dark frames independently. See Camera Options(See 8.14.9)
- Add Feature: Run an application after slewing to a target and crossing the meridian. See Control Settings(See 8.14.5)

5.03.0 October 25, 2011

- Bug fix: SkyStar chosen focus star will not exceed Max. E and/or Max. W mount altitude limits
- Bug fix: SplitterDistance program error fixed.
- Change: Focus before Target Run Start will slew to vicinity of target before focusing.
- Change: Precision slew will occur even if Focus before Target Run Start and focus at series start are both checked.
- Change: Default PinPoint expansion set to 0.3

5.02.9 October 12, 2011

- Bug fix: Telescope(PulseGuide) in Maxim
- Bug fix: Spurious Dec. Format error message
- Add: CCDAutoPilot5 credit graphic.(See 2.)
- Change: The filter name learning from the camera control program is terminated by either the default filter name, e.g. filter6, or a blank name.

5.02.8 September 27, 2011

- Bug fix: Log not being written.
- Bug fix: Stop guider if running to allow guide star detection

5.02.7 September 25, 2011

- Add Feature: Detect Too Light condition from Cloud Sensor II. See description.(See 8.14.5)
- Change: Add workaround for CCDSoft AO detection bug. See description.(See 8.2.2)
- Bug fix: Corrected pause for cloudy condition abort processing.
- Bug fix: Initial focus before target run was inserting an offset relative to the first filter in error after focusing.

5.02.6 September 21, 2011

- Bug fix: Compliation error prevented auto guide star exposure from working with Maxim.

5.20.5 September 20, 2011

- Add Feature: Bias level for flats now done automatically for cameras with and without shutters.
- Change: Initialization warning moved from a separate dialog box to the Warnings section of the Run page.
- Bug fix: Guide star not being detected at series start when self-guided
- Bug fix: Correct flat acquisition when using custom light source
- Bug fix: Valid target sometimes incorrectly skipped due to altitude.
- Bug fix: Manual data assessment sometimes incorrectly flagged frames as failed.

5.20.4 September 17, 2011

- Bug fix: Excessive CPU usage

5.02.3 September 16, 2011

- Change: Test CCDNavigator input format. Warn if incorrect
- Change: Enable Darks Now without a telescope connection being required
- Add Feature: Guide star detection now happens only when necessary with off-axis guided and guide scope operation.
- Change: Add ReverseY(See 8.12.3) option for meridian flip with guide scopes.
- Change: Improved focuser temperature detection code.
- Change: Added temperature readout for Maxim focusing if supported in Maxim.
- Change: Do not repeat Focuser temperature warning if temperature not available.
- Change: Prevent a blank entry for Guider or Imager plate scale.
- Change: Prevent RA/Dec format error when using ASCOM (only) for telescope control.
- Change: Add warning of dome activity planned but no dome linked.
- Change: Skip targets that haven't risen at target start time.
- Bug fix: Weather abort fixed, improved. Details(See 8.14.5)
- Bug fix: AO recentering on every exposure fixed
- Bug fix: Realign to target is now scheduled properly
- Bug fix: Last target in list is now exported correctly
- Bug Fix: Last target time gap not being closed when selecting Reset Time Gap between Active Targets.
- Bug fix: Next Focus Time is now properly initialized.
- Bug fix: Correct starting exposure for Custom Flat Light Source.
- Bug fix: Dome is unlinked when weather abort is triggered.
- Bug fix: Control file throwing error incorrectly.
- Bug fix: Allow comets to be added, e.g. C/2009P1
- Bug fix: Prevent auto star select for G2V when not using TheSky
- Bug fix: Prevent error if PC clock changes massively during a session.

5.02.2 June 23, 2011

- Add Feature: Hot Pixel Filter(See 8.12.1)
- Add Feature: Dome control support for TheSkyX (X2). Requires TheSkyX Professional Build 4568 or later.
- Change: Support ASCOM Dome Park
- Change: DDWCP improved. Now waits for dome to stop slewing before proceeding.
- Change: Set CCDSoft guider series to 1 on connect
- Change: Prevent AO centering if no AO connected
- Bug fix: Permit sync option on return precision slew when Focus Program Picks Star focusing method is used.

- Bug fix: Eliminate "SplitterDistance" program error.

5.02.1 June 11, 2011

- Bug fix: Close time gap for active targets fixed
- Bug fix: Eliminate spurious "wait for astronomical dawn" for dusk flats
- Bug fix: Correct dark session time when bias frames selected

5.02.0 June 8, 2011

- Change: Always show next focus time in session window
- Change: Performance improvement in large target databases
- Change: Prevent invalid coordinate data from being entered
- Bug fix: Correct session time estimates.
- Bug fix: Correct ephemerides dates
- Bug fix: Prevent error when no astronomical twilight
- Bug fix: Prevent update error on Session page

5.01.9 June 2, 2011

- Add Feature: Added ability to move rotator (See 8.6.3)to a specific location at the end of a session.
- Change: Add target coordinate format checking/warning. Improved help topic(See 8.4.1).
- Change: Add warning if too few stars in a plate solve
- Change: Add automadome support for TheSkyX
- Bug fix: Correct AO initialization error (Maxim)
- Bug fix: Remove spurious dusk warning message

5.01.8 May 19, 2011

- Bug fix: Update sun ephemerides as needed for session planning and warnings
- Bug fix: Reflect @Focus2 requirement in startup message for filter offset wizard
- Bug fix: 3x3 binning not showing up as a plate solve alternative in some cases.
- Bug fix: ASCOM telescope coordinates not being properly reported for Initialization
- Change: CCDSoft Series count is reset to 1 upon Link to Software.

5.01.7 May 11, 2011

- Bug fix: Double-clicking on an empty target list
- Bug fix: End of session UPDATE error
- Bug fix: Ensure proper meridian flip/abort label in session window

5.01.6 May 8, 2011

- Change: Add target loop count index to file name template and show on session window if greater than 1(See 8.8.1)
- Change: Add workaround for Maxim versions < 5.08, which caused Program Error when initializing
- Bug fix: Error when loading a profile with readout mode other than 0 selected.

5.01.5 May 6, 2011

- Bug fix: Properly handle negative TAKometer values

5.01.4 May 5, 2011

- Bug fix: Correct TAKometer fault
- Change: Enhanced some warnings messages
- Change: Unhandled exception reporting and display

5.01.3 May 4, 2011

- Bug fix: Prevent error at end of session with single target

5.01.2 May 4, 2011

- Change: Minimum TCC application is 1.5.23
- Change: Accommodate both CCDAP4 and CCDAP5 control files
- Change: Add guide method to session review
- Change: Add focuser slip warning in Focus Offset Wizard Measurement(See 8.14.7) topic.
- change: Increase decimal places for focus exposure and calibration magnitude
- Bug fix: Rotator direction test no works properly at all angles
- Bug fix: Prevent error with one-shot color cameras
- Bug fix: Correct data assessment when using plate solving
- Bug fix: Filter offset measurement now works with @Focus2

5.01.1 April 24, 2011

- Change: Support higher dpi display settings
- Change: Stability improvements
- Bug fix: Add serial number to file name when Description field is used.

5.01.0 April 14, 2011

- Bug fix: Prevent error when leaving Focusing page
- Change: Improve Precision Slew accuracy with TheSkyX

5.00.9 April 13, 2011

- Bug fix: Prevent error at end of series for some regions
- Bug fix: Prevent error when running a session with no targets selected

5.00.8 April 11, 2011

- Change: Increased resolution of min. and max. guide exposure and max guide error.
- Bug fix: Temperature compensation not working properly
- Bug fix: Prevent negative goals achieved.

5.00.7 April 8, 2011

- Bug fix: eliminate "moon error"
- Bug fix: do not assess data when only Insert WCS is enabled.
- Change: Add warning when exposure time is too short for either data assessment or WCS insertion.
- Change: Eliminated native Optec driver code. You may have to reselect your rotator on the Setup page.

5.00.6 April 7, 2011

- Bug fix: correct date error at startup for some regions
- Bug fix: prevent dither wander with over 24 exposures per target

5.00.5 April 6, 2011

- Bug fix: Target start time being changed in error under some circumstances.
- Change: Use ASCOM driver for Optec rotators, available here.

5.00.4 April 5, 2011

- Bug fix: TheSky6/X loading with non-us regions
- Bug fix: Maxim camera drivers with 0 readout modes
- Bug fix: Exception with over 48 exposures on the same target
- Bug fix: Data assessment achievement count
- Bug fix: Staircase rename caused a problem.
- Bug fix: Some minor log details

5.00.3 April 3, 2011

- Bug fix: Version check to work with comma as decimal separator
- Bug fix: CCDNavigator import
- Enhancement: "Stairstep" changed to "Staircase" for consistency with CCDNavigator. This will be reflected in the default templates only if a new default database is selected. See New Database(See 8.)

5.00.2 April 2, 2011

- Bug fix: unable to update

5.00.1 April 1, 2011

- Bug fix: CCDAP terminates if Initialize selected without a filter wheel.

5.00.0 April 1, 2011

- Initial Release

2.2 Edition Differences

Professional Edition

The Professional Edition provides all the features, functions and tools described in this help file.

Basic Edition

The Basic Edition is intended for beginning imagers. It is limited to one target per session and does not provide the control file for customization. Email/text message notification, filter offset and G2V ratio wizards are also not available.

2.3 Application Requirements

Certain minimal revision levels are required for the applications CCDAutoPilot will command. CCDAutoPilot will simply **not work** with earlier versions. Version checking is incorporated to prevent operation with applications that do not meet these minimum versions. In most cases, updates are freely available from the software publisher and must be implemented for successful CCDAutoPilot operation.

- Windows XP, Vista 32-bit or 64-bit, Windows 7 32-bit or 64-bit as long as .NET 4.0 (Extended) Framework is loaded.

- .NET FrameWork 4.0 The extended edition is required.

One of the following camera control programs:

- CCDSoft version 5.00.205 or later, 5.00.215 recommended.
- MaxImDL version 4.62 or later. 5.08 or later recommended, requires the ASCOM platform specified below.

One of the following telescope control programs/environments

- ASCOM platform 5.5.1 or later including the NOVAS-COM Astrometry Engine v2.1 or later and Kepler Orbit Engine v1.0a or later
- TheSky6 **Professional Edition** 6.00.65 or later
- TheSkyX **Professional Editio**n 10.1.11 or later

Focusing

- FocusMax 3.4.40 or later. FocusMax requires the ASCOM platform, identified above.
- TheSky6 or TheSkyX for SkyStar focusing.

Plate Solving

- CCDSoft and TheSky6 as specified above
- PinPoint v5.x or later
- TheSkyX as specified above.

One of the following rotator control programs

- ASCOM-compliant driver and the ASCOM platform as specified above
- AstroDon TAKometer Control v 0.0.1 or later
- RCOS TCC Software, version 1.5.23 or later

One of the following dome control programs

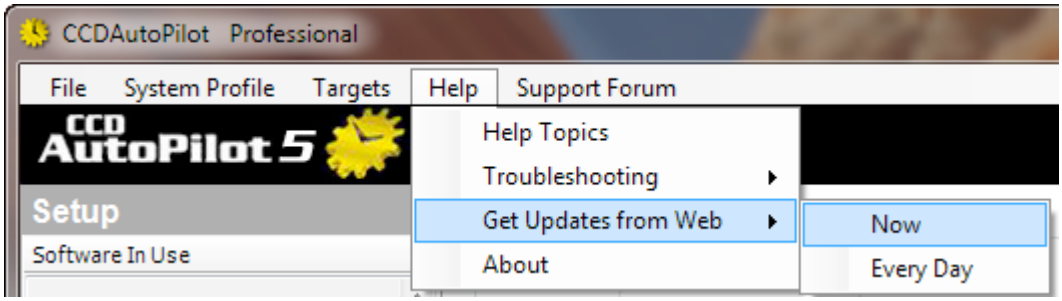
- ASCOM-compliant drive and the ASCOM platform as specified above
- AutomaDome version 1.00.014 or later
- Technical Innovations DigitalDomeWorks

Weather

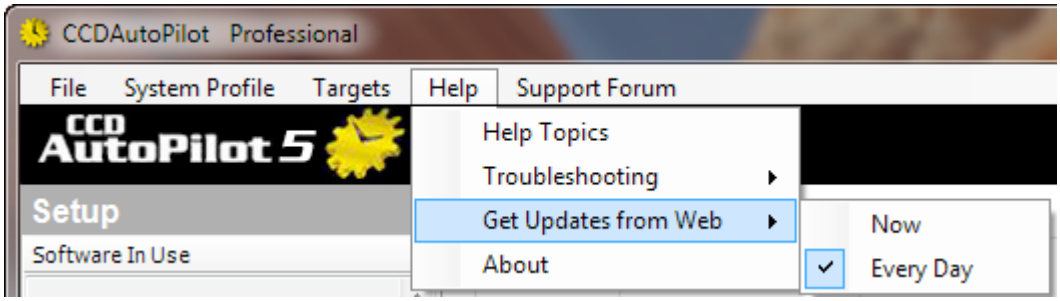
- Boltwood Cloud Sensor I, II, TI/AAG Cloud Sensor and compatible cloud sensors that provide the single line data file in a folder accessible to CCDAutoPilot
- (Other weather sources coming)

2.4 Getting Updates

CCDAutoPilot offers both a Manual and Automatic method of getting updates.



Using the menu to select Help/Get Updates from Web/Now will immediately check for available updates.



Clicking on Every Day will set or clear a check mark. If the check mark is present, CCDAutoPilot will check for updates once a day at the first execution of the day.

If you have a remote observatory without Internet access, first update CCDAutoPilot on a PC that does have Internet access. The update installer files are always located in (My) Documents\CCDWare\CCDAutoPilot5\Updates\. Simply copy those files to a flash drive and install them on your observatory PC. Don't forget to copy your license file as well.

2.5 License

When errors are found in the Software, the Licensor will release a new version of the Software that no longer contains those errors a reasonable amount of time after the Licensor is given an accurate description of those errors. What amount of time is reasonable will depend on the complexity and severity of the errors. The Licensor will mention the release on the Web Site and, at the Licensor's option, directly contact the Licensee to announce the new release. The Licensee can then, at their option, upgrade to the latest version or to continue to use the older version the Licensee already has. In either case, no payment to the Licensor is required. In the latter case, the Licensee will no longer be entitled to technical support until the Licensee has upgraded to the latest version.

The Licensor reserves the right to charge an upgrade fee in the case of major new enhancements or additions to the Software. This major new version will then start a new version line that will use version numbers clearly distinguishable from the old version line. The Licensee has no obligation to upgrade to the new version line and the Licensor will continue to make the latest version of the previous version line available for download to Licensee.

You must not attempt to reverse compile, modify, translate or disassemble the Software in whole or in part. You must not run the Software under a debugger or similar tool allowing you to inspect the inner workings of the Software.

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The Licensor reserves the right to revoke your license if you violate any or all of the terms of this license agreement, without prior notice.

3. Imaging Strategies

4. Imaging Strategies

CCDAutoPilot is designed to make your imaging data collection easier and more repeatable. In addition to "pushing buttons" for you, it also has a number of tools, wizards, features and options that can make the quality of your acquired data better and the entire acquisition work flow more repeatable. In fact, once you have an optimal approach worked out, you can simply determine your target and go.

To use CCDAutoPilot to maximum advantage, it is best to review some underlying concepts surrounding data acquisition. The next few sections are intended to give you some background on these concepts.

There is a significant amount of technology in image acquisition with CCD cameras but with an understanding of some of the underlying concepts, best use can be made of the available time. This section will hopefully provide some "getting started" concepts. As your skills and understanding develop, you may delve more into the underlying details to further optimize your data acquisition.

One of the first questions asked is how long should my sub-exposures be? This simple question can take an "urban legend" kind of answer - as long as possible, go deep, "10 minutes is what I use", etc. But there is some underlying science that can be applied to make sense of all this and determine what is best for your telescope, camera and sky conditions

Imaging is all about Signal-to-Noise-Ratio (SNR). Noise is that grainy background that we see in the faint areas of the target after our exposure is complete. There are multiple sources of noise - the camera electronics and the camera sensor (read noise) and even noise from the sky itself, in the form of sky glow. The goal is to minimize the impact of the things we can control. How we deal with these issues is a function of whether we are doing narrow band imagine (H alpha is one example, along with Sulfur II and Oxygen III) and broad band (Luminance or clear filter along with RGB typically) is another.

Broad Band imaging
With broadband imaging, the sky glow forms an appreciable illumination component. Like most light sources, there is a noise component, technically called Poisson arrival statistics, that contributes uncertainty (noise) to the value (signal) of the sky glow. Since sky glow is a uniform component of the signal, it can be effectively subtracted from the data but the noise can not be subtracted. Noise sources combine like the Pythagorean theorem - the square root of the sum of the squares. So, given the noise in sky glow, we make our sub-exposures long enough so that the sky glow noise is the major noise component and overwhelms read noise. A typical strategy is to make the sub-exposure time long enough so that read noise contributes 5% of the total noise. The sub-exposure calculator provides a convenient way to measure camera gain, read noise and sky glow for popular camera sensors so that you can arrive at a suitable minimum sub-exposure time. It should be noted that the luminance component carries the resolution and color information is generally blurred so the noise in the color channels is not as important as the read noise.

Once we have a sub-exposure time determined, we can look at dark current. Every sensor has dark current, which is another signal that can be subtracted from the data but again it has a noise component that can not be subtracted. Here, cooling the sensor reduces the dark current typically by one-half for every 6 degrees C. We can use a similar strategy to determine how much we want to allow the dark current to contribute to the total noise. Since dark frames are easy to come by on cloudy nights, we can set experiment with the sub-exposure calculator to determine camera operating temperature and number of dark frames we need. In many cases, a surprising camera operating temperature for a given dark noise contribution results. For example, with a KAF16803 sensor and my suburban skies, a 600 sec. sub-exposure is sufficient so that read noise contributes 2.5% to the total noise and to have the dark current contribute 0.5% to the total, I need only 6 dark frames and can run the sensor at -15 degrees C. Again, once your gain, read noise and sky glow is known, you can experiment with sub-exposure calculator settings to see the effect of cooler temperatures on the dark noise contribution and number of dark frames needed.

(It should be mentioned that there is another quasi-noise source called pattern noise. This is pixel-to-pixel differences in dark current for each sensor. Technically, this also represents noise but dithering and subsequent registration and statistical rejection combining minimizes this contribution for aesthetic imaging. The order of magnitude of this pattern noise is approximately equal to the dark signal. For precision photometry, the temperature should be reduced approximately another 7 degrees C from that calculated above to reduce the pattern noise. The number of dark frames calculated above should also be doubled.)

Narrow Band Imaging
With Ha, OII, SIII and similar narrow band filters, the sky glow is essentially negligible. Here, the noise sources are primarily read noise and secondarily dark signal noise. Read noise is relatively insensitive to temperature. Since exposure times are generally long, the number of dark frames should be calculated after inputting your exposure time and camera operating temperature. If your imaging scale is sufficient, binning can reduce the effective read noise. For example, binning 2x2 means 4 pixels are read with one read cycle. If your read noise is 10e for example, then that will be applied to 4 pixels and your effective SNR will be increased by approximately 4. This may not happen in all cases with all sensors and cameras. To be sure, take advantage of CCDAutoPilot's Sub-Exposure calculator tool to actually *measure* read noise for unbinned and binned conditions.

The above discussion barely scratches the surface of SNR. Interested readers are referred to available texts on this issue.

Subsequent sections in this topic will explore key contributors to overall data quality.

4.1 Focusing Techniques

Keeping your system in focus is, as might be expected, of critical importance in achieving high data quality. Not only does excellent focus give smallest stars and highest resolution but it also gives higher signal. So focusing and maintaining focus is very important.

Focusing Programs
There are three focusing methodologies supported in CCDAutoPilot - FocusMax, @Focus2 and Maxim's own focusing routine. When properly initialized or calibrated, both will do an excellent job of achieving critical focus.

FocusMax is a free program put in the public domain by Steve Brady and Larry Weber. It supports a wide range of focusers and is widely used and respected. It works with both CCDsoft and Maxim. It requires an initial calibration routine that might take 30 minutes or so but once done, will never need to be revisited unless you change cameras or the imaging telescope's focal length, by a focal reducer for example. Consult the FocusMax help file for more details.

@Focus2 is a unique technology to Software Bisque and is incorporated in CCDSoft. It supports most popular focusers. Initial calibration requires determining the exposure time for a given magnitude star that results in a peak count of 25,000. This must be done for each filter and can take 10-15 minutes or so for 5 filters. Once done, it will not need changing unless the camera or imaging telescope's focal length is changed. Consult the CCDSoft help file for more information.

Maxim Focuser uses a similar approach as FocusMax by measuring the half-flux density of an out-of-focus star. It does not require the calibration that FocusMax and, as a consequence, individual focus sessions will take a bit longer, perhaps 20-30% longer. If focus offsets are required, then the Maxim Focuser must connect to an ASCOM hub so that both CCDAutoPilot and Maxim can access the focuser simultaneously.

The Problem
For each optical system, focusing must be maintained within the Critical Focus Zone (CFZ). Classical optical theory as the best focus, limited to the wavelength of the incoming light and the size of the Airy disk, which is primarily a function of the imaging telescope's aperture. Recent work suggests that with automated focusing programs, focusing should be targeted at being approximately one-third of the classical CFZ and this is what CCDAutoPilot's CFZ calculator gives. Even assuming an accurate initial focus, the focus can change over the course of the imaging run due to a number of sources.

- **Filters:** Different filters may have different optical thicknesses, resulting in a change in focus as different filters are used. Even parfocal filters, filters which have the same optical thickness, may not result in the same focus point if the imaging telescope has significant refractive elements. The best corrected APO refractors will still show a focus difference between red and blue filters for example. Reflective telescopes typically do not show this problem.
- **Temperature:** Aluminum is a component in most telescopes and is subject to contraction as temperature decreases. This usually results in a focus change, unless mechanically compensated. And some lower cost telescopes might have optical elements made from non-zero temperature coefficient glass, leading to a potential change in focus.
- **Mirror Flop:** This is an issue primarily with lower cost SCT's, where the mirror moves due to change in OTA attitude. This issue may also be exacerbated by the meridian crossing "flip" with an equatorial mount. In flipping from east to west, the OTA effectively rotates by 180 degrees!

Solutions
From the above it is clear that there is a need to focus during the course of the evening. CCDAutoPilot provides a number of techniques to focus and has the ability to characterize your system. You can characterize your system during moon time by a couple of techniques.

Filter Effect: CCDAutoPilot includes a Focus Offset Measurement(See 8.14.7) Wizard that automatically determines the focus offset arising for each filter in concert with the characteristics of your OTA. This requires a true absolute focuser whose position is completely repeatable. If your focuser meets that requirement, you can use the wizard to determine the offsets for focusing. Simply center the scope on a suitable focus star, say magnitude 4 - 5, set your starting focus exposures appropriately on the Focusing page, select a reference filter(Green is suggested as a mid-band filter range) and the number of measurements/Filter (minimum 5 recommended, more is better), and hit the

Measure button. The wizard will make the specified number of focus runs per filter, calculate the median for each filter, calculate the necessary offsets and enter them on the Focusing page. If the entered offsets are within the CFZ (Use the calculator in the left pane of the focus page to determine CFZ), then you can use the same filter for focusing without worrying about the offsets Even if there are significant offsets, you can program in those offsets on the Focus page so that they will be added or subtracted as necessary to achieve excellent focus.

Temperature Effect: This will probably take a full evening's run again during moon time. You will need a method of recording temperature over the evening. CCDAutoPilot can acquire temperature from a number of sources. Set up a number of focus stars that will be within 20 - 30 degrees of the meridian over the course of the evening. (This requires the Professional edition, since each focus star is a target. For the basic edition, you will have to set up individual sessions.) Unless you know you don't have a mirror flop issue, you should keep to one side of the meridian. Set up SkyStar with Center Focus Star checked. Do 5 series of a short exposure with the same filter. At the conclusion of the evening's run, you can assess how much focus changes with temperature and how much temperature change causes you to exceed the CFZ. You can then program CCDAutoPilot to focus on a temperature change that corresponds to 1/3 of the CFZ for example.

Mirror Flop: Set up a number of series with the same filter and select focus at series start. Choose a suitable value for the number of sets to insure the imaging time carries through a meridian flip. Select Focus At Star Center with Center Focus Star checked. For meridian flip settings, check Focus On Flip as an additional data point. At the end of the session, examine the log to see how much the focus point changes across the meridian flip. If you see a significant change, be sure to always use the focus after meridian flip option.

Unknowns: The above covers what we know but other things can happen that we don't know about. For example, a passing cloud can obscure the focus star and you may get a bad focus reference. Periodic focusing, focus at series start even with focus offsets set up, can help catch and correct for those events. See the Focusing topic in the Command Summary for details on the many focusing tools provided in CCDAutoPilot.

4.2 Guiding and Tracking Techniques

Guided Imaging

Long exposures generally consist of a number of shorter sub-exposures and because of that, the telescope must be kept accurately pointing to the target during the course of the sub-exposures. A very precise mount may be able to track accurately enough for the sub-exposure duration but most do not. That is where guided imaging comes in. A guide star is selected and its centroid calculated with every exposure. As the centroid moves from the starting position, commands are sent to the telescope to bring the centroid back to its original position. However, the guiding routine is always acting after the error has occurred so there is an inherent delay in this correction. By the time the correction has been sent to the telescope has been sent, there might be a different and even opposite correction required. A number of guide parameters can be adjusted to minimize this effect.

However, recall the discussion about pattern noise. That can be minimized by dithering (intentionally moving the guide star position between sub-exposures). When the resultant sub-exposures are aligned, any pattern noise will not be reinforced by alignment but sky details will. If a subsequent statistical combining method is applied to the aligned, dithered images, the pattern noise will be greatly reduced. Of course dithering must be such that the same location is not duplicated and CCDAutoPilot provides such a capability with its Enhanced Dithering option.

There are a number of parameters that must be properly set to achieve successful guiding.

- **Minimum Move Time:** This is the time (or movement) that must be exceeded by the guiding algorithm to cause the telescope to move. This must be set to avoid "chasing the seeing" and causing frequent but unnecessary movement of the telescope. In other words, set this value so that only those corrections that will impact the image will be sent to the telescope.
- **Maximum Move Time:** This is the maximum time (or movement) that will be sent by the guiding algorithm to the telescope. It must be set high enough to have a reasonable correction response time but not so long that an occasional cosmic ray or other effect can cause the telescope to move too far so that it has to come back on the next correction.
- **Aggressiveness:** This is a measure of how much of the calculated correction is actually sent to the telescope. At first blush, one might be tempted to send the complete correction but recall there is a lag from the time the error is calculated until the telescope is moved. So my sending less than 100% of the correction, the tendency to

overshoot is minimized. On the other hand, setting it too low may mean the telescope never catches up to the starting guide star position.

- **Guide Exposure:** During the guide star exposure, the guide star position is essentially being averaged for the duration of the guide exposure. If the guide exposure is set too short, the telescope won't have time to respond, there will always be a lag and we will be chasing the seeing again. Set it too long and the corrections will be delayed too much to properly correct for mount tracking and elongated stars will result. On the other hand, the guide exposure has to be long enough to get an adequate SNR for the guide routine to be able to accurately calculate the star's centroid. (Note: there is a type of guiding called AO for Adaptive Optics, in which a mirror or piece of glass is moved. As such it can be moved more quickly due to its lower mass, compared to a telescope. In this case, shorter exposures are desirable since the lag is greatly reduced because of this lower mass.)
- **Dithering:** How much dithering is enough? Too little and the pattern noise will not be shifted enough from frame to frame so that it won't be removed in stacking; too much and the guider will spend a lot of time recovering from the dither, reducing data gathering efficiency.
- **Guide Star Selection Algorithm:** Normally for guided imaging, you want the brightest guide star you can find for best guiding performance. With narrow field imaging and guiding, getting a sufficiently bright guide star is generally a challenge. However, when using a wide-field guide scope, you may accidentally find a guide star in the FOV that is too bright (saturated). As you might expect, guiding accuracy is impacted if this saturated star, being the brightest in the FOV, were chosen to guide on. CCDAutoPilot will reject any guide star whose peak value exceeds 55,000 ADU to avoid this problem. It will choose a star whose peak value is less than 55,000 ADU automatically.

CCDAutoPilot has tools to enable efficient starting point settings for these variables. The Guide Calculator on the Tools page suggests minimum and maximum moves. The Suggest button on the Tracking & Guiding page recommends a Maximum Dither that is appropriate for your system, based on your entries in the Settings page. For non-AO operation, I suggest a minimum guide exposure of 3 sec. The maximum guide exposure depends on how well your mount tracks. Longer gives more averaging of the guide star's position. There is an Auto Guide Exposure facility that allows you to set the minimum and maximum guide exposure so that your Target Guide ADU can be achieved by automatically setting the guide exposure between those two limits.

Finally, CCDAutoPilot has a number of recovery options in case the guide star is temporarily lost. See the Guiding topic for more details.

Guiding with Adaptive Optics (AO)

AO guiding consists of using an additional optical element, either a mirror or a piece of glass, in the optical path. This element is driven to correct for positional errors in the guide star due to seeing (to a first order), mount and other sources of error. Instead of moving the entire telescope, as is the case with conventional guiding, only the optical element, which is a much lower mass than the mount is moved. This has the benefit of being able to move much faster than is possible with a mount and can correct for some seeing issues.

The optical element has limited travel and at some point, it will run out of range. This limitation is resolved by moving the mount when the AO gets near its maximum movement. This is causes "bumping" the mount. The mount is moved while the AO is guiding so the AO effectively corrects for any disturbance induced by the mount bumping.

There are therefore two calibrations that are required - mount bumping and AO. AO calibration is done once (manually) and mount bumping normally has to be done at every sky location. CCDAutoPilot will properly provide the calibration for mount bumping once initialized. Thus, all you need to do is calibrate the AO using your camera control program, initialize CCDAutoPilot and you won't ever have to worry about any calibration for your AO system unless you change something in your physical camera arrangement.

Unguided Imaging

If a mount tracks well enough for a sub-exposure duration, then unguided imaging is a much simpler operation. Of course, one should dither for the same reasons one dithers with guided imaging.to mitigate pattern noise. However, even the best mounts will slowly drift off target over a time if a substantial number of sub-exposures are taken. CCDAutoPilot has the ability to correct pointing to the target periodically. Use the Realign To Target Frequency feature and set the period to whatever value you find you need. 30 minutes might be a good starting point.

Meridian Crossing with a German Equatorial Mount

For best quality imaging, it is always desirable to collect data through the least amount of atmosphere and this means around the meridian. Unfortunately most German equatorial mounts (GEM) can't track indefinitely through the meridian. CCDAutoPilot provides automatic meridian crossing detection and supports a number of setup options to maximize imaging near and through the meridian so that as little time is lost as possible. There is also an option to terminate imaging at the meridian if that is your desire.

4.3 Target Selection via TheSky

If you are imaging a single target per night, it is best to time your data so that important data occurs near the meridian since you look through the lowest air mass and atmospheric stability will have the least impact on resolution. One way to assess seeing, the stability of the atmosphere is to visually look at stars from the zenith to lower in altitude. If you have a reasonably good night, you will see minimal twinkling at the zenith but as you go lower in altitude, the twinkling will begin to appear. A good night might show twinkling at 45° or so. If you see twinkling at the zenith, you have a poor night and that might make a good night for acquiring binned data.

Multiple Targets

One way to minimize atmospherics is to take multiple targets with differing transit times over multiple nights. Using this approach, you can time each target's data to be close to the meridian crossing. Of course, this requires a reasonable run of clear nights and may not be appropriate for all locations.

Target Location

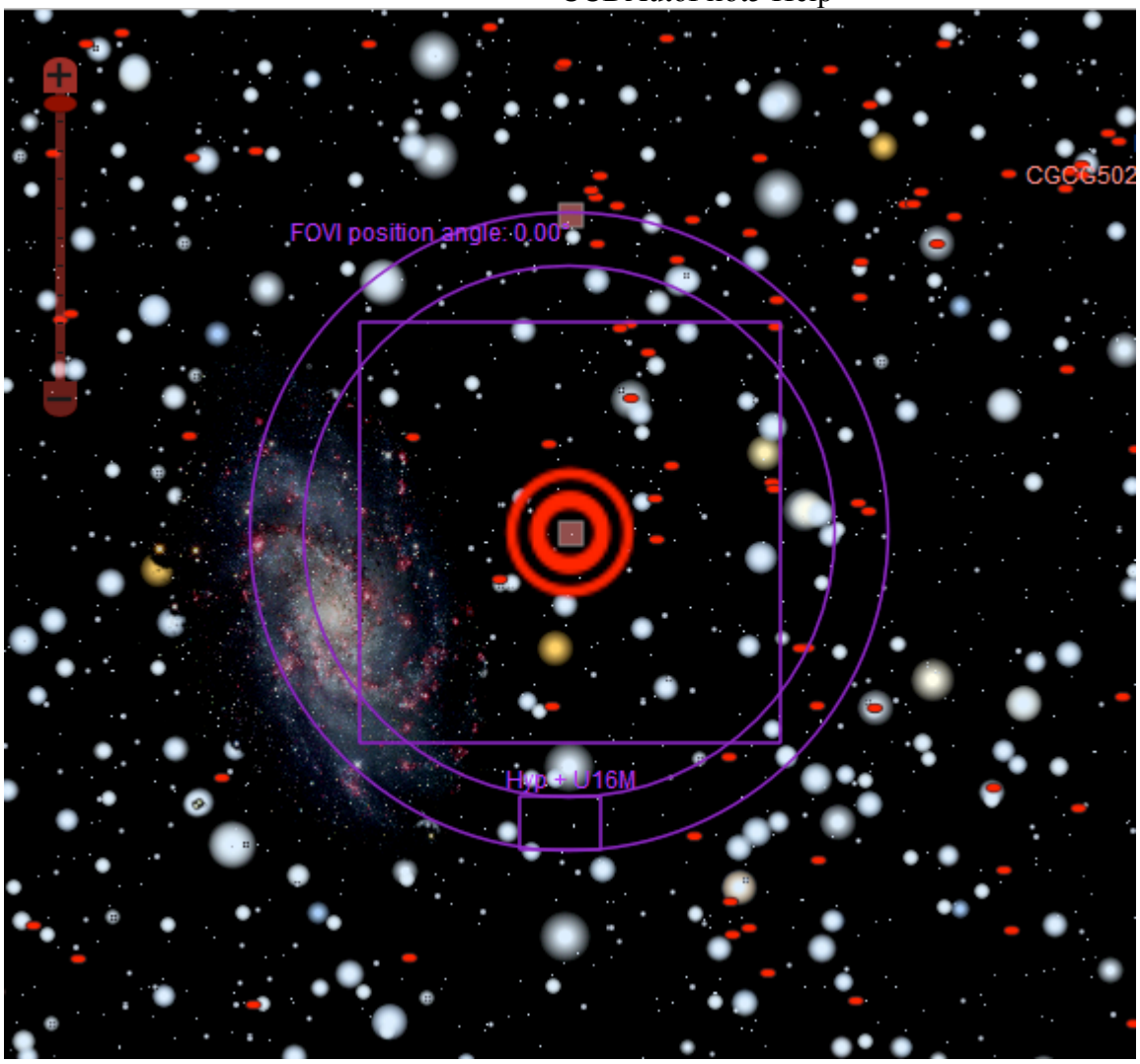
Ultimately, target location has to consist of Right Ascension (RA), Declination (Dec) and Position Angle (PA). This defines a position in the sky and a rotation of the camera. RA and Dec are to be given in J2000 equinox data for consistency. Any precession to the current equinox is handled by CCDAutoPilot. Once the target coordinates are defined, they can be entered into CCDAutoPilot via a number of techniques. See the Targets(See 8.12) page command summary for details.

If you have TheSky6 or TheSkyX, a nice way to enter target coordinates is via the Field of View Indicator (FOVI). Here are the steps to do that. TheSkyX is being used for the screen shots but the technique is applicable to both TheSky6 and TheSkyX.

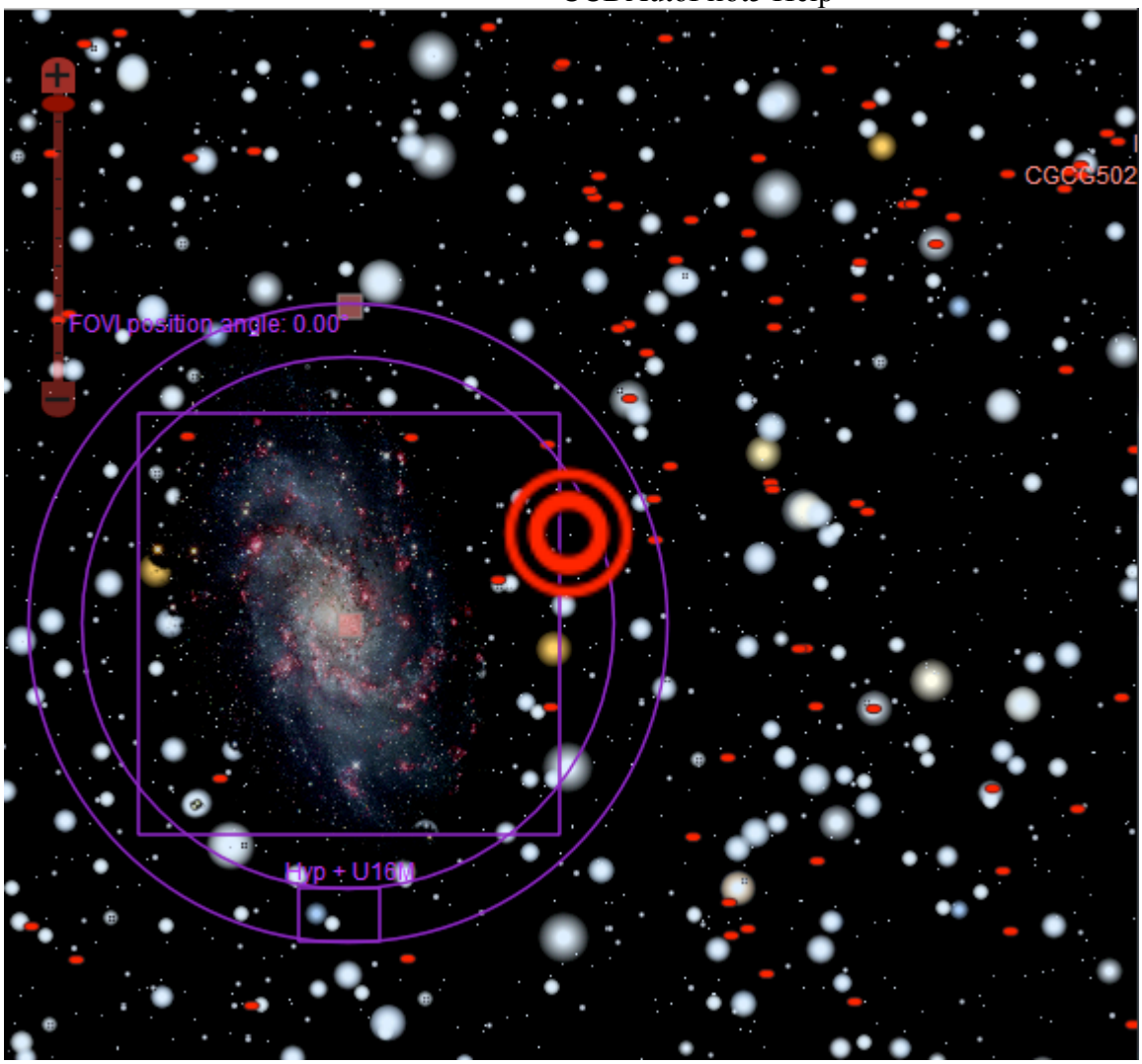
Target Selection via TheSky

By combining the power of CCDAutoPilot and TheSky6, target planning an acquisition becomes immensely easier. No more image links or plate solving or trial and error. All that is required is TheSky and an accurate Field Of View Indicator (FOVI). All that is needed is to orient the FOVI appropriate to your situation and use a precision slew to target as part of your session. The coordinates will be precisely arrived at by the mount and, if you have a rotator, it will rotate to the appropriate position angle (PA) automatically. Here is an example.

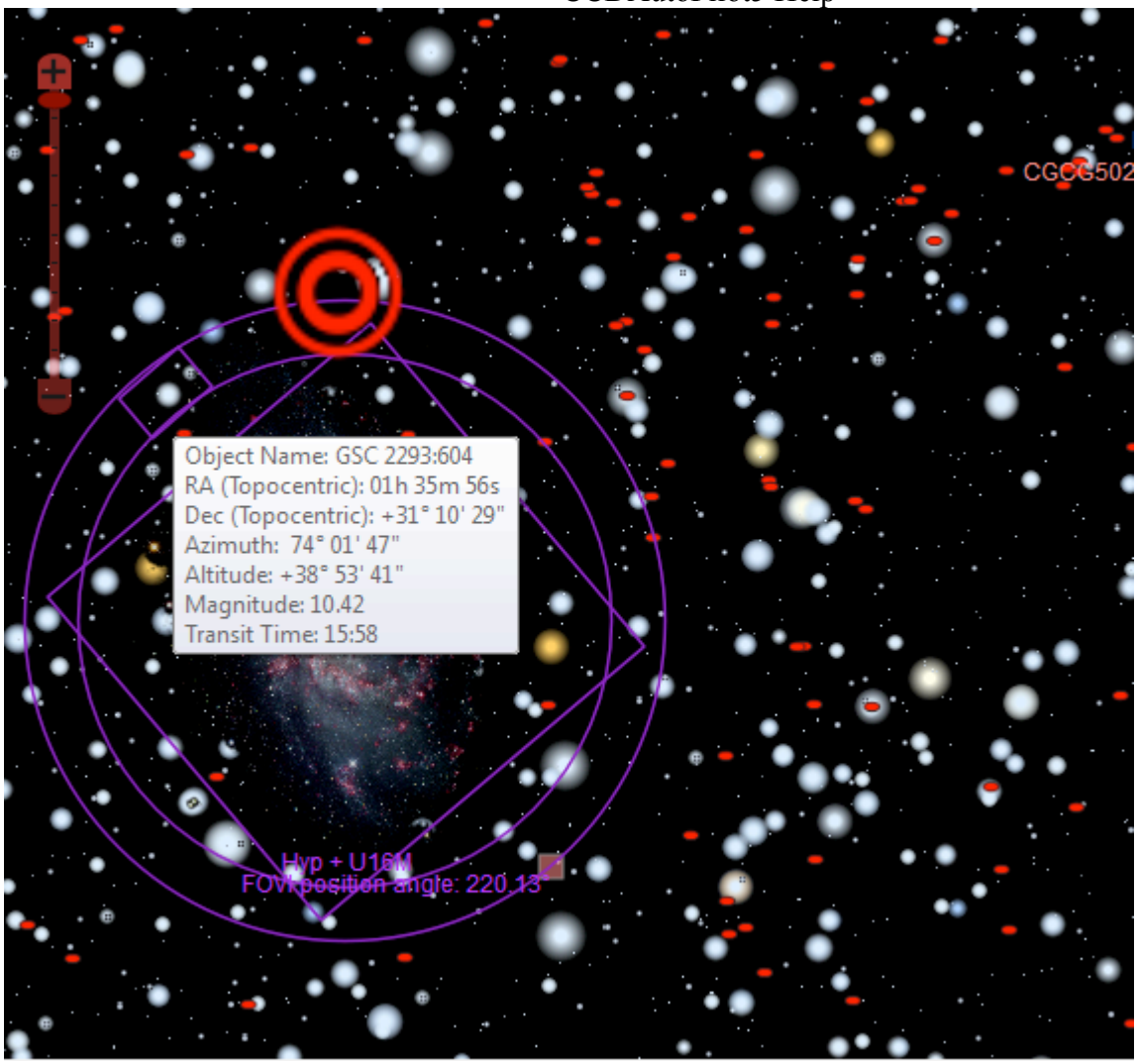
Assume you want to image M33. Here is what you might see in TheSkyX:



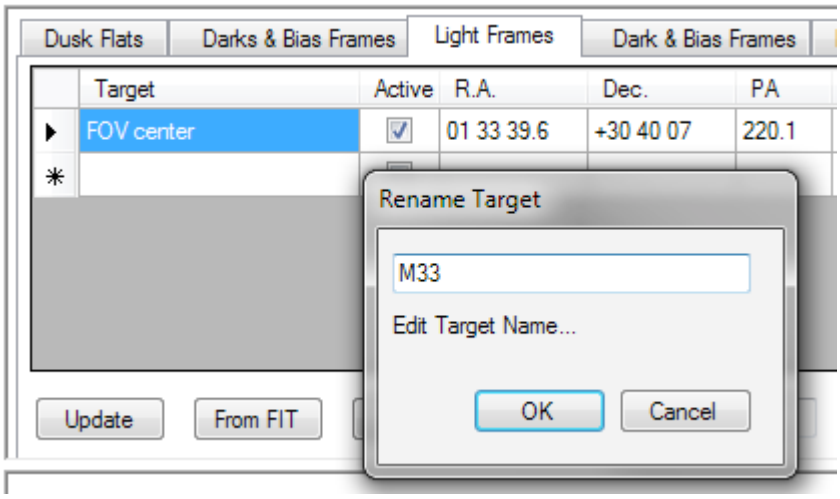
Note M33 is located the left edge of the FOVI. Note the two squares that are part of the FOVI. Clicking and dragging on the center one translates the FOVI; clicking and dragging the lower one in a circle rotates the FOVI. First I will translate the FOVI to a position that includes M57 and a guide star is somewhere between the two circles.



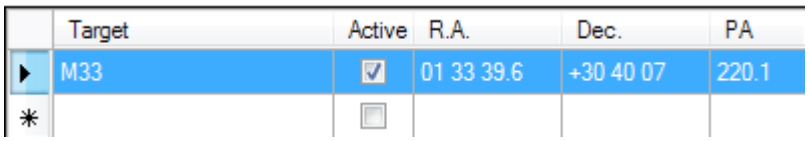
I have moved the FOVI off-center to frame M33. and there is a suitable guide star at the 11 o'clock position. I'll click on the upper square to rotate the FOVI until the guide star falls on the guider FOVI.



The guider FOVI now includes the guide star. TheSky indicates a position angle of 220.13 degrees. By hovering the cursor over the guide star, I see information about the magnitude of the guide star. This guide star is more than suitable for this image. The next step is to use this information as a target for CCDAutoPilot. With CCDAutoPIlot linked to TheSky, all that is required is to hit the Get button on the Targets page with no entry in the field. The RA and Dec of the center of the FOVI and its position angle will be automatically transferred to the Targets List as shown below.



Note the coordinate information is now in the Target list with the non-unique name "FOV Center". Double-clicking on the box with "FOV Center" brings up an edit window so you can change the target name to something more descriptive - like M33! After hitting OK on the Rename Target window, the target row now becomes:



	Target	Active	R.A.	Dec.	PA
▶	M33	☑	01 33 39.6	+30 40 07	220.1
*		☐			

I have now completely described the position of the target for CCDAutoPilot. When this target is selected for running, the telescope will slew to the target, rotate the rotator as needed to match the PA of 220.1, plate solve and adjust the telescope pointing so that it is within a few arc-sec. of the desired target. Since guider calibration is no longer necessary with the automatic calibration algorithm of CCDAutoPilot, guided imaging can now begin at this location.

This same technique can be repeated as many times as required for an evening's imaging session. You do not need to be connected to the actual telescope or camera hardware, just be connected to TheSky. You can plan an entire evening's imaging away from the telescope and, when you are later connected to your telescope and camera, focuser and rotator if used, begin imaging. You can be sure imaging will proceed as planned.

For those without a rotator...

You can use much of the same technique described above but with some modification. If you do not have a rotator, there are two choices. Either frame the target as best you can with translation only or manually rotate the camera to the desired PA, 220.1 in the above example. As long as you have initialized the system at any rotation angle, CCDAutoPilot will automatically determine the needed calibration vectors for your autoguider.

4.4 Light Frames

Light frames are the main goal of everything we are doing - this is our "data". Assuming color data is desired, we need to take data through appropriate filters if using a monochrome camera, make sure focus is maintained for each filter, be aware of the differing atmospheric extinction for each filter and properly combine the color data appropriately for the given filters and sensor quantum efficiency. CCDAutoPilot can help with all of these requirements but you must make some tactical decisions. One of the first is whether to use Staircase or Shuffle for image acquisition

Staircase Acquisition
Here you acquire data that is least impacted by atmospheric extinction at lower altitudes and that which is more impacted at higher altitudes. Red and Green data is least impacted (that is why the setting sun is yellow) and Blue and Luminance is most impacted. In a typical LRGB imaging approach, the L data provides the resolution information and the RGB provides the color information. Using the letters R, G, B, L to represent the color or clear frames, Staircase acquisition would be something like:
RRR GGG BBB LLLLLLLL BBB GGG RRR
The goal would be to center the L frames on the meridian crossing to optimize the critical luminance data. If the meridian crossing does not occur in the middle of your available dark time, you could do something like this:
BBB LLLLLLLLLLLLL BBB GGGGGG RRRRRR
One disadvantage of Staircase is of clouds roll in at some point in the evening, you might not have a complete data set from which to assemble the data. The advantage is you have an optimally acquired data set by minimizing the effect of the atmosphere as much as possible.

Shuffle Acquisition
Here, the data is acquired sequentially so that you always have enough data to assemble an image. It would look like this:
LRGB LRGB LRGB LRGB etc.
Here you have data after the first set and the longer you go, the more data, and presumably the better SNR you get. The disadvantage here is that your critical L data is at varying altitudes and therefore subject to varying atmospheric effects due to seeing and air mass. A secondary consideration is that when you determine your RGB combine ratios, the RGB data was taken at varying altitudes so atmospheric extinction correction becomes tedious.

Color Combine Ratio
Assuming you have an accurate color combine ratio measurement for your OTA/Filters/Camera, you will need to correct your data for atmospheric extinction impact on each data frame. CCDAutoPilot, Professional Edition (only), keeps track of each color frame's altitude for you. If you have previously obtained your color combine ratio either automatically via CCDAutoPilot or manually enter it, CCDAutoPilot will provide the extinction corrected color combine ratio for each target, whether you used Staircase or Shuffle Acquisition.

4.5 Calibration Frames

Calibration frames consist of dark, bias and flat frames that are used to remove various sensor and OTA defects from the data. The better job we do with calibration, the better our data is and the more we can stretch it in post-processing to reveal faint details. First, some definitions of the calibration frames:

- **Dark:** This is a frame that is exposed *with the shutter closed* for the same duration and at the same camera temperature as the light frame to which it will be applied. Needless to say, this also means for the same camera.
- **Bias:** This is a frame that is exposed *with the shutter closed* at the same temperature as any light frames to which it will be applied. The exposure duration is 0 sec. Thus a Bias frame is a 0 sec. exposure duration dark frame.
- **Flat:** This is a light frame that is exposed to capture the pixel-to-pixel sensitivity variation for a given sensor and the overall light fall-off of the OTA. It must be taken at a low enough signal level to insure linear operation.

Usage

Dark frames are **subtracted** from the light frames. This subtraction removes pattern noise, a fixed artifact of a given sensor and dark signal, a false signal that increases linearly with exposure time. To avoid adding noise to the data, an appropriate number of dark frames must be combined to make a master dark frame. This typically reduced the noise by the square root of the number of frames being combined. Based on the sensor, the camera operating temperature and exposure duration, it is possible to calculate the number of darks to be combined to reach a desired noise contribution as a percentage of total noise. CCDAutoPilot provides such a calculator on the Settings page, Tools tab.

Bias frames are handled like dark frames - they are **subtracted** from the light frame we are trying to correct. If exposure times are short enough, time-matched dark frames are not required for correction since little dark signal will accrue. Thus for short exposures, a zero-time-exposure dark frame, i.e. a bias frame, can be subtracted to remove pattern noise from the short-exposure light frame. The principal noise component of a bias frame is read noise. The noise contribution from read noise is reduced by the square root of the number of frames being combined.

Flat frames are **divided into** the light frames. Note that they are not subtracted. Mathematically, if S is the signal, F represents the loss/change in going through the sensor and OTA and L is the resultant acquired light frame, then L = F * S. since what we want is the unmodified signal S, then S = L/F. That is why the flat frame is divided into the light frame. Noise from this division behaves differently than subtraction. Noise from division combines as the reciprocal as the sum of the reciprocals. (For electrical engineers, this is like resistors in parallel.) An example may make this more clear.

Let's assume we have a camera with a gain (g) of 1.4 and have exposed a number of flats to a level of 20,000 ADU. Each flat will have a signal of 1.4 * 20,000 or 28,000e. The SNR of such a flat is the square root of the signal, 28,000 in this case, or 167. Now, let's assume we have a light frame that has a faint area SNR of 3, generally considered a minimum level of SNR for a very faint region. 1/167 + 1/3 = 0.339. 1/0.339 = 2.95. Thus, our original faint area SNR was very minimally degraded - in fact one would be hard-pressed to measure the degradation! If we combine 4 flats, we get a SNR of 334. The resultant impact on our faint area SNR is to reduce it to 2.97. Where flat SNR becomes important is on high SNR areas, areas of bright signal. Assume we have a galaxy core that is 8000 ADU. Its SNR, using the above discussion, is 106. Our 4 flats would reduce this SNR to 80. This is a more significant issue but may or may not impact the appearance of the resultant processed image.

One occasionally hears you need "a million electrons" of flats. Let's see what that means. In the above flat example, this would correspond to 1,000,000/28,000 or 36 flats. Properly combined, our master flat would have an SNR of

167*6 or 1000. The impact on our faint area SNR is 2.99 and our galaxy core is 95.8. Clearly more flats are better but how much is enough? That is left to you to determine. I suspect for aesthetic imaging, 4 flats are more than sufficient but for scientific purposes, i.e. milli-mag photometry, more are required.

To maximize flat frame signal-to-noise ratio, the target ADU exposure should be as high as possible while staying within the linear range of the CCD. CCDAutoPilot has a wizard(See 8.14.7) to help you determine that target ADU.

Acquisition

A "suitable number" of dark and bias frames may be taken at any time, assuming the ambient light level is low enough. Typical CCD cameras are very sensitive and not very light-tight so if care is not taken, the dark frames might have a gradient from light leakage.

Flat frame acquisition is a subject of much debate, discussion and opinion, which is beyond the scope of this discussion. There are basically two types of flats - sky flats and artificial flats.

Sky flats are taken at twilight with the telescope pointing to a specific area in the sky that has a minimum light gradient. The gradient is a function of the FOV of the imaging system, the larger the FOV, the larger the gradient. Also, during twilight, the sky brightness is constantly changing so exposure times must be adjusted to maintain a desired signal level. Lastly, since there is a limited amount of twilight available, both the number of flats and the filter sequence must be optimized to get the needed flats. Further, if you use a rotator to acquire data on both sides of the meridian, you need to determine whether your OTA's light fall-off or vignetting is sufficiently symmetrical after rotation or not. If not, you'll need to take flats at both rotations, i.e. PA's. The number of flats is generally limited by exposure and download times as well. So there is a lot that needs to be considered. While experimentation on the number of flats that can be acquired during twilight is required, all of the other considerations are provided automatically by CCDAutoPilot.

Artificial flats are taken with the telescope pointing to a uniformly illuminated light source. The design and performance of such an artificial source is challenging. Such flats can be taken at the end of the evening while the environment is still dark. Here there is less of a limitation on the number of flats to be acquired since the light source can be on as long as necessary.

References

For more details, background and analysis, the interested reader may want to review my papers on various image acquisition topics.

4.6 Introduction to Automation

Observatory automation is the process of allowing an executive program to control the various programs that themselves interact with your hardware. For example, when using your camera control program to take an image, you set exposure parameters such as what filter to use, what binning to use, how long to expose and click on an Expose button. The camera control program is the interface between you and the hardware.

There may be different layers of software between the camera control program and the physical camera. There is typically a software layer provided by the camera control program, another software layer or driver between that and the physical hardware and perhaps even firmware in the camera itself. All of these layers must be working properly for your clicking on the Expose button to work. So it is with CCDAutoPilot. It communicates with the various programs through the Microsoft Common Object Model (COM) interface. This is a Microsoft standard method of inter-program communications that has been basic to Windows for decades. In this environment, your camera control program might be called a "server" and you pushing the button is a "client". When CCDAutoPilot takes over, it is the client.

Now, just as two astronomers pushing buttons on the same camera control program would not expect good results, so too when CCDAutoPilot is controlling an application, it is best to not disturb the server application. Even though you might not see anything at the user interface (UI) level, there is most likely things going on under the hood.

Extend this concept from camera servers to include telescopes servers, focus servers, rotator servers, plate solve servers, dome servers and weather servers and you can quickly see there is a lot of complex sequencing that is going

on. Thus the best thing to do when an automated session is underway, is to not disturb the PC. Depending on the processing capability of the PC controlling the observatory, this would include using other applications such as web browsing. If your PC is a dual processor PC or better and you have more than 1 GB of RAM, you can probably use other applications without incident - the key word being "probably". When in doubt, leave it alone.

So, keys to successful automation is insuring stable, reliable operation of all the hardware via the appropriate server program with you as the client. Once that is assured, you are well on your way to successful automation.

One more essential ingredient to automation - plate solving. Plate solving is a term for taking an image of a bunch of stars and determining the coordinates of that image, coordinates being Right Ascension, Declination and Position Angle. A plate solving routine may or may not need a starting set of RA and Dec coordinates to successfully determine the center coordinates. The stars in the image are identified by the software and compared to a defined star catalog. Knowing the "plate scale" (generally the unbinned image scale multiplied by the binning) and starting coordinates, the plate solving software determines the center of the image relatively quickly. Since CCDAutoPilot will be moving the telescope around the sky, it must know where the telescope is pointing very precisely and this is where plate solving comes in.

Using Precision Slew, CCDAutoPilot tells the telescope to slew to your specified target location and takes an image. A plate solve is performed, calculating the center of the image. The difference between where the telescope "thinks" it is pointing and where the plate solve determines it actually is pointing is the pointing error. CCDAutoPilot calculates this error and moves the telescope accordingly. Since a number of mount issues can conspire to make that pointing correction imprecise, another plate solve can be taken to see where the mount correction wound up and make a subsequent correction if necessary. A user-specified tolerance determines how close to be.

The keys to successful and reliable plate solving is proper choices of exposure, binning and start catalogs. See Plate Solving Notes(See 12.2) for more information on this very essential requirement for automated imaging.

Another key aspect of successful automation is properly configured and reliably wired hardware. You should review the Troubleshooting(See 12.) topic and the various sub-topics for recommendations on hardware configuration that might apply to your system.

With your "server" software working properly and reliably with you as "client" and plate solving working reliably, you are ready to hand off the detailed workings of the observatory to CCDAutoPilot, so you can do other things.

4.7 Data Organization

A large number of files can be expected over the course of an evening's imaging session. In addition to your light frames, you will have flat frames and most likely dark and bias frames. CCDAutoPilot provides a number of ways of dealing with these file names and locations.
Typically master dark frames are used and match the data frames in exposure duration, binning and cooler temperature. Master bias frames are also developed as needed. Flat frames, whether taken from the sky of an artificial light source, are generally grouped by filter, binning and perhaps the camera rotation. CCDAutoPilot can be customized to meet your work flow and desires in a number of ways.

Folders

Folders can be defined on the Settings page/File Settings tab. If all the folder names are blank, the default base folder will be:

```
(My) Documents\CCDWare\CCDAutoPilot5\Images\
```

If the folders for the other four frame types are blank, corresponding frames will be stored in:

Light frames: `(My) Documents\CCDWare\CCDAutoPilot5\Images\yyyymmdd\Data Files\`

Dark, bias and flat frames: `(My) Documents\CCDWare\CCDAutoPilot5\Images\yyyymmdd\Calibration Files\`

where yyyy = year, mm = month and dd = day.

Now, suppose I want a different base folder, say C:\Astro but I leave all the others blank. Then the corresponding folders would be:

Light Frames: `C:\Astro\yyyymmdd\Data Files\`

Dark, bias and flat frames: `C:\Astro\yyyymmdd\Calibration Files\`

Suppose I want the dark frames in one place and the flat and bias frames in another since bias frames are used most often to calibrate flat frames. Then, I leave the light frames folder blank and navigate to suitable folders for the calibration frames, such as:

Dark frames: `C:\Astro\Dark Frames\`
Bias frames: `C:\Astro\Flat Frames\`
Flat frames: `C:\Astro\Flat Frames\`

Log files are always written in a folder called `CCDAutoPilot_Logs` in the base folder.

File Names

By entering suitable file names in the description field for each series in each session phase, you can precisely customize those file names. This can get tedious. There is an easier way by taking advantage of file naming templates. These are described on the Setting page/File Settings tab, By using these templates, you can get automatic file naming very easily. Any character immediately following a '%' character defines the element that replaces the combination of the '%' character and that letter. These definitions are shown in the box immediately to the right of the File Names box.

For example, suppose you wanted the light frame file names to have the target name, file name, binning, exposure time in seconds and side of the meridian the exposure took place as part of the file name. Entering a template %t&f&b%e%s would result in a file name of:

`M33Red1X1600E.00004.fit`

But maybe you'd like to make that a little clearer. Entering %t_%f%b_%eSec_E would result in

`M33_Red1x1_600Sec_E.fit`

Maybe you'd like all the light frames to be in a folder of their target name. Entering &t\&t_%f%b_%eSec_E would result in exposures for M33 going into an M33 folder with file names like `M33_Red1x1_600Sec_E.fit` and exposures for M32 going into an M32 folder with file names like `M32_Red1x1_600sec_E.fit`. Note that the proper folder delimiter for Windows is the backslash, '\'.

You can experiment with these file templates and see what the name would look like simply by hovering the mouse over the file name template box.

The starting sequence is an arbitrary serial number for each exposure and is indexed by one as each exposure is saved. In certain rare conditions, you may want to avoid the serial number. Entering %n in the template structure will do that but you will overwrite each file with the subsequent one. You will be warned in this instance. Lastly, you can set the extension to be fit, FIT, fits or any variant that is compatible with your processing system.

By way of example, assuming the folders are defined as above. Here is what some full file names would be

Light frames: %t\%f%b_%m%dM_%e : `C:\Astro\M33\Red1x1_10m_235E.0001.fit`

Dark Frames: %mM\%c%i%b_%mM would be `C:\Astro\Dark Frames\10M\-35Dark1x1_10M.0002.fit` (all my dark frames of a given exposure are in the same folder.)

Bias Frames: %c%e%b would be `C:\Astro\Flat Frames\-35Bias1x1.003.fit`

Flat Frames: %f%b_%d%r would be `C:\Astro\Flat Frames\Red1x1_235PAEast.fit` (This way I can match up the flats with the light frames for position angle and side of meridian.

By experimenting with various templates and folders, you can customize your file names pretty much any way you would like with minimal effort.

4.8 Goals and Measurements

We normally plan an imaging session with an idea of the number of sub-exposures we want through each filter for a given target. At the end of the session, the sub-frames are examined and those with poor guiding, excessive star sizes (Full Width Half Maximum or FWHM) are rejected. We then note how many good ones we have and how many we need to pick up the next night.

CCDAutoPilot, working in concert with other programs, can help establish goals, measure sub-exposures *on the fly* as they are taken and either record them as successful frames or move them to a specified folder for later evaluation. When setting up a session for a given target for the first time, you can enter the number of exposures as your goal. As the session runs and each frame is evaluated, the number of frames meeting your goal is maintained. At the end of the session, you can transfer the difference between the goal count and the good count as the goal for the next session.

4.9 Enhanced Automation

By checking Abort Darks for Light Frames(See 8.6.2), the time between civil dusk and the first target start time can be used to accumulate dark and bias frames. One possible way to acquire darks is by selecting a number of series with one or more dark or bias frames. That way you will get a number of each before the first targets start time. You can do something similar for the dark and bias phase after light frames. When Abort Light and Dark Frames at Dawn is checked, the dark/bias frame series will be aborted when it is time for dawn flats. These two options can take advantage of all available time to get calibration frames if desired.

By checking AutoRun(See 8.2), CCDAutoPilot will start automatically after a 5 second delay, link to all specified software and immediately begin to run a session. For best results, the Session Start time should be defined by checking Begin Session Relative to Sunset. This can lead to a true Auto Start operation if your hardware and software responds properly. For example, Maxim will load and connect to the camera, FocusMax will load and connect to the focuser, TheSkyX will load (but not connect to the telescope until it needs to slew the telescope), and any other programs will load and link to their hardware if possible. AutoRun can be enabled by either double-clicking on the CCDAutoPilot icon or double-clicking on a CCDAutoPilot System Profile or shortcut. If a shortcut to either CCDAutoPilot or a System Profile is placed in the Windows Startup folder, the session will start when the PC is powered up! By including a suitable windows command called shutdown either directly or in a command file called by Run 8, the PC will shut down at the end of the session. When AutoRun is checked and CCDAutoPilot is started, the AutoRun can be aborted by unchecking AutoRun within the first 5 seconds of starting.

By checking Loop Session(See 8.6.1), CCDAutoPilot can be configured to run continuously. It will start at the Begin Session Time you specify, run through all the session phases of calibration frames before light frames, light frames, calibration frames after light frames and handle any dome/roof openings, cooler warm-up's that you specify. If adverse weather conditions occur, the session will conclude for that evening, and be ready to start the next night. See the warning about weather conditions.

This can be used in a couple of ways. When Auto Date Correc(See 8.6.1)t is checked, the same target(s) will be run night after night, with the start date(s) adjusted if the dates before adjustment are in the past. Future dates will not be affected. Be aware that the start time(s) will not be adjusted so that eventually your starting altitude will get lower as the days progress. Even when running manually, Auto Date Correct eliminates the tedium of having to correct starting dates in the target list.

CCDAutoPilot is now more tightly integrated with **CCDNavigator (version 3.0.14 or later)**. When the path(See 8.14.5) to a CCDNavigator session plan is specified, CCDAutoPilot will check that folder for a session plan whose date corresponds to the current date approximately 2 hours before sunset. If such a plan exists, it will be automatically imported and run at the appropriate time. If any targets other than those specified in the session plan are active, they will be automatically unchecked. If any targets have the same name as the session plan, their coordinates, session plans, etc. will be updated automatically to conform to the CCDNavigator session plan. By entering a number of

session plans for different dates, multiple target acquisition plans can be entered at one time and CCDAutoPilot will choose the session plan with the current date.

This is a very powerful partnership between CCDNavigator and CCDAutoPilot that can change your imaging paradigm from ad-hoc target selection to advanced seasonal planning. By previewing and choosing targets of interest in CCDNavigator and deciding how you want to image them, CCDAutoPilot will be informed each evening with the targets in your seasonal plan that are available tonight and instructed to capture only the number of images needed to achieve your goals for these targets. This lets you optimize your imaging opportunities and never inadvertently pass on a chance to capture data for targets you want, regardless of the season in which you are imaging.

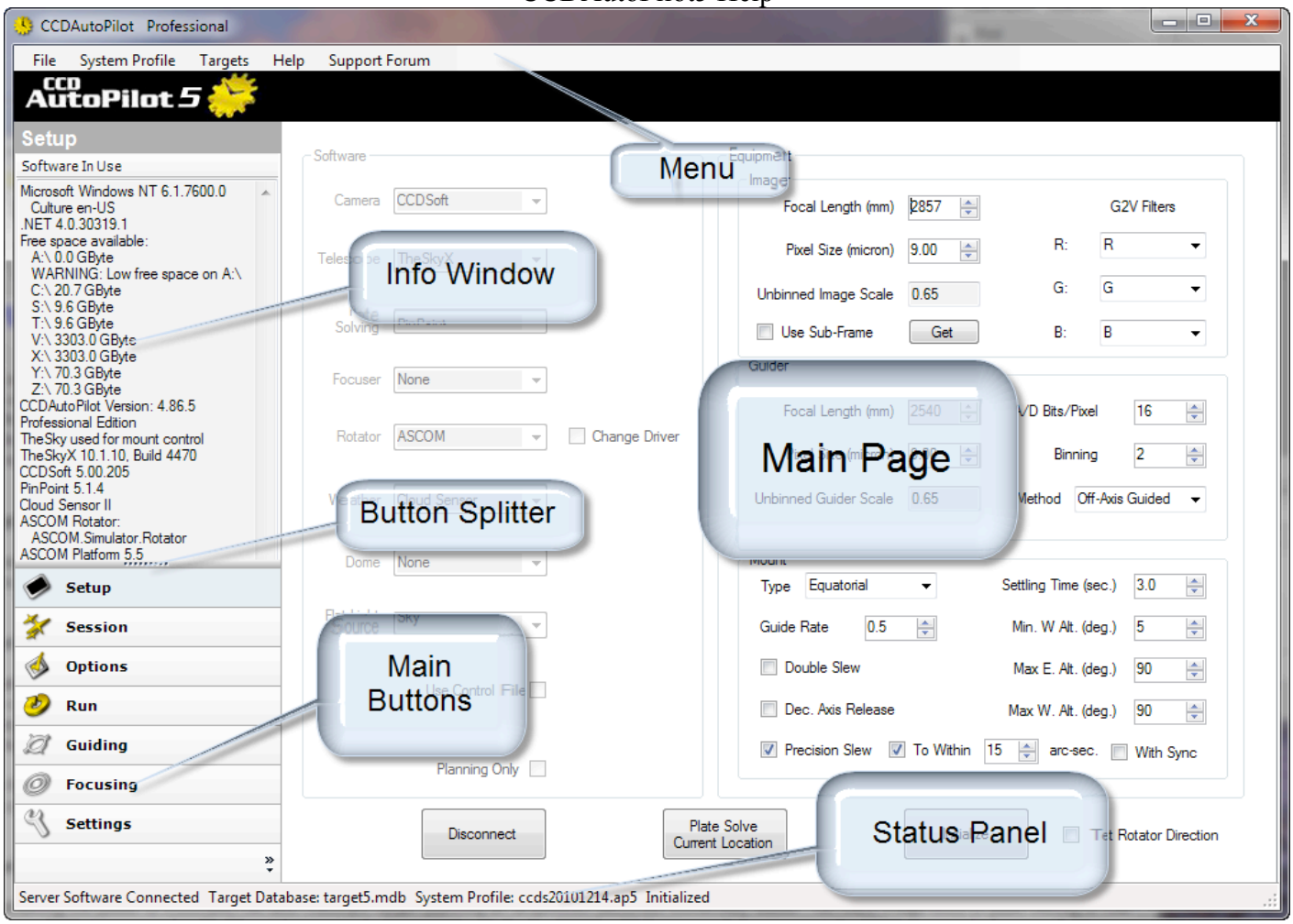
When a CCDNavigator session plan is successfully concluded, the session results are placed in a specific folder. When CCDNavigator is next started, the results are imported into CCDNavigator to aid in planning a subsequent session to meet the desired goals. See CCDNavigator Help for details. The CCDNavigator goals/results database is separate from that maintained in CCDAutoPilot.

If the session path is specified, using the CCDAutoPilot menu Target/Import/From CCDNavigator will automatically import the current session plan. If the path is empty, the normal windows navigation window will be presented. (To clear the session path, simply click on the navigation button,  and then hit Cancel on the windows navigation window.)

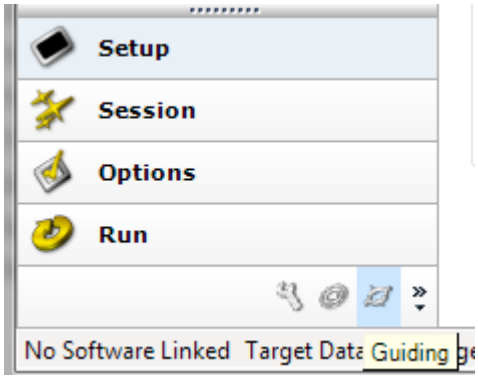
5. The User Interface

6. User Interface

CCDAutoPilot's user friendly interface is continued and enhanced in version 5. This overview will give the general organization of the interface. The rest of the command summary will give details for each command by page or menu. Here is a view of the opening window.

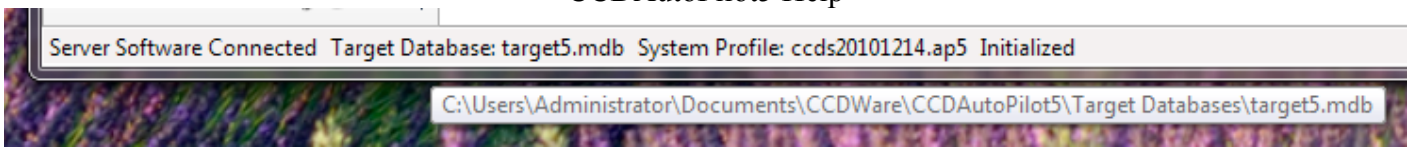


The Main Page has the controls used for a given Main Button selection. The lower buttons may be hidden by clicking on and moving the button splitter vertically. For example, once the Focusing, Guiding and Preference settings are established for your system, they can be hidden in the tray at the bottom like this:

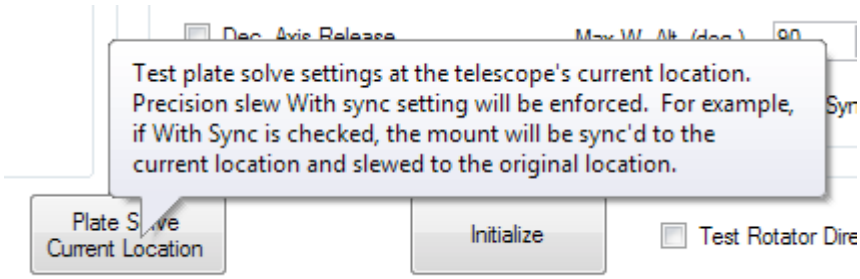


The controls are still there, just minimized to the button tray at the bottom.

The main buttons at the lower left bring up the corresponding main page and info window. There is a status panel at the bottom of the main page that has four panes. The first shows the connection status, the second the target list in use, the third the system profile in use and the fourth shows status of any activity initiated from the user interface. Hovering the mouse over the Target Database or System Profile will bring up the complete path to the file in question. For example, hovering the mouse over the Target Database shows this:



There are a number of aids to operation. With most settings, hovering the mouse over a given control (checkbox, entry field, button, etc.) will give some tips on its use and application. From any page, hitting F1 on the keyboard will bring up the command summary help file topic for that page. Where a given field entry might be long (status panel at the bottom of the window, paths, command files, etc., hovering the mouse will show the full field. Items that are grayed out are not usable. Hovering the mouse over many of the controls will display a "tip" giving some hints on that controls use. It takes around a half-second with the mouse till for the tip to appear. Here is an example:



CCDAutoPilot uses a number key files, the system profile, the target database, the session log and the control file.

System Profile

The system profile represents the settings you would use from night to night for consistent operation of your imaging system. This includes not only all the settings on all the pages but includes the selected control programs on the settings page. You can have multiple system profiles if you have multiple camera/OTA systems. The system profiles end in .ap5 and are registered to Windows. Double-clicking on a system profile will start CCDAutoPilot with that system profile loaded. Any control programs that are not loaded will be started.

Target Database

New in version 5, the target database is a relational database that maintains referential integrity. What this means is it is very unlikely the database can be corrupted. It also allows on-the-fly session editing. The target database stores all target information and session exposure information as described on the Session page. This allows you to plan your sessions days, weeks, months or for a whole year at one time. You can either add targets to the target database on your planning computer, if different from your observatory computer or network into your observatory computer and add session planning information directly. A session plan must have at least one target to take any light frames. With the basic edition, one and only one target can be entered and used.

Session Log

The session log is a detailed log with time stamping of nearly every event, command and response between CCDAutoPilot and the various servers. It is essential for troubleshooting and contains much useful information concerning your session. It is written to a CCDAutoPilot_Logs folder off the Base Folder directory. If you haven't changed it on the Preferences/File Setting tab, the log will be located in
`(My) Documents\CCDWare\CCDAutoPilot5\Images\CCDAutoPilot_Logs\`
The file name will be
ccdapyyyyMMdd_HHmmss.log where yyyy = year, MM = month, dd = day, HH = hour, mm = minute and ss = seconds of the start of the session.

RunOnError.vbs

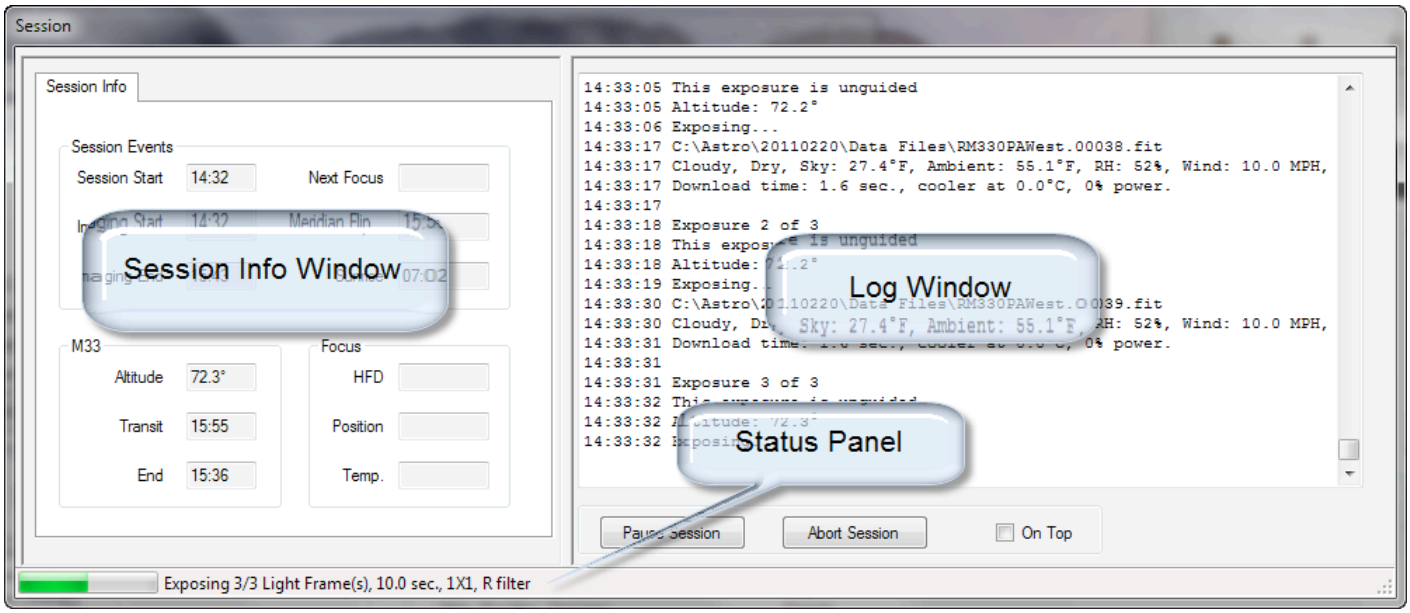
In the event of a program error, RunOnError.vbs(See 12.1) is executed.

Control File *(Professional Edition Feature)*

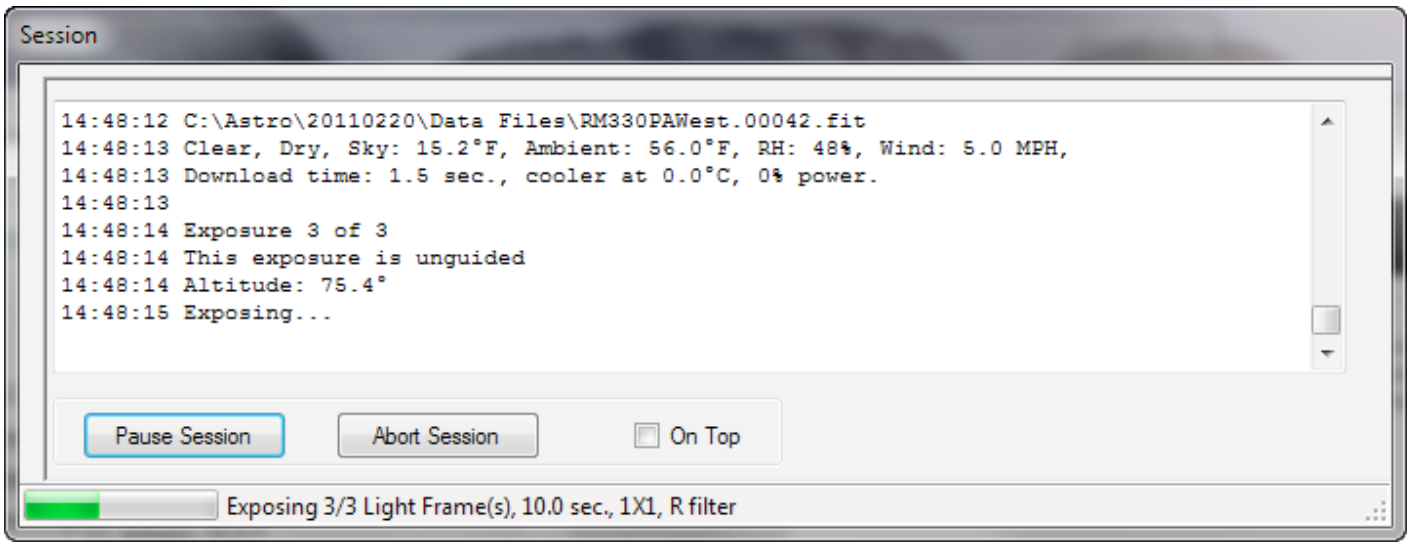
The control file provides external control and configuration of CCDAutoPilot. By use of the Control File Editor, various notification configurations can be defined. An external program can write to the control file to control session execution, notifications and

6.1 Session Window

The Session Window comes up the first time a session is run.



The Session Info Window shows key events for the session in progress. The Log Window shows detailed information on the various actions taking place. The Status Panel shows the highlights of current events as well as the progress for a given series, the exposure etc. Clicking on and dragging the Splitter Bar allows customization of the size and composition of the Session Window. Here is another arrangement that minimizes screen real estate by dragging the splitter bar and resizing the window:



Here the Session Info Window has been minimized by dragging the splitter bar to the left and the overall window has been reduced to show only the Log Window and Status Panel.

You can customize the Session window to fit the way you like to work.

6.2 Concurrent Session Editing

In the desire to get a session started quickly, some critical settings for the latter part of the session may be forgotten or needed to be changed. The Warning area on the Run page highlights the more common missed settings that can impact a session but given the many settings and options, it is understandable that some can be missed. With the new structure of CCDAutoPilot Version 5, this is easily accommodated. In general almost any setting on the main window can be changed while a session is running. Of course this excludes items on the Setup page.

Making changes should in general be while an exposure is in process. This might include settings that might impact another session phase, such as flat settings, Data Assessment criteria, Notifications, etc. If you are making changes that may impact the session exposures, such as changing the number of exposures for a series or adding a target, it is a good idea to pause the session, make your changes and then resume the session. Make sure you use the Update button for whatever session phase(s) you change. There is no need to abort a session and restart it.

Edits not Recommended On-the-fly

Here is a brief list of edits not to make while a session is running. It is not exhaustive but should be illustrative of what not to do. In general, if the edit being contemplated is not currently in process, you can make the change. When in doubt, pause the session first.

- Don't change anything on the Setup page.

- Don't change the order of targets. Changing series settings for a given target is ok while the session is paused.

- Don't change Focusing settings while focusing is in process. Pause the session first.

- Don't change Focus Offset settings unless the session is pause

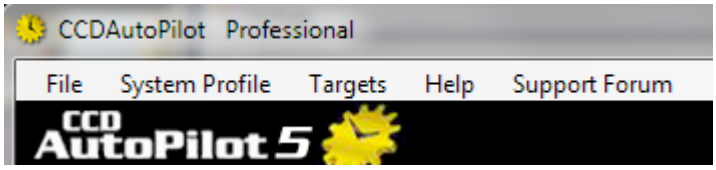
- Don't change anything on the Guiding page that is active, e.g. during a light frame exposure. Pause the session first.

7. Command Summary

8. Command Summary

This section is organized by Pages selected by the Main Buttons on the left. Following are the menu choices off the main window.

Menu Choices



File

- **Exit** exits the program. The size and position of both the main window and the session window, if open, are saved upon exit.

System Profile

- **Load** provides navigation to load another system profile.
- **Save** saves the current system profile along with any changes that have been made since the last save.
- **Save As** allows saving the current system state as a new system profile. You will be prompted for a new system profile name.
- **New** creates a new system profile with original defaults.

Targets

The following menu items are active only when the Session page is selected and a session is not running.

- **Import From CCDNavigator Session Plan** imports target and series data from a CCDNavigator session plan if no Session Plan Path is set and no session plan is in the path for the current date.
- **Import From Target List As Text File** imports a list of targets as either comma delimited or tab delimited text file. See here(See 8.4.1) for format.
- **Import From Starry Night Pro Observing Plan** imports a list of target names and coordinates from Starry Night Pro
- **Export Targets to Text File** exports the current target name and coordinate data to either a comma delimited or tab delimited text file. See here(See 8.4.1) for format.

The following menu items are active only when the Setup page is selected and a session is not running.

- **Load Database** loads a new database.
- **Save Database As** saves the existing database to a new database. You will be prompted for a new target database name.
- **New Database loads a new empty database. Only default customized templates will be available in a new target database. Any templates you have added will be lost.**

Help

- **Help Topics loads this help file**
- **Troubleshooting Information opens the help file to the Troubleshooting topic with suggestions on where to begin.**
- **Reset: If CCDAutoPilot fails to load, selecting CCDAP5 Reset(See 10.) from the Start menu resets all key data as if CCDAutoPilot were never installed (except for the trial period status of course). Your system**

profile(s) and target list(s) are not affected. You can also access this function from Start/CCDWare/CCDAutoPilot5/CCDAutoPilot5 Reset.

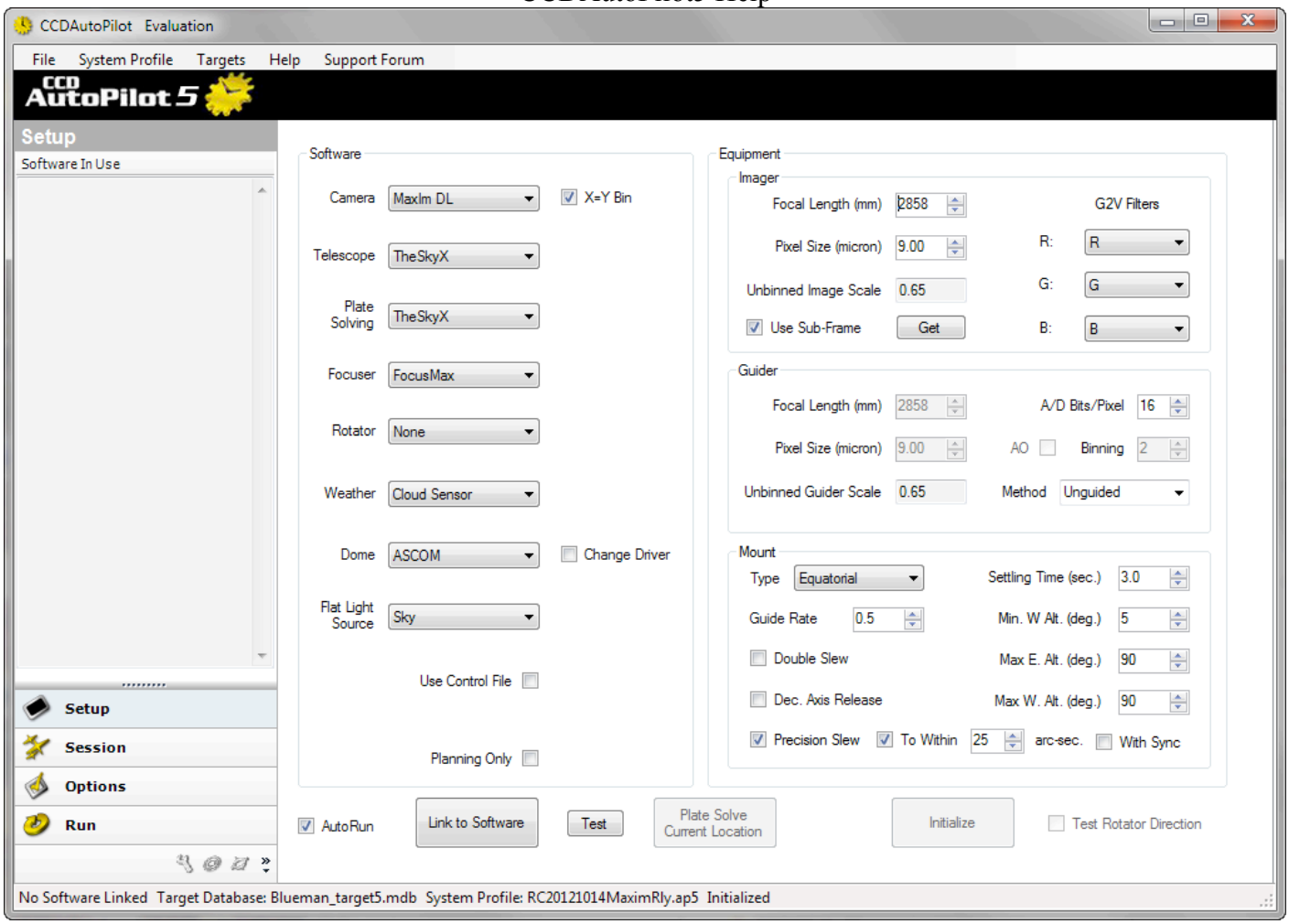
- **Trace: While the status window and the attendant log provide event logging during an active run, there are possible occasions when things don't go as expected before starting an actual session. The trace facility can be used whenever things don't seem to be "working right" before running a session. The Trace facility provides diagnostic information for this condition. When this topic is selected, CCDAutoPilot's trace facility is turned on and CCDAutoPilot closes. When CCDAutoPilot is next started, the trace facility is engaged and a trace file will be written to `(My) Documents\CCDWare\CCDAutoPilot5\`. A new file is written each time CCDAutoPilot is started. The file has a file name of `Trace<yyyymmdd>_<HHmmss>.log` and will record any error messages. When Trace is enabled, all plate solving images ("Sync_Image") are saved, whether successful or not. Trace being on is indicated by a check next to the Help menu selection. To turn Trace off, select this topic again. CCDAutoPilot will close and Trace will be disabled when CCDAutoPilot is next started. Contact support for interpretation of any messages in the trace file.**
- **Get Updates From Web See Getting Updates(See 2.4)**
- **About displays version and license information.**

Support Forum provides a direct link to the CCDWare support forum. If you can't solve a problem, this is the best place to come for support.

8.1 Setup

8.2 Setup

CCDAutoPilot always opens at the Setup page. This is where you define your server software and hardware to be controlled. It is important that the information on this page be accurate and the server software be functional.



The Software and Equipment boxes will be described in subsequent topics

Link to Software: When pressed, CCDAutoPilot links to the server software as defined in the Software box. This action will attempt to launch all specified programs. If this does not happen, see Troubleshooting(See 12.). Linking to Software in Planning mode as a minimum is required for session planning. If you plan to use the From FIT function on the Session page, a suitable Plate Solve choice is also required. The linking progress is shown at the left end of the status panel. When linking is complete, the button text will change to Disconnect so that you can disconnect from the software. The info window at the left will show the software connected, as well as info about your PC and Windows environment. If you see a version reported as "9999", this means CCDAutoPilot was unable to determine the version of this particular software on its own. Make sure the application meets the minimum version requirement described here(See 2.3). This data is replicated in your log whenever a session is run.

AutoRun: When checked, CCDAutoPilot will start automatically after a 5 second delay, link to all specified software and immediately begin to run a session. When AutoRun is checked and CCDAutoPilot is started, the AutoRun can be aborted by unchecking AutoRun within the first 5 seconds of starting. See the Enhanced Automation(See 4.9) topic for suggested usage.

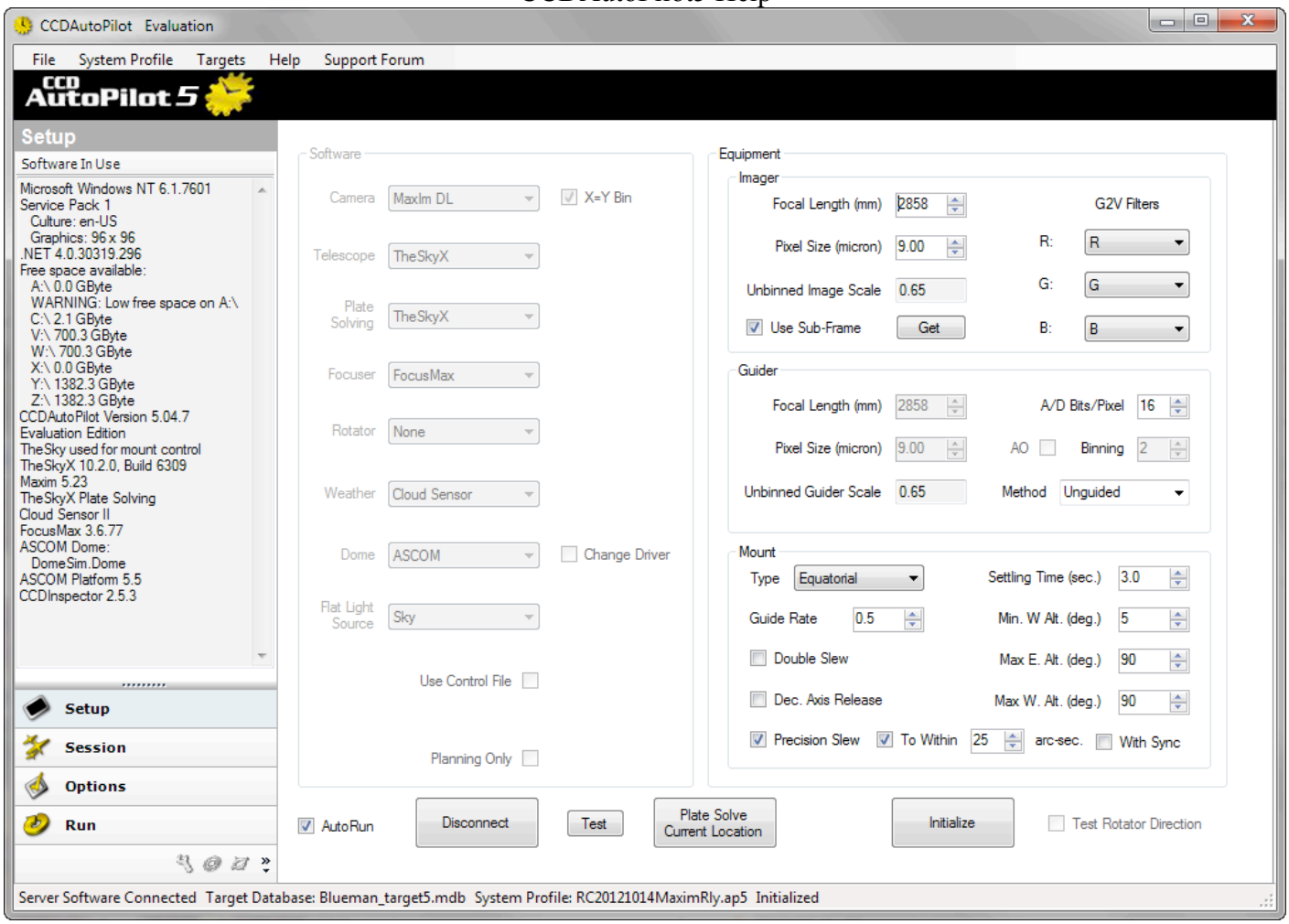


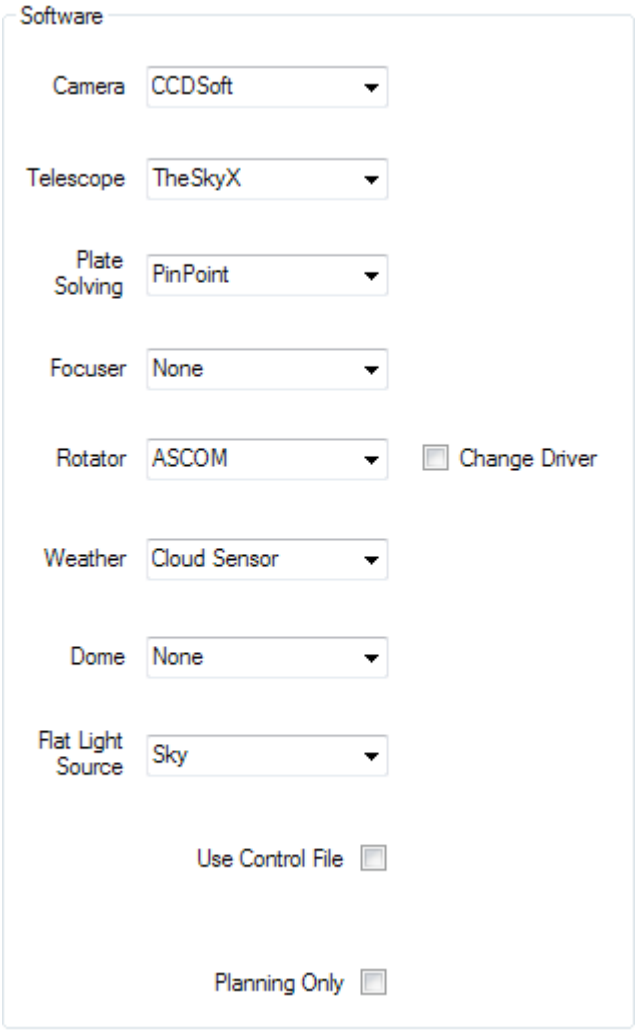
Plate Solve Current Location: is a convenient way to test plate solving. CCDAutoPilot will attempt to plate solve the current telescope location and upon your confirmation, attempt a precision slew to the solved coordinates. Since no telescope pointing is perfect, you should generally see a slight movement of the telescope upon a successful plate solve. If plate solving fails, then there will be no correcting slew and the telescope won't move. The progress is displayed in the status panel. Hint: If you like to do an initial sync at the start of a session, check With Sync in the Mount box and a sync will be performed. Don't forget to uncheck With Sync if you do not use this option as part of your mount operation.

Initialize: This starts the Initialization process. See the Initialization (See 8.2.3)topic for more details.

Test Rotator Direction: When checked, the rotator will be moved three times to insure the rotator moves in the proper direction, consistent with Position Angle. Once your rotator direction is confirmed, this box can be unchecked for faster initialization.

8.2.1 Software

Software



- **Camera:** Select from None, CCDSoft or Maxim. You have your camera program connected to your camera system at least once for CCDAutoPilot to learn your filter names and binning options. Once they are read, they are saved in the system profile for planning without connecting to the hardware. If you are using CCDSoft, make sure in CCDSoft, Camera/Server Settings that "Allow Remote Connections" is checked. If Maxim is selected, you can elect to have x and y binning be the same via the x=y bin checkbox. If it is not checked, a window will appear, giving the user a chance to enter the desired vertical binning. If None is selected, no imaging is possible.

  Maxim-specific requirements: Go to the Camera Control window, hit the Settings button to bring up the Guider Settings window. Select the Advanced tab. Under Guider Motor Control, make sure to select Do Not Change On Pier Flip. Do not check Pier Flip on the Camera Control Window/Guide tab. If you connect to your telescope in Maxim's Observatory window, be sure to uncheck Auto Scope Dec., Pier Flip and Auto Pier Flip. CCDAutoPilot manages all necessary meridian flip issues internally and allowing Maxim to make flip-related changes will most likely cause guiding problems. A telescope connection is required to use pulse guide, called "Telescope" in Maxim's Autoguider Output Control Via selection. When using the Telescope guide option, It may be helpful to check Safety Slew on the Guiding page, Meridian Flip box of CCDAutoPilot.

- **Telescope:** Select from None, ASCOM, ASCOM/TheSky6, ASCOM/TheSkyX, TheSky6, TheSkyX. Selecting ASCOM, TheSky6 or TheSkyX means those functions will be used exclusively for telescope control and planetarium functions (looking up targets, solar ephemerides, etc.). When using either version of TheSky make sure in Telescope/Setup neither Keep Crosshairs on Screen nor Impose Slew Limits as these will interfere with CCDAutoPilot operations. When using TheSky6, be sure Allow Remote Connections is checked in

Telescope/Server Settings. When using ASCOM, you will need to select an appropriate ASCOM driver for your telescope the first time. If you want to change the selection, check the Change Driver checkbox before you Link to Software. TheSkyX/Paramount users, see here(See 12.3).

- **Plate Solving:** Select from None, CCDSoft/TheSky, PinPoint, TheSkyX. Regardless of the selection, Maxim can still be used as the camera server. Due to PinPoint licensing restrictions, the full licensed version of PinPoint, not the LE version that accompanies Maxim, must be used. With CCDSoft/TheSky, whichever version of TheSky is selected for the Telescope server will be used in concert with CCDSoft. TheSkyX has a particularly robust plate solve routine - see Plate Solving Notes(See 12.2) for some suggestions. Plate solving is essential for most CCDAutoPilot features and unattended operation.

- **Focuser:** Select from None, CCDSoft @Focus2, FocusMax, Maxim. Focus routines specific to a camera server require that camera server be chosen for the camera. If you are using Maxim, you will need to set up an ASCOM hub. Use the Change Driver checkbox to select an ASCOM hub. Configure the hub to connect to your ASCOM focuser driver. In the Maxim Observatory window, hit the Options button, then Choose... to select the same ASCOM hub as selected above. This arrangement is necessary to enable Maxim to control the focuser for focusing and CCDAutoPilot to control the focuser for focus offsets and temperature compensated focusing.

- **Rotator:** Select from None, ASCOM, RCOS PIR and TAKometer. When using ASCOM, you will need to select an appropriate ASCOM driver for your rotator the first time. If you want to change the selection, check the Change Driver checkbox before you Link to Software. When using RCOS PIR or TAKometer, there respective control software can be up and running.

- **Weather:** At present, the selections are None, Cloud Sensor. When using Cloud Sensor, CCDAutoPilot will automatically determine which the Boltwood Cloud Sensor I or II TI/AAG CloudWatcher is used. You will need to set the path to the cloud sensor's Single Line Data File. This is not the log file. Consult the cloud sensor's documentation for more details.

- **Dome:** Select from ASCOM, AutomaDome or DDWCP (Digital DomeWorks Control Program or TheSkyX (X2) interface (Build 4568 or later). When using ASCOM, you will need to select an appropriate ASCOM driver for your dome the first time. If you want to change the selection, check the Change Driver checkbox before you Link to Software. When using TheSkyX (X2), select and configure the appropriate driver in TheSkyX. Set the Dome Update Interval to 500 ms.

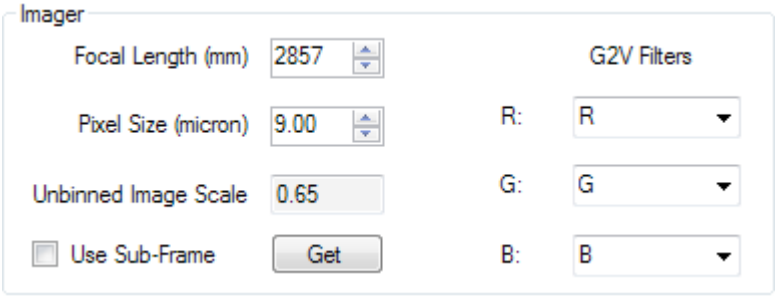
- **Flat Light Source:** Select from Sky, FlipFlat/FlatMan or Custom. Selecting Sky will use the twilight sky for flats. Selecting FlipFlat/FlatMan will use Alnitak AstroSystems' artificial light source. It is completely integrated into CCDAutoPilot and you will only need to specify the COM port used. No other program can use this COM port at the same time. Custom allows flats to be taken toward the end of the session when the scope is at the park position, assuming the park position points the telescope at a suitable artificial light source. On the Options page/Data Acquisition tab, use Run 5 to execute a script to turn on the artificial light source and Run 6 to execute a script to turn it off. On the Settings page/Flat Settings tab, set the min. and max. exposure limits so that the target ADU for each flat filter/binning can be met.

- **Use Control File:** *(Professional Edition Feature)* See the Control File Editor(See 10.1) topic for more information.

- **Planning Only:** When checked, only the planetarium side of the Telescope server is used. All other choices are disabled. This mode allows target planning either independently with TheSky or manually with ASCOM, or importing CCDNavigator plans. You are able to edit and adjust your image acquisition plan on the Session page without being connected to your observatory. You are notified of this condition in CCDAutoPilot's title bar and status panel. To exit the planning mode, Disconnect and uncheck the Plan Only checkbox

- **Sky Quality Meter: CCDAutoPilot will read the sky quality file outout by the SQM Reader by www.knightware.biz. SQM Reader can use the Unihedron SQM. The file must be placed in (My) Documents and the file name must be `SQMReadings.txt`. Any other file name or location will be ignored. When properly located, CCDAutoPilot will log the file header and most recent entry after every light frame that is saved.**

8.2.2 Equipment



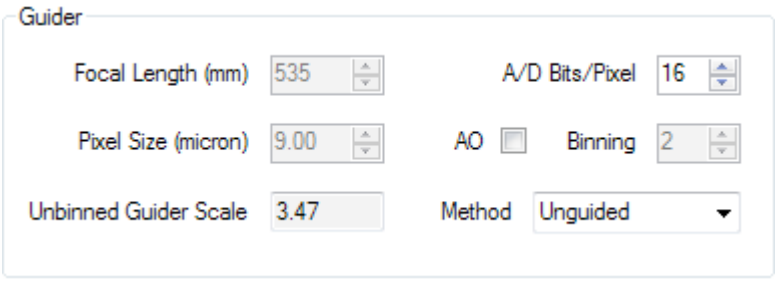
- **Focal Length (mm):** Enter the focal length of the imager scope

- **Pixel Size (micron):** Enter the pixel size of your imaging camera. Consult the guider documentation for this value.

- **Unbinned Image Scale:** Automatically calculated after the above values are entered.

- **G2V Filters:** Select the filter names corresponding to the filters you will use for G2V balance calculations.

- **Use Sub-Frame:** If you wish to use a portion of your imaging sensor for all your imaging, CCDAutoPilot will maintain your desired sensor cropping for light frames and all calibration frames, including flats. When the Sub-frame box is checked, the Get button will become active and you will be prompted through the steps to define your sub-frame. That definition will be maintained in your system profile.



Select the **Guider Method** from the following:

- **Self-Guided:** Used primarily with SBIG cameras having a built-in guide sensor.

- **Off-Axis Guided:** Select if you are using an off-axis guider such as the AstroDon MOAG series.

- G**uide Scope:** Select if you are using an external guide scope.

- **Unguided:** Select if you are not guiding.

Depending on which of the above selections are made, you will need to enter some or all of the following:

- **Focal Length (mm):** Enter the focal length of the guide scope

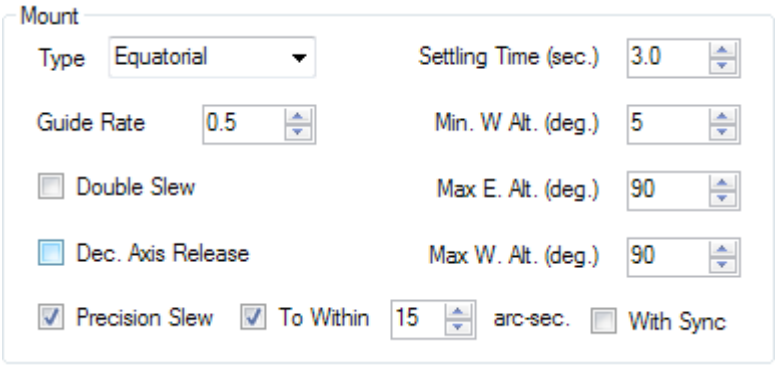
- **Pixel Size (micron):** Enter the pixel size of your guide camera. Consult the guider documentation for this value.

- **Unbinned Guide Scale:** Automatically calculated after the above values are entered.

- **A/D Bits/Pixel:** Enter a value appropriate for your guide camera. Consult the guider documentation for this value.

- **AO: When using CCDSoft, you must check this box when using an AO and uncheck it when not using an AO. The selection is automatic with Maxim.**

- **Binning: Enter the guider binning you want to use. For most users, binning of 2 or 3 is most successful.**



- **Type: Select from Equatorial and Fork. Equatorial should be chosen if the mount has to flip when crossing the meridian. This typically results in a rotation of the image plane by 180°. If this is not the case, choose Fork. If your mount supports any automatic meridian crossing logic to control guider directions or polarities, please disable it to prevent interfering with CCDAutoPilot's Predictive Guiding.**

- **Guide Rate: Enter the guide rate as a fraction of sidereal rate.**

- **Double Slew: When checked, the mount will slew to the same coordinates twice. With some mounts this can relieve belt tension and may result in better guiding.**

- **Dec. Axis Release: When checked, the mount will perform a series of dec. axis slews to relieve any stiction or binding and may improve guiding with large payloads.**

- **Precision Slew: When checked, the mount will slew to the specified target, plate solve the location, compare to the desired coordinate and make another slew to correct the position.**

- **To Within: When checked, the mount will perform a Precision Slew and, after making the correcting slew, take another plate solve and see if it is within the specified tolerance. If it is not, up to two additional correcting slews will be performed in an attempt to get within tolerance. The slew tolerance should be chosen as a reasonable value related to the Unbinned Image Scale. If the Unbinned image scale is .65 arc-sec./pixel and you want to lose no more than 30 pixels on your imaging sensor, then choose a scale of .65 x 30 or 20 arc-sec.**

- **With Sync: When checked, the mount will sync to the first plate solve and then slew to the desired coordinates. This should get the mount very close to the desired coordinates. Do not use With Sync if you are using a Tpoint model as repeated syncs into the Tpoint model will pollute the model and actually make pointing worse.**

- **Settling Time: Choose an amount appropriate for your mount to settle. For high end mounts with modest loads, this can be as little as 3 seconds; with heavier loads or less precise mounts, it can take as long as 30 sec. for the system to settle.**

- **Min. W Alt: This is the altitude at which imaging will be terminated for a given target once its altitude in the west falls below the specified value.**

- **Max. E Alt & Max W. Alt: You can set altitude limits for your mount, depending on your OTA and camera geometry and observatory walls. Setting a Min. W Altitude limit will insure your mount stops tracking before that limit. This is a nice fallback in case you miscalculate your run time. If Min. Alt is set to 0, there will be no minimum altitude limit applied. If this limit is exceeded during a target run, the light frame acquisition will cease for this target. Either the next target will be selected and acquired or the next programmed task will be executed. Max. E and Max W. Altitude limits can prevent your OTA from coming too close to your pier or tripod.**

8.2.3 Initialization

Initialization is the process by which CCDAutoPilot learns about the relationships between your imager, guider and rotator if used. It can also check your rotator direction to see if its rotation direction is consistent with CCDAutoPilot requirements. In order for initialization to be successful, the Equipment data must be accurately entered and plate solving must be functional. Initialization must be performed under the stars with the telescope, camera and if used rotator functional and linked to CCDAutoPilot. For unguided imaging, CCDAutoPilot will confirm your image scale and determine the difference between your imaging camera and the Position Angle in TheSky. If you are using a rotator, it will calibrate any rotator offset so that it can precisely move to a desired PA automatically. For guided imaging, additional data will be taken on your guider's orientation and sensitivity by doing a guider calibration. The necessary information from this process will be saved in the system profile.

Unguided Initialization
Simply point the telescope to a point in the sky above 60° altitude and hit the initialize button. CCDAutoPilot will take an image and plate solve it. You will be given an opportunity to save the data to a system profile. Please do.

Guided Initialization
Point your telescope to a point in the sky above 60° altitude. Adjust the telescope position so that a reasonably bright guide star is located in the guider's FOV. With your camera control program, choose a guide star exposure to get a good signal. Again using your camera control program, calibrate your guider, making sure the guide star stays on the guide chip throughout the calibration. Once a successful calibration is completed, you are ready to Initialize. Hit the Initialize button. CCDAutoPilot will take an image and plate solve it. It will then perform a guide calibration. Upon successful completion, you will be given an opportunity to save the data to a system profile. Please do.

Hints
Choose meaningful names for your profile. Some examples are MX080526RY, which would mean to me Maxim, May 26, 2008, camera relays used. Another might FSQCS0526DG, which would mean FSQ-106 telescope, CCDSoft, May 26, 2008, DirectGuide. Anything that helps you identify the profile afterward. Remember you can double click the profile to launch CCDAutoPilot so meaningful names are helpful.

As long as you don't disturb the relationship between your imager, guider and the sky, you don't need to initialize again. No matter where in the sky you image, any RA, Dec or PA, either side of the meridian, CCDAutoPilot will provide optimized calibration vectors to your camera control program. (These are not simple transformed guide vectors from a possibly marginal calibration; these are derived from proprietary algorithms to optimize guiding performance.)

When To Re-initialize

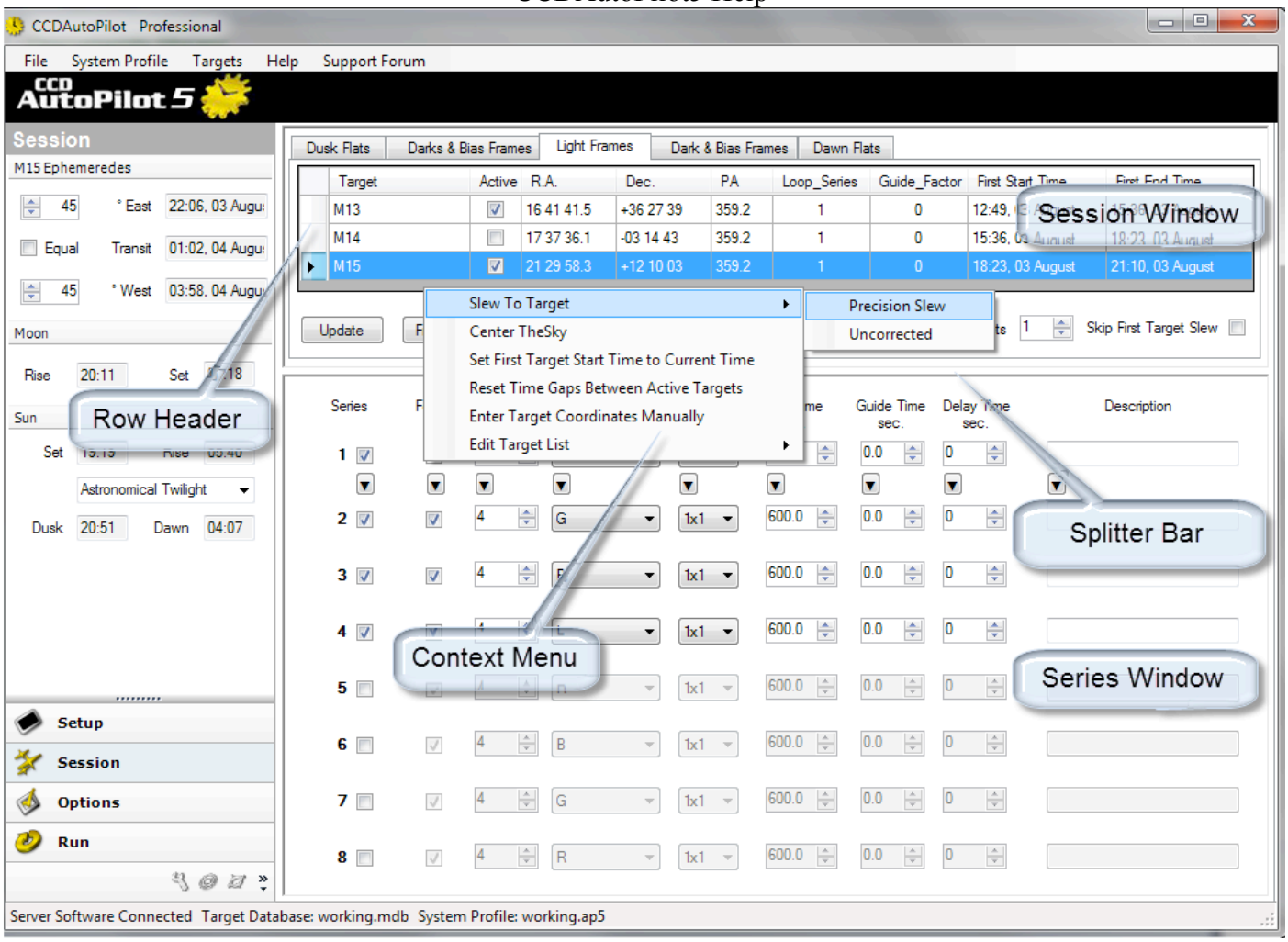
- Imaging telescope FL change, either different telescope or focal reducer
- Guide telescope FL change
- Different imager or guider
- If using a powered rotator, change to the relationship between the imaging camera and/or guiding camera to the rotator
- Change in guide method, e.g. from self-guided to Off-axis guided
- Change in guide control, e.g. from camera relays to DirectGuide or MicroGuide
- Change in guider binning
- Change in camera control program, e.g. from Maxim to CCDSoft
- Lose your home setting with the RCOS PIR

Easy Method for Initializing
This method requires TheSky6 and saves you from hunting the telescope position to get a guide star centered in the guider FOV. Read the above sections on Unguided and Guided Initialization.
1. Perform an unguided initialization. Save the profile.
2. Using the techniques outlined here(See 4.3), position TheSky's FOVI so that a suitable guide star is in the guider's FOV.
3. Slew to the FOV_Center target with precision slew checked. Once the process completes, you should have the guide star on the guide chip.
4. Run a guider calibration with your camera control program to insure the guide star stays on the chip for all movements
5. Set your guide method as desired and initialize again.

8.3 Session

8.4 Session

The Session page is a convenient all-in-one page to plan your session's data acquisition for light frames and calibration frames. There is a lot happening on this page so please review this and the following topics carefully. Since you are interacting with a database, it is important to hit the Update button before leaving a target to move to another or before change from one tab to another. Failure to do this may result in loss of part of your session plan.

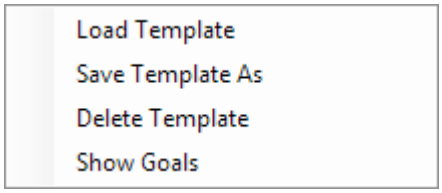


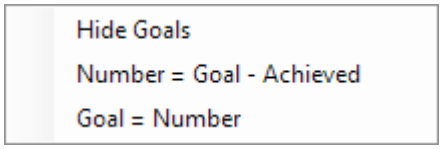
Across the top of the page, you see 5 tabs representing possible data acquisition from dusk to dawn, with dark/bias opportunities on either side of the light frames. When moving from one session phase to the other, you will see the various elapsed times updated in the Session info window. When on the Light Frames session, reference information is presented for the selected target, sun and moon ephemerides.

The top half of the page is the Target Window. Here, the targets database is shown. All entries can be edited by simply clicking on them, entering the new data and hitting the update button before moving on to the next target. Because the target name is a primary key in the database, it can only be edited by double-clicking on the target name and being up an edit window. Duplicate target names are not allowed.

Targets are selected by clicking on the Row Header for the target. Right-clicking anywhere in the Target Window brings up a context menu as shown. The function of these menu items is described in the command summary,

The Series Window allows entering the series data for the selected target. There is also a two-stage context menu, available by right-clicking anywhere in the Series Window. These are the two menus:





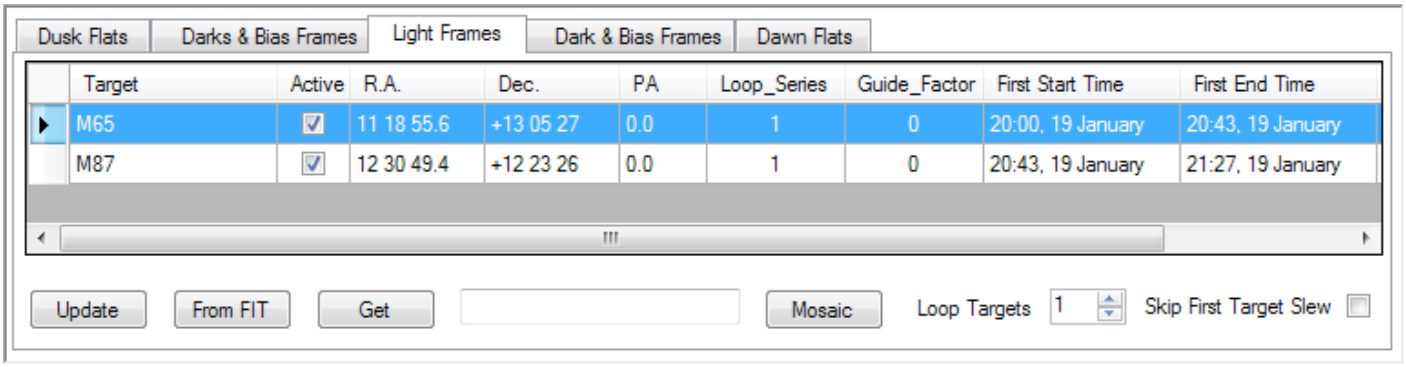
Again, the function of these context menus are discussed in the command summary.

The Splitter bar can be moved vertically by clicking on it and dragging it down. This is useful if you are dealing with a large number of targets and want to minimize scrolling.

8.4.1 Session Phases: Light Frames

When the Light Frames tab is selected at the top of the page, the data portion of the session plan is displayed. The upper half is concerned with targets and the lower half with the exposure series taken for a given target. This topic is concerned with the Target half.

Light Frames



The grid shows the target information. Column headings are:

- **Target:** A unique target name. Duplicate names in the database are not allowed.
- **Active:** When checked, the target is active and will be a part of the session plan.
- **R.A.:** The right ascension of the target, formatted in hours, minutes and seconds.
- **Dec.:** The declination of the target, formatted in signed degrees, minutes and seconds.
- **PA:** The position angle of the target, formatted in degrees.
- **Loop_Series:** Defines how many times the set of series will be repeated or looped
- **Guide_Factor:** Defines a delay that will be introduced after starting the guider and before the exposure starts. This delay is equal to the Guide_Factor times the Guide Time entered in the series. Normally this is not needed with the Automatic Guide Star Recovery(See 8.12.1).
- **First Start Time: This is the time and date that data acquisition for the target will start. This is the actual exposure start time. If scheduling between multiple targets allows, the mount will slew to the target, perform precision slew and/or focus up to 10 minutes before starting the first exposure. The mount will wait on station until the user specified start time and will start the first exposure precisely at that start time.**
- **First End Time: This is the time and data that data acquisition for the target is forecast to end.**
- **RA Rate: The RA tracking rate in arc-sec./sec. Default value is 0.**
- **Dec Rate: The Dec tracking rate in arc-sec./sec. Default value is 0.**

Note: RA Rate and Dec Rate are made visible by slewing the horizontal scroll bar in the target grid. These rates are added automatically when using the Get function for non-sidereal objects such as comets, asteroids and satellites. For example, If you enter "ISON" in the Get box and press Get and the comet database is loaded in TheSky, the coordinate data and tracking rates for ISON will be loaded into the target list. These values can also be added manually by editing the appropriate cells in the target grid.

- **Update: Updates the target database. This should be hit whenever editing is completed with one target and its associated series and before changing to another target or the edits may be lost.**

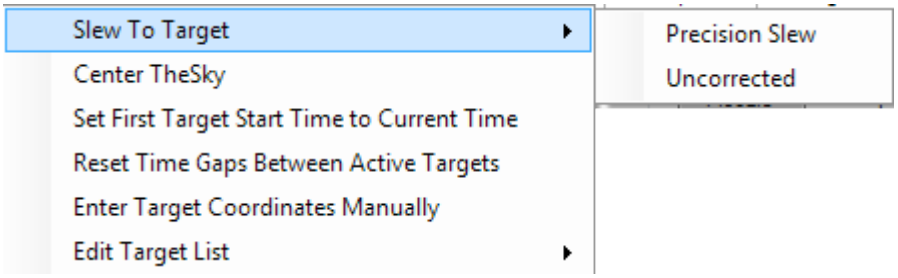
- **From FIT: Allows navigation to a fits file, plate solves it and brings the File Name and coordinate information into the target database. The target name can be edited as needed. When adding a target, you are asked for a template. Please see the Templates (See 8.4.5)topic. Once the template is entered, the Exposure Series will be populated. Be sure to hit the Update button to enter the target and series into the database.**

- **Get: Get is only functional when TheSky is used as the planetarium server. Enter a target to search for by entering its name in the space provided and hit the Get button. If it exists in TheSky6's database, the coordinates will be transferred into the Target list. If Get is hit with no entry, the RA and Dec of the FOVI's center in TheSky6 will be entered. The PA of the FOVI will also be entered. It is the FOVI center that determines the transferred coordinates, not any selected star or object. If you want to get a selected star in TheSky's window, move the FOVI over that object. This is a powerful target framing feature that is described in more detail here(See 4.3). When used in conjunction with a rotator, you can select a suitable guide star using the FOVI and CCDAutoPilot will move the scope and the rotator to those precise coordinates. When adding a target, you are asked for a template. Please see the Templates (See 8.4.5)topic. Once the template is entered, the Exposure Series will be populated. Be sure to hit the Update button to enter the target and series into the database.**

- **Mosaic: Used to create a target list from the mosaic function in TheSky (*Professional Edition only*). With the desired mosaic set up in TheSky, pressing the Mosaic button will bring them into the Target List. Each mosaic element may then be edited by using the Edit Function or Edit Button. If you are doing guided imaging, then you can move the FOV indicator as needed to locate a guide star and replace each Mosaic entry in the target list with an adjusted FOV Center, via the Get button. When adding mosaic elements, you are asked for a template. Please see the Templates (See 8.4.5)topic. Once the template is entered, the Exposure Series will be populated. Be sure to hit the Update button to enter the target and series into the database.**
- **Loop Targets: Defines how many times the list of targets will be repeated in the order given.**
- **Skip First Target Slew: If checked, no precision slew is made to the first target the first time.**

Context (Right-Click) Menu

Right clicking anywhere in this section of the Session page brings up this context menu:



- **Slew to Target: Causes the telescope to slew to the coordinates of the highlighted target. The slew can be chosen to be either a precision slew, as defined on the Setup page or a simple, uncorrected slew.**

- **Center TheSky: When TheSky is used as the planetarium program, this will cause TheSky's star chart to be centered on the target coordinates.**

- **Set First Target Start Time to Current Time: Sets the first target start time to the current time, leaving all other times unchanged.**

- **Reset Time Gaps Between Active Targets: Removes any time gaps between active targets so that the next target starts right after the preceding active target.**

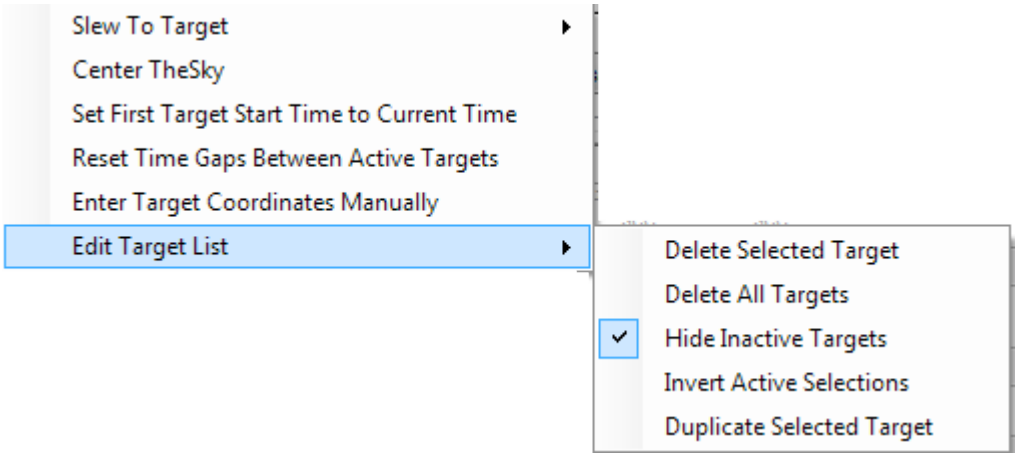
- **Enter Target Coordinates Manually: This will open a window in which you can enter the target name and coordinates manually.**

The target name must be unique. RA, Dec. and PA must be in the proper format and can not be blank:

RA: hh<space>mm<space>ss<decimal>s, eg. 12 34 56.7
Dec: <sign>dd<space>mm<space>ss, eg -12 34 56
PA: dd<decimal<d>, e.g. 12.3

When you enter one field, use the Tab key to move to the next. You can exit the target entry mode at any time by hitting the ESCape key on the keyboard. After the PA is properly entered, the Tab or Return key will complete the target entry. When adding a target, you are asked for a template. Please see the Templates (See 8.4.5)topic. Once the template is entered, the Exposure Series will be populated. Be sure to hit the Update button to enter the target and series into the database.

- **Edit Target List brings up a sub-menu with the following options:**



- **Delete Selected Target: Deletes the highlighted target. The target can also be deleted by hitting the Delete key on the keyboard.**

- **Delete All Targets: Deletes all targets in the database.**

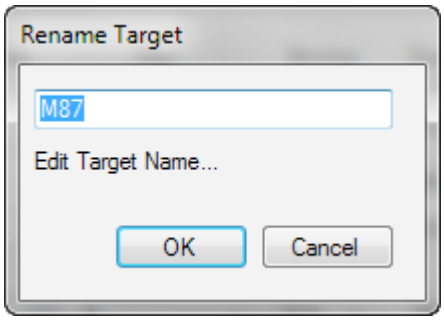
- **Hide Inactive Targets: Toggles whether or not to hide inactive targets. When checked, inactive targets are hidden; when not checked, inactive targets are visible.**

- **Invert Active Selections: It a target is active, it is made inactive; if a target is inactive, it is made active.**

- **Duplicate Selected Target: This duplicates the highlighted target. You must rename the duplicate and then select the appropriate template to complete the duplicate target addition.**

Editing Targets

The Target name can be edited by double-clicking on the target name field. This will bring up the target edit window.

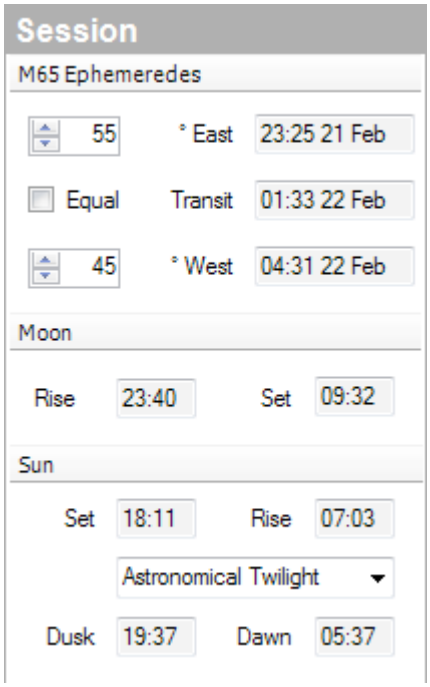


Enter the desired target name. CCDAutoPilot will check the database in case that name already exists.

All other fields can be edited by clicking on them and simply typing the desired change. For the first start time field, clicking on it and then double-clicking will bring up a calendar so that you may adjust the starting date as well as time.

When finished editing the target row, be sure to hit the Update button.

Info Window



The Session info window is helpful in planning your session. In the above example, you can see the ephemerides info for the selected target, M65. The East and West times corresponding to the time at which the target is at the altitude shown to the left. So if you have an obstructed view to the east that limits your lowest altitude to 55°, set this value and you will see the time at which the M65 rises above that altitude. If you have a clear east and west horizons but don't want to image below a certain altitude, check the Equal box and you can simply scroll the upper (E) box. The (W) input box will track it. The east and west times will track the scrolled altitude limits.

Note: Hovering the mouse over an active target's name will show the mid-point of the light exposure time as a tooltip. This is handy if you are trying to center a staircase exposure sequence in time such that the data acquisition straddles the meridian. Compare this light exposure mid-point to the target transit time shown in the Info window (See below) at left for a given target.

Sun and moon rise and set times are also listed. Also, Civil, Nautical and Astronomical twilight times are available. Since most astronomical cameras are not particularly light tight for daylight operation, it is generally best to not take darks before civil dusk or after civil dawn. Astronomical twilight is a guide for sufficiently dark skies to light frames. It is generally best to not take light frames before astronomical dusk or after astronomical dawn. There are exceptions of course but these are reasonable guidelines.

Target Order Management *(Professional Version)*

CCDAutoPilot has the ability to change the order of targets in a multiple target database by a combination of dragging and dropping the target row or sorting based on a column header.

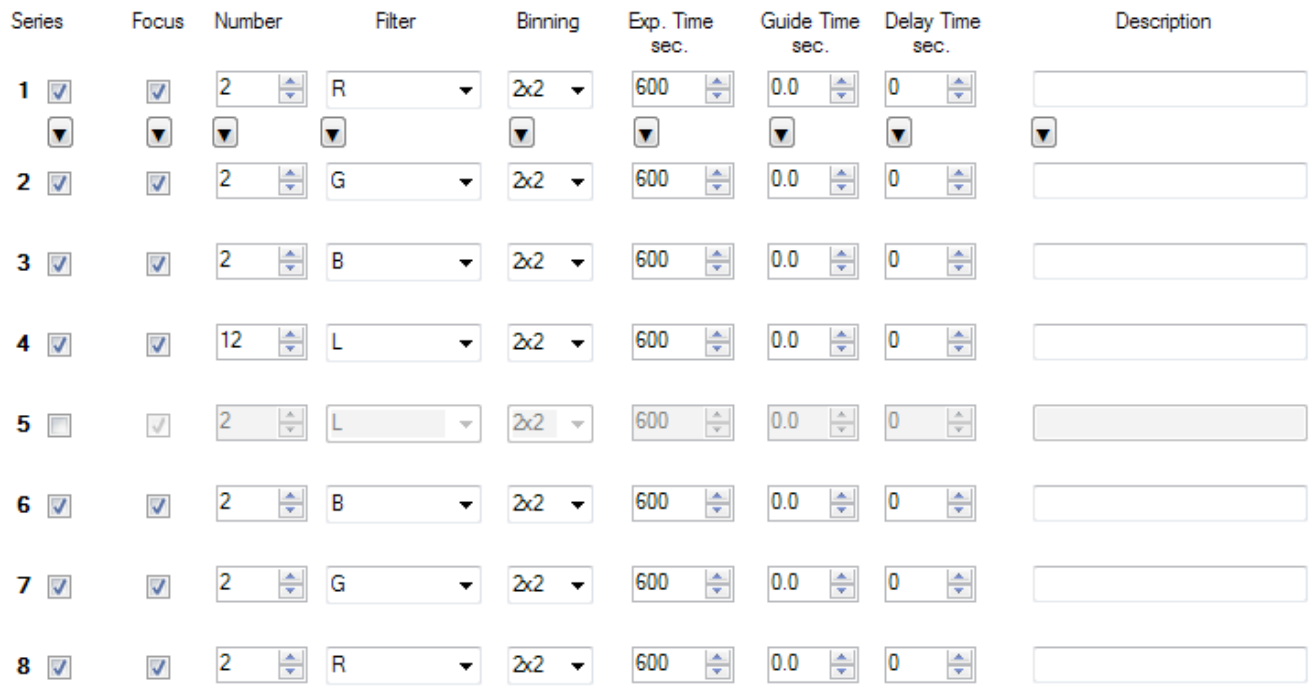
A given target row can be moved up or down in the target list by clicking on the row header until the drag/drop symbol appears. While holding the left mouse button down, drag the mouse up or down as appropriate to relocate the target row at the desired order. Some experimentation may be required to get a feel for the movement. Once the order is as desired, hit the Update button.

The target list can also be sorted by clicking on the Column header for Target, Active, RA, Dec and PA. Click once to sort in ascending order. Click again to sort in descending order. Once the order is as desired, hit the Update button.

After any change to the target order, the target start times will need to be reset as desired for the new target order.

8.4.2 Light Frames Exposure Series

On the lower half of the Lights Frame tab, there are 8 series to define the exposures that will be taken for a given target. Any or all series can be enabled. Exposures are taken in series order from 1 to 8.



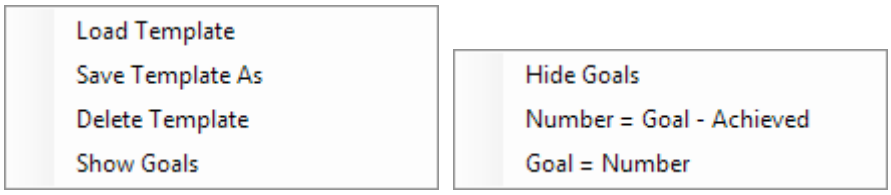
- **Series:** When checked, the series is enabled. When not checked, the series is skipped and the remainder of the fields for the series are grayed out as a visual reminder.
- **Focus:** When checked, the focus method and settings defined on the Focusing (See 8.10)page are executed at the start of the series with the chosen filter.
- **Number:** This is the number of exposures that will be taken for a given series.
- **Filter:** When using a filter wheel, this defines the filter to be used for the series exposure(s). When a filter wheel is not present, this entry will not be present.
- **Binning:** This is the binning to be used for the series exposure(s).
- **Exp Time: This is the exposure time in seconds to be used for the series exposure(s). When the exposure time is set to 0 and Focus is checked, only a focus operation will be performed. This is useful if you want to use a specific star to focus on before or during a target session. You can set a target to be that focus star, select one series with Focus checked and exposure set to 0 and that star will be used for focus. By interspersing the focus star target among multiple instances of the same target, you can specify the focus star to be used. When focusing with this arrangement, the Focus Method chosen on the Focusing page will be maintained and restored. What this means is this. Assume you have chosen SkyStar as your focusing method. If you introduce a target (presumably a focus star) and have both checked Focus and set Exp. Time to 0, the system will slew to that point, focus using the Brightest Star in FOV method and then move on to the next target using SkyStar as specified for any focusing with non-zero Exp. Time.**
- **Guide Time: This is the guide exposure time in seconds for the series. If Guider AutoExposure is checked on the Guiding (See 8.12)page, this entry will be ignored. However, if a non-zero Guide_Factor is entered for the target, this entry times the Guide_Factor will be the number of seconds the start of the imager exposure will be delayed. If Guider AutoExposure is not checked and a 0 is entered for this value, this series will be unguided, regardless of the guider selection.**
- **Delay Time: This is the time in seconds the start of the *next* exposure will be delayed.**
- **Description: You can enter a custom description here. If the description field on any series on the Session page is not blank, then the file name will be defined by that Description, followed by a 5 digit sequence number, followed by a file type extension, typically .fit. If the description field is blank, the default**

file naming convention defined on the Settings page, File Settings tab will take effect. See the File Setting(See 8.14.2) topic for additional information.

The ditto button , is a convenient way to replicate the setting of a given column in the first series to all the series below.

Context (Right-click) Menu

Right-clicking anywhere in the Series section of the page will bring up the context menu.



The left box describes Template management and is discussed in the Templates (See 8.4.5)topic. The last entry, Show Goals, changes to the Goals Template, which is showed on the right.

Goal Oriented Imaging

In some cases, a number of exposures is desired for each filter or series. Unfortunately clouds, guiding and other factors can intervene to make some exposures unsuitable. Through CCDAutoPilot's data assessment capability, the number of usable exposures can be identified at the end of the evening. Even if more exposures per filter a desired than can be obtained in a given evening are desired, this feature can be used with or without data assessment. Here is what is displayed when Show Goals is selected:

Series	Focus	Number	Filter	Binning	Exp. Time sec.	Achieved	Goal	Description
1	☑	☑	6	R	2x2	600	0	0	
2	☑	☑	6	G	2x2	600	0	0	

Note the new Achieved and Goal columns. Achieved is the number of exposures that were achieved the previous night. This will be 0 for the first time the exposure is taken but will be populated after some exposures have been achieved. Goal is the desired number of exposures. So, for the first night, select Goal = Number from the menu. This sets the goals as shown below:

Series	Focus	Number	Filter	Binning	Exp. Time sec.	Achieved	Goal	Description
1	☑	☑	6	R	2x2	600	0	6	
2	☑	☑	6	G	2x2	600	0	6	

With the goals set, the session can be run. After the session is run and data assessment was done on each exposure, we might see something like this:

Series	Focus	Number	Filter	Binning	Exp. Time sec.	Achieved	Goal	Description
1	☑	☑	6	R	2x2	600	3	6	
2	☑	☑	6	G	2x2	600	4	6	

3 R frames and 4 G frames were achieved. After selecting Number = Goal - Achieved:

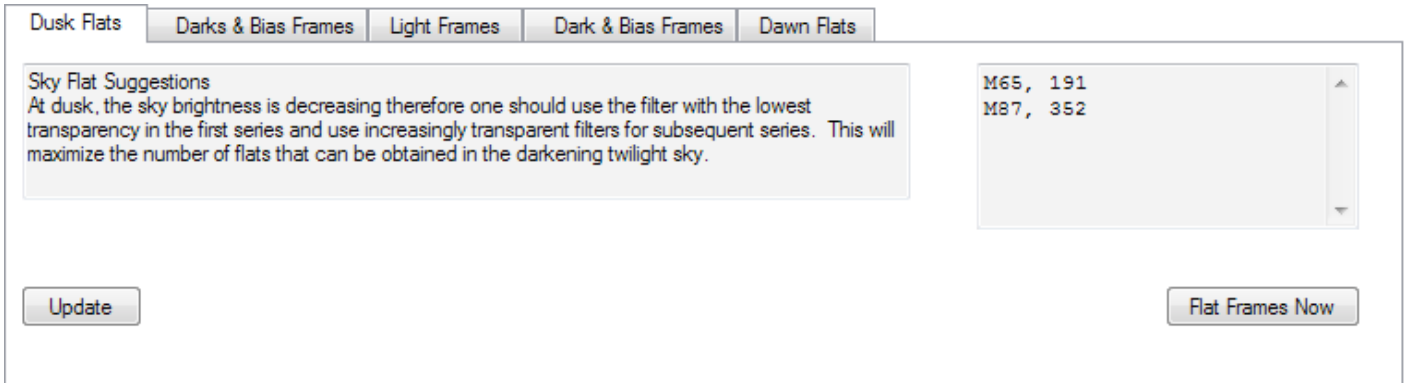
Series	Focus	Number	Filter	Binning	Exp. Time sec.	Achieved	Goal	Description
1	☑	☑	6	R	2x2	600	3	6	
2	☑	☑	6	G	2x2	600	4	6	

We can see that 3 R frames and 2 G frames are ready to be taken tonight.

8.4.3 Session Phases: Calibration Frames

Dusk Flats and Dawn Flats

Sky as Flat Light Source (twilight or sky flats)

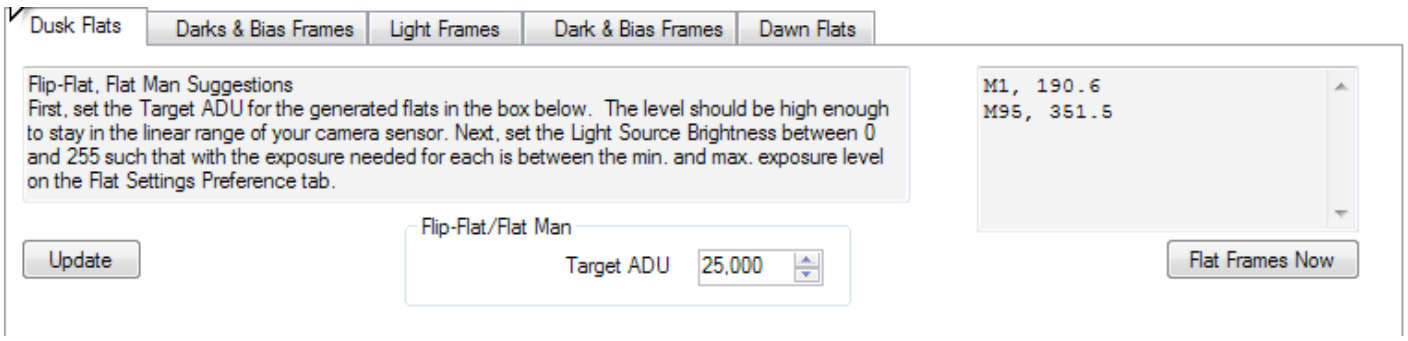


The left box will have suggestions for taking flats. The hints for Sky flats are shown. The right box shows the active targets and their corresponding position angle. If you are using a rotator, this is a handy reference for what Rotation Angle to enter in the Series section.. The optimal Target ADU can be measured for your camera using the Linearity Measurement Wizard(See 8.14.7). When acquiring dawn flats, be aware that CCDAutoPilot's automatic exposure routine is reactive, not predictive. The exposure for a flat is determined by measuring the previous one and adjusting the exposure time. Since the sky is brightening and depending on the camera download time, the next flat's ADU will be a bit higher. So it is best to choose a somewhat lower Target ADU than the Linearity Measurement Wizard recommends. This will prevent running dawn flats into the non-linear region. You will need to experimentally determine that brightness level. The opposite effect occurs for dusk flats. The first exposure will be close to the Target ADU and subsequent ones will have a slightly lower ADU.

- **Update:** updates the database with the current Series settings and updates the times in the Session Window at the left.

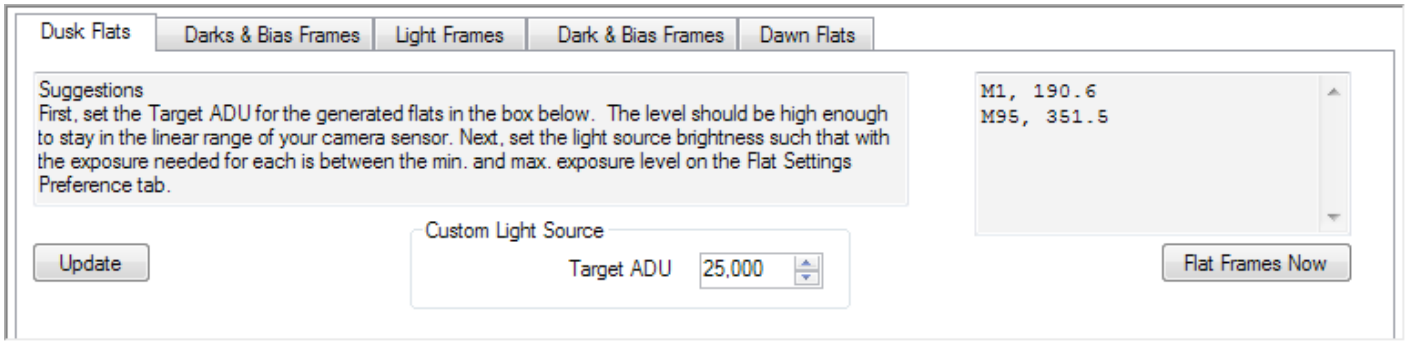
- **Flat Frames Now:** will immediately begin taking the flat frames as specified in the Series section.

FlipFlat/FlatMan as Light Source



In addition to the above controls, this adds a **Target ADU** for flats. This is target ADU level CCDAutoPilot will try to achieve by adjusting the exposure between minimum and maximum exposure settings from the Preference page, Flat Settings(See 8.14.3) tab. The optimal Target ADU can be measured for your camera using the Linearity Measurement Wizard(See 8.14.7).

Custom Light Source



If you have an unsupported artificial light source, you can still take flats automatically. You will need to turn the artificial source on and off by running programs at the appropriate points on the Options page and you will have to insure your min. and max. flat exposure times are sufficient to meet the target ADU for all filters. **Target ADU** should be set as needed. This is target ADU level CCDAutoPilot will try to achieve by adjusting the exposure between minimum and maximum exposure settings from the Preference page, Flat Settings(See 8.14.3) tab. The optimal Target ADU can be measured for your camera using the Linearity Measurement Wizard(See 8.14.7).

Dark and Bias Frames

- **Flush Imager:** when checked, the series of exposures as defined to the right will be taken. For some sensors, this can reduce the residual bulk image (RBI) from light frames. The frames will be taken and read out but not saved.
- **Number:** Number of flush exposures
- **Filter:** Filter to use for flush exposures
- **Binning:** Binning to use for flush exposures
- **Exp. Time:** Exposure time in seconds to use for flush exposures

- **Update:** updates the database with the current Series settings and updates the times in the Session Window at the left.

- **Loop Series:** The number of times the active series will be repeated.

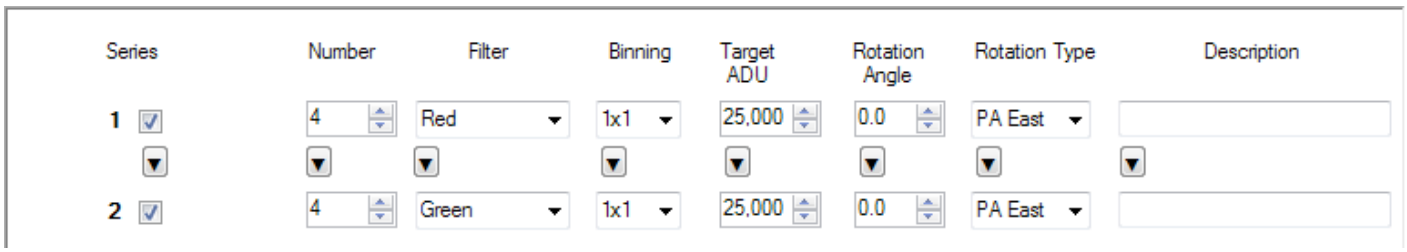
- **Dark Frames Now:** immediately begins taking the dark and/or bias frames specified in the Series section.

8.4.4 Calibration Frames Exposure Series

Dusk Flats and Dawn Flats

The Series columns will change, depending on what Flat Light Source is used.

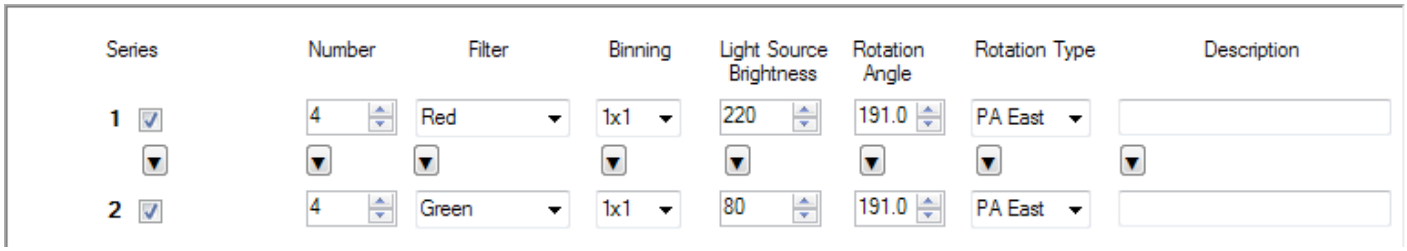
Sky as Flat Light Source (twilight or sky flats)



- **Series:** When checked, the series is enabled. When not checked, the series is skipped and the remainder of the fields for the series are grayed out as a visual reminder.
- **Number:** This is the number of exposures that will be taken for a given series.

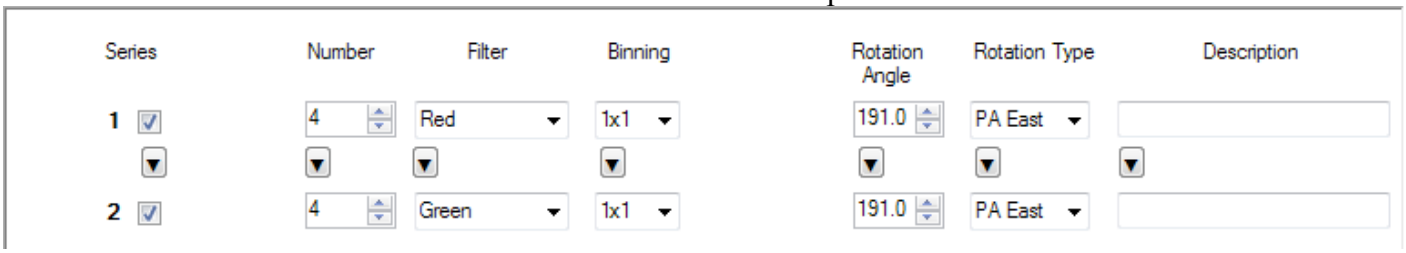
- **Filter:** When using a filter wheel, this defines the filter to be used for the series exposure(s). When a filter wheel is not present, this entry will not be present.
- **Binning:** This is the binning to be used for the series exposure(s).
- **Target ADU:** This is target ADU level CCDAutoPilot will try to achieve by adjusting the exposure between minimum and maximum exposure settings from the Preference page, Flat Settings(See 8.14.3) tab.
- **Rotation Angle:** Depending on the Rotation Type selection, this will be either a position angle or a rotator position at which you want to take your flats.
- **Rotation Type:** If you are trying to match light frames taken on each side of the meridian with an equatorial mount, select either PA East or PA West to match your light frames. Select Rotator to use the absolute rotator position. Select None and the rotator position will be ignored.
- **Description:** You can enter a custom description here. If the description field on any series on the Session page is not blank, then the file name will be defined by that Description, followed by a 5 digit sequence number, followed by a file type extension, typically .fit. If the description field is blank, the default file naming convention defined on the Settings page, File Settings tab will take effect. See the File Setting(See 8.14.2) topic for additional information.
-

FlipFlat/FlatMan as Light Source



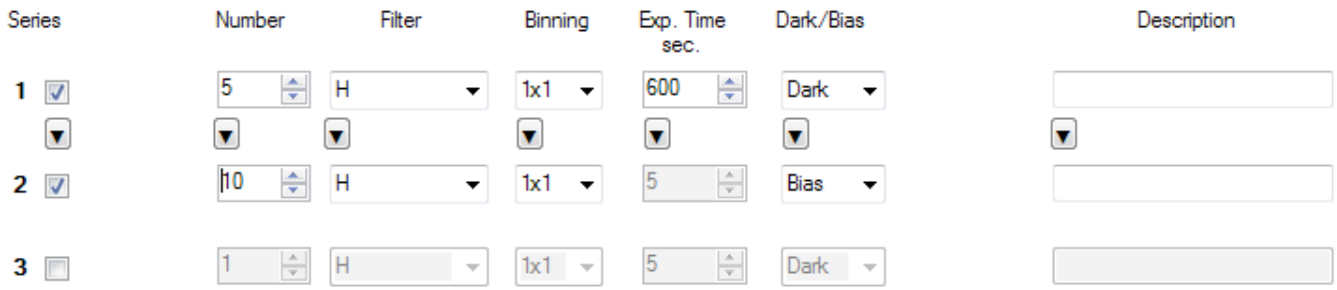
- **Series:** When checked, the series is enabled. When not checked, the series is skipped and the remainder of the fields for the series are grayed out as a visual reminder.
- **Number:** This is the number of exposures that will be taken for a given series.
- **Filter:** When using a filter wheel, this defines the filter to be used for the series exposure(s). When a filter wheel is not present, this entry will not be present.
- **Binning:** This is the binning to be used for the series exposure(s).
- **Light Source Brightness:** This sets the FlipFlat/FlatMan brightness level. The value should be between 0 and 255. It should be chosen so that an exposure between the minimum and maximum exposure settings from the Preference page, Flat Settings(See 8.14.3) tab, results in the Target ADU. Once determined, save these settings as a Template (See 8.4.5)to make future flat settings easier.
- **Rotation Angle:** Depending on the Rotation Type selection, this will be either a position angle or a rotator position at which you want to take your flats.
- **Rotation Type:** If you are trying to match light frames taken on each side of the meridian with an equatorial mount, select either PA East or PA West to match your light frames. Select Rotator to use the absolute rotator position. Select None and the rotator position will be ignored.
- **Description:** You can enter a custom description here. See the File Setting(See 8.14.2) topic for additional information.

Custom Light Source



- **Series:** When checked, the series is enabled. When not checked, the series is skipped and the remainder of the fields for the series are grayed out as a visual reminder.
- **Number:** This is the number of exposures that will be taken for a given series.
- **Filter:** When using a filter wheel, this defines the filter to be used for the series exposure(s). When a filter wheel is not present, this entry will not be present.
- **Binning:** This is the binning to be used for the series exposure(s).
- **Rotation Angle:** Depending on the Rotation Type selection, this will be either a position angle or a rotator position at which you want to take your flats.
- **Rotation Type:** If you are trying to match light frames taken on each side of the meridian with an equatorial mount, select either PA East or PA West to match your light frames. Select Rotator to use the absolute rotator position. Select None and the rotator position will be ignored.
- **Description:** You can enter a custom description here. See the File Setting(See 8.14.2) topic for additional information.

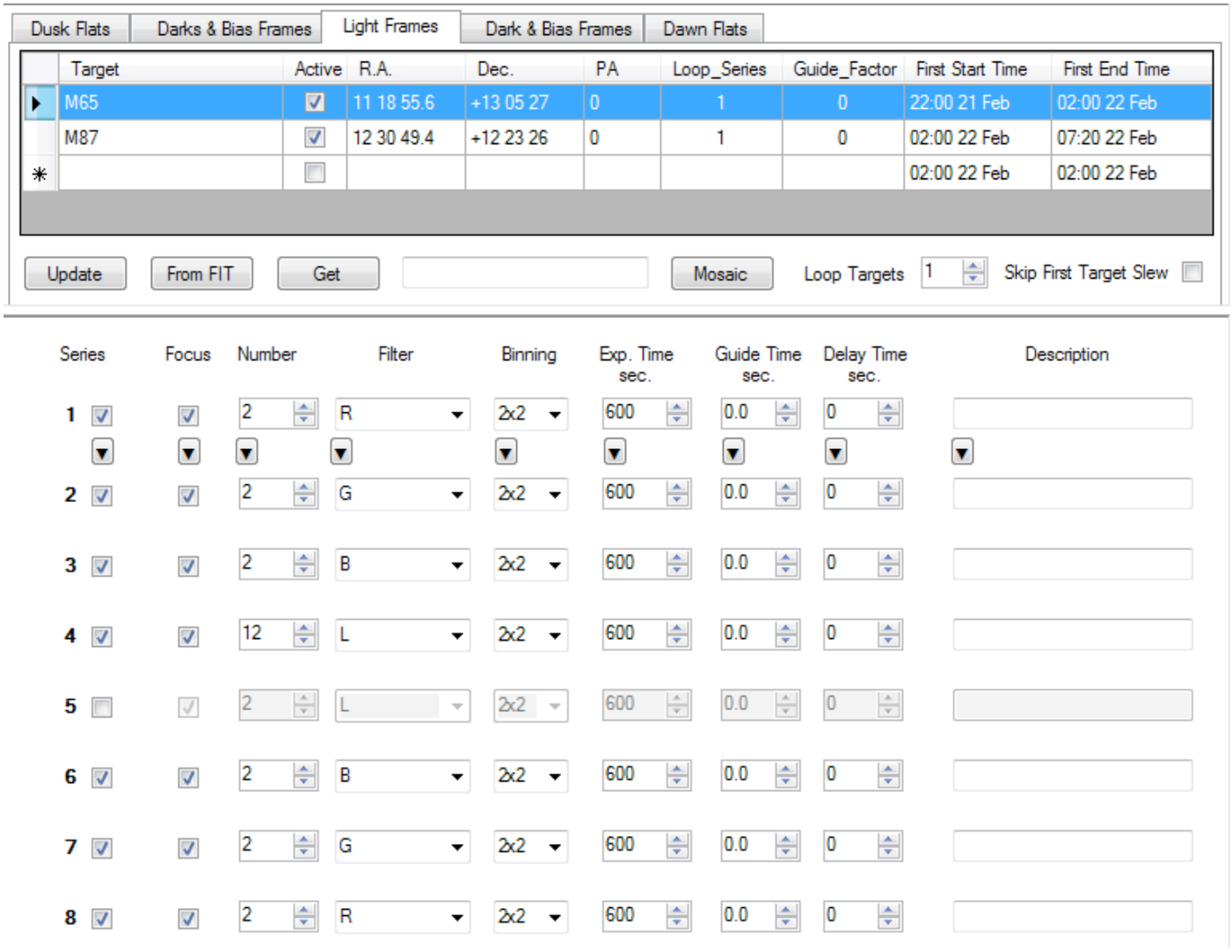
Dark and Bias Frames



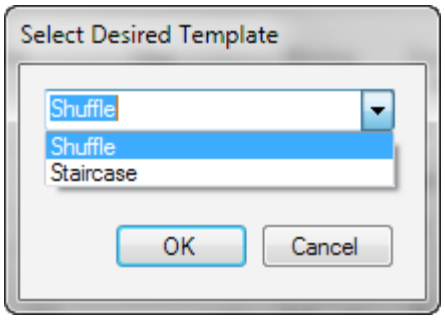
- **Series:** When checked, the series is enabled. When not checked, the series is skipped and the remainder of the fields for the series are grayed out as a visual reminder.
- **Number:** This is the number of exposures that will be taken for a given series.
- **Filter:** When using a filter wheel, this defines the filter to be used for the series exposure(s). When a filter wheel is not present, this entry will not be present.
- **Binning:** This is the binning to be used for the series exposure(s).
- **Exp. Time:** This is the exposure time in seconds to be used for the series exposure(s).
- **Dark/Bias:** When Bias is selected, the exposure time is ignored and set to 0 since a bias frame is a 0 exposure length dark frame.
- **Description:** You can enter a custom description here. See the File Setting(See 8.14.2) topic for additional information.

8.4.5 Templates

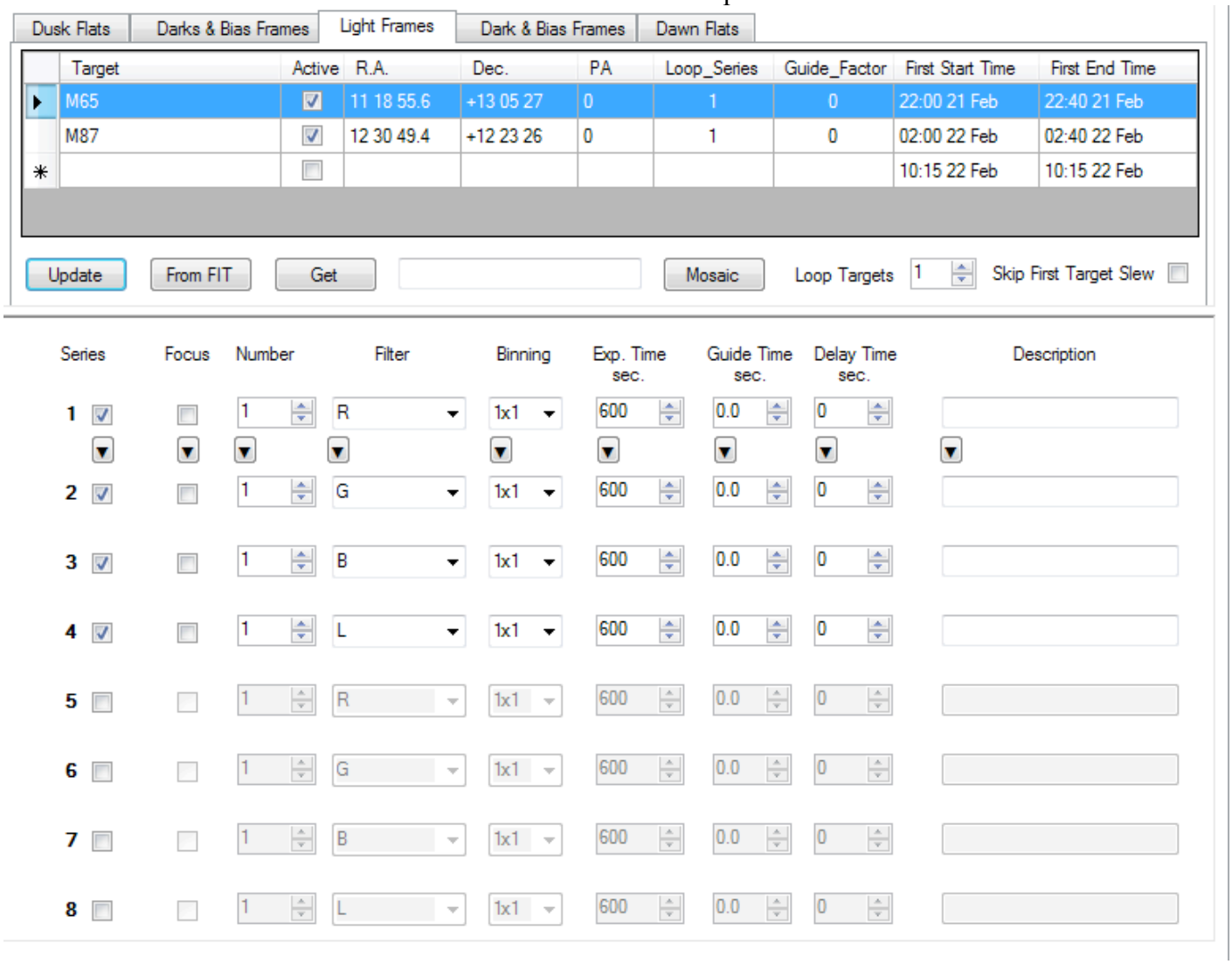
Templates are a convenient way to enter a number of series settings that are frequently used. There are two default templates provided for Shuffle and Staircase, as described in the Light Frames(See 4.4) topic. For example, here is the series settings for M65:



This is essentially a Staircase template. We can change this to a Shuffle plan by right-clicking and select **Load Template**



After selecting the Shuffle template, the series for M65 now looks like this:

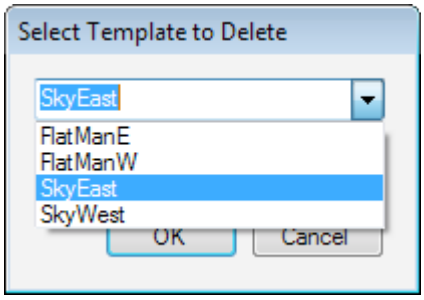


You can also define your own templates by setting up a series as you like and right-clicking and select **Save Template As**. You can review the existing template names by using the pulldown and then type in the pulldown box to enter the name for your new template. Template names not have spaces. If the template name already exists, you will be asked if you want to overwrite the existing template. (The template name you type over will not be deleted or renamed.)

Finally, you can right-click and select **Delete Template** to delete any template you wish.

Examples

You can use templates on calibration frames as well. Assume you have a rotator and need both dawn and dusk flats. Since the flats need to be taken in least to most transmissive order at dusk and the opposite order at dawn, entering these each time can be streamlined by setting up templates. Here are my flats templates:



By selecting SkyE, the series are all populated and all I have to enter is the Rotation Angle. I can do this by simply entering the desired Rotation Angle in the first series and using the ditto button. Thus in three clicks, I have defined my dusk flats:

Series	Number	Filter	Binning	Target ADU	Rotation Angle	Rotation Type	Description
1	4	Red	1x1	25,000	0.0	PA East	
2	4	Green	1x1	25,000	0.0	PA East	
3	4	Blue	1x1	25,000	0.0	PA East	
4	4	Luminance	1x1	25,000	0.0	PA East	
5	4	Red	1x1	25,000	0.0	PA East	
6	4	Red	1x1	25,000	0.0	PA East	
7	4	Red	1x1	25,000	0.0	PA East	
8	4	Red	1x1	25,000	0.0	PA East	

I can set up similar templates for artificial flats, as taken with a FlatMan for example. Here I selected FlatManW for my dawn flats:

Series	Number	Filter	Binning	Target ADU	Rotation Angle	Rotation Type	Description
1	4	Luminance	1x1	55	0.0	PA West	
2	4	Blue	1x1	80	0.0	PA West	
3	4	Green	1x1	80	0.0	PA West	
4	4	Red	1x1	220	0.0	PA West	
5	4	Green	1x1	25,000	0.0	PA East	
6	4	Blue	1x1	25,000	0.0	PA East	
7	4	Red	1x1	25,000	0.0	PA East	
8	4	Red	1x1	25,000	0.0	PA East	

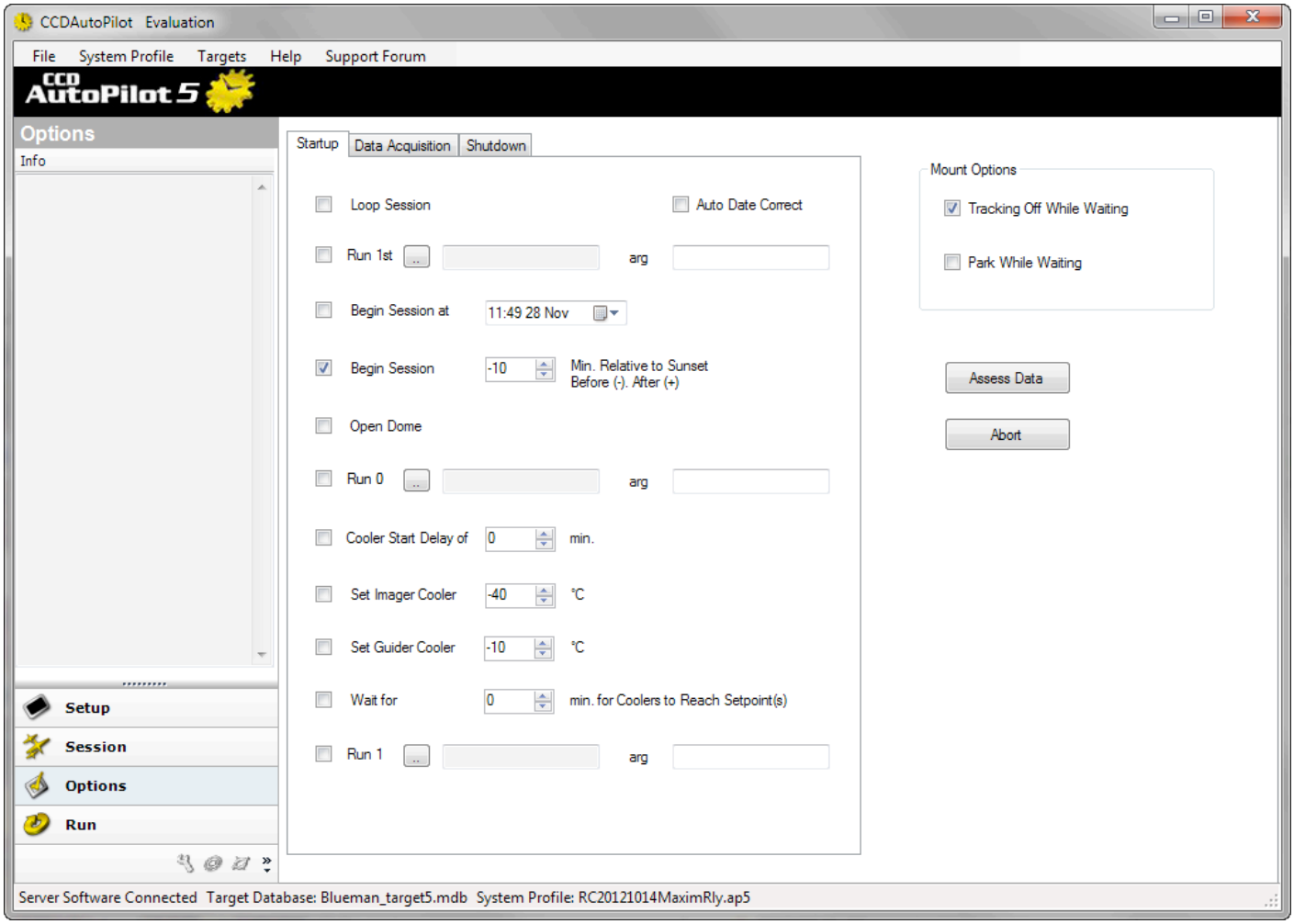
My FlatMan brightness levels are already entered and again, all I need to do is enter the Rotation Angle and hit the ditto button.

Templates can be a powerful aid in automated imaging. I have templates for Galaxy exposures, Cluster exposures and NarrowBand exposures. There is no limit to the number of templates you can enter.

8.5 Options

8.6 Options

On this page, you can set the activities and events during the course of a session. The options are divided into 3 phases as indicated by the tabs at the top of the page. Activity flows top to bottom from the first entry on the Startup tab, through the Acquisition Tab to the last entry on the Shutdown page. Each tab is described in its on topic.



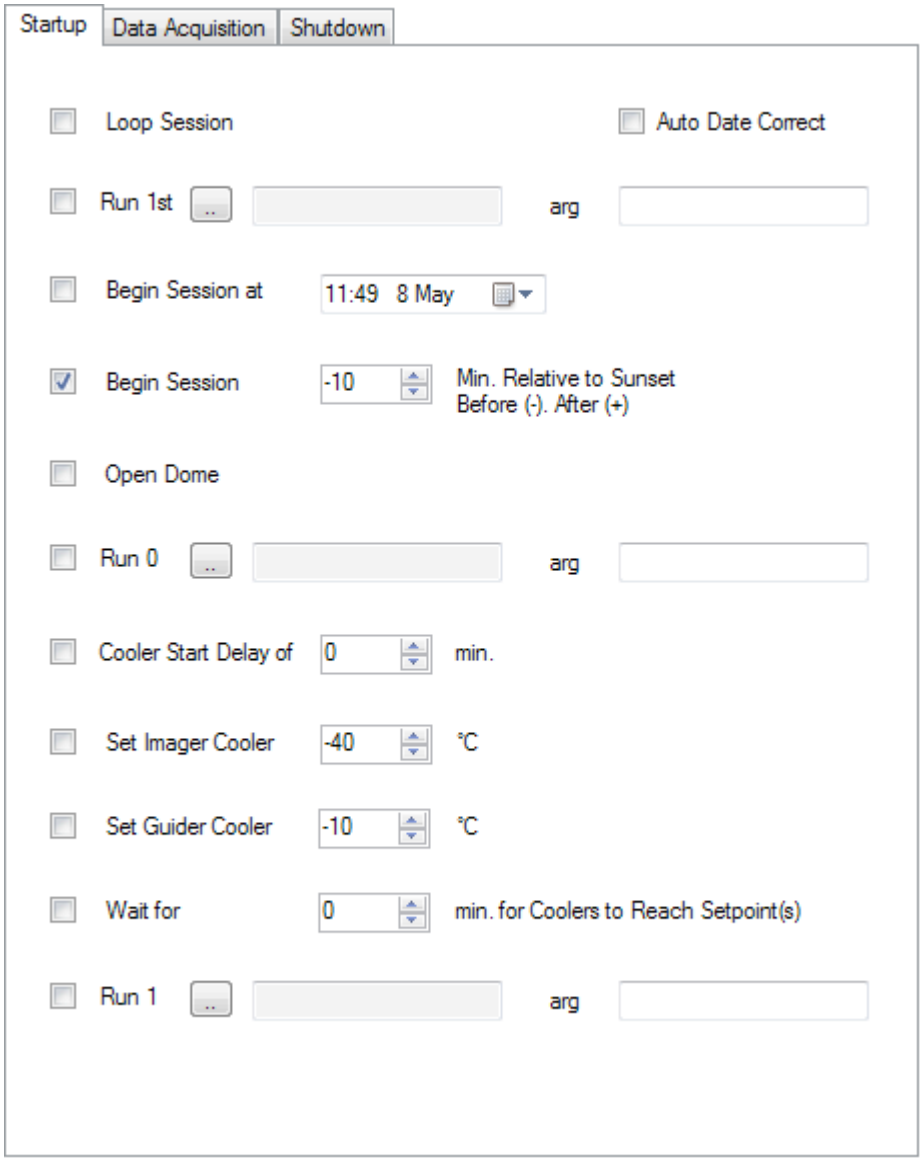
Mount Options

You can select **Tracking Off While Waiting** or **Park While Waiting** to determine what your mount does while waiting. For example, when I take dusk flats, I select **Tracking Off While Waiting** so that the telescope will be pointed nominally to the zenith to facilitate cooling. Others may not need this and can select **Park While Waiting**.

- **Assess Data:** If you have Data Assessment checked on Preferences, Assess Data tab, this button will be active. With it you can select a folder containing FITS data and CCDAutoPilot will run the assessment criteria against all files in that folder, reporting the results on the Info window to the left of the page.

- **Abort:** ends the assessment activity in progress.

8.6.1 Startup



- **Loop Session: When checked, CCDAutoPilot will run continuously. It will start at the Begin Session Time you specify, run through all the session phases of calibration frames before light frames, light frames, calibration frames after light frames and handle any dome/roof openings, cooler warm-up's that you specify. If adverse weather conditions occur, the session will conclude for that evening, and be ready to start the next night. See the warning (See 8.14.5)about weather conditions. See the Enhanced Automation(See 4.9) topic for suggested usage.**

- **Auto Date Correct: When checked, the target starting date of all active targets is adjusted to the current date if the original date is in the past. Future dates are not affected. The starting time is unchanged. See the Enhanced Automation(See 4.9) topic for suggested usage.**

- **Run First: When checked, CCDAutoPilot will run whatever application is entered at this point in the session. To enter an application, hit the ... to navigate to the specific application to be run. If the application requires any arguments to follow the application, enter them manually in the arg space. To clear an entry, simply hit Cancel after hitting ...**

- **Begin Session: The session can begin at as specific time and date or at a time relative to sunset. The advantage of the latter is you don't have to worry about changing the start time from day to day. However, if starting at a specific time and date is needed, the option is available. If you use a specific time and date, don't forget to set the date as needed by using the calendar pulldown.**

- **Open Dome: Check this to open the dome.**

- **Run 0: When checked, CCDAutoPilot will run whatever application is entered at this point in the session. To enter an application, hit the ... to navigate to the specific application to be run. If the application requires any arguments to follow the application, enter them manually in the arg space. To clear an entry, simply hit Cancel after hitting ...**

- **Cooler Start Delay: Check if you want the dome to be open a while before having the cooler start. In some situations, this can relieve any heat trapped in the dome during the day and allow the cooler to reach a lower temperature. Set the delay time you wish.**

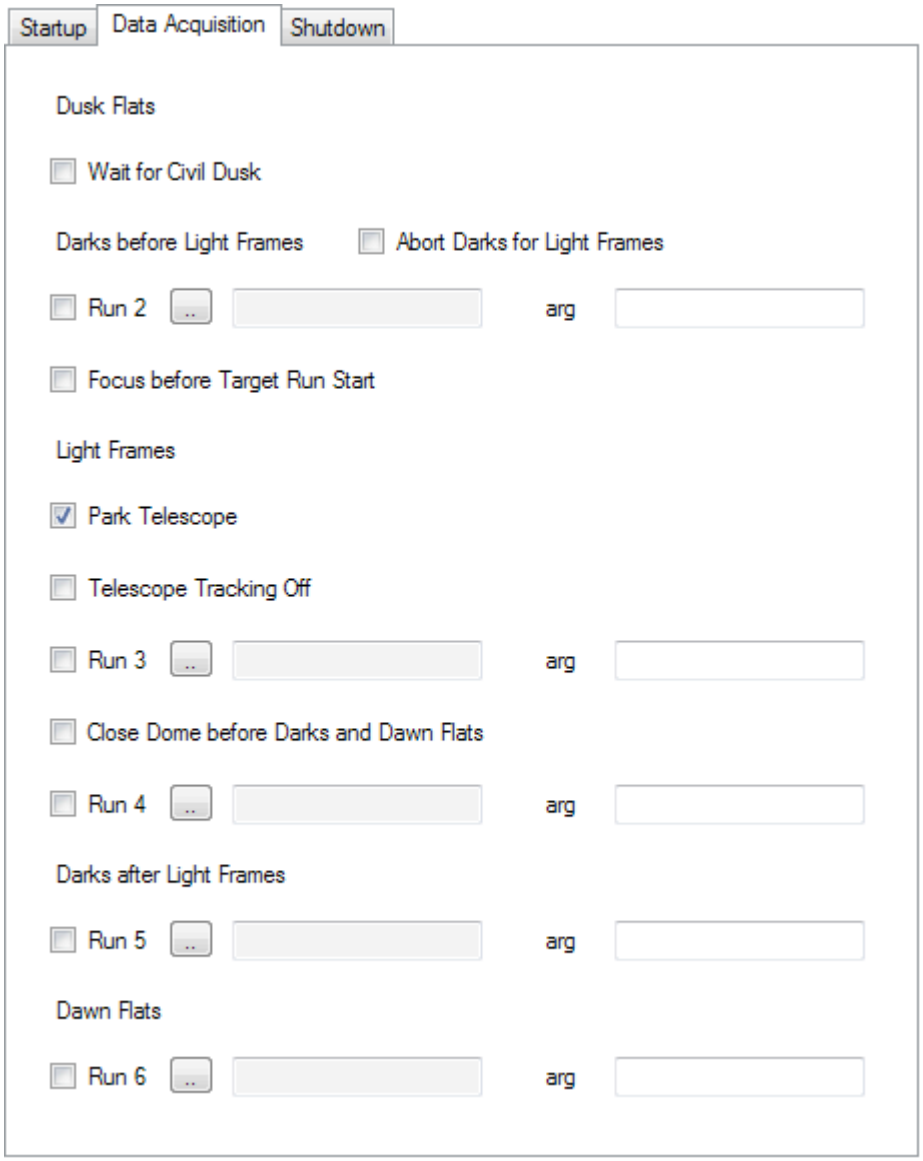
- **Set Imager Cooler: When checked, this sets the imager cooler to the specified temperature.**

- **Set Guider Cooler: When checked, this sets to guider cooler to the specified temperature.**

- **Wait for coolers: When checked, this waits the specified time before continuing to allow the coolers to reach their specified temperatures. CCDAutoPilot will wait for the cooler(s) to reach their desired temperature for the specified time. If the time is elapsed and the coolers haven't reached their specified temperatures, the session will continue.**

- **Run 1: When checked, CCDAutoPilot will run whatever application is entered at this point in the session. To enter an application, hit the ... to navigate to the specific application to be run. If the application requires any arguments to follow the application, enter them manually in the arg space. To clear an entry, simply hit Cancel after hitting ...**

8.6.2 Data Acquisition



- **(Dusk Flats): I**f there are active series, flat frames will be taken at this point in the sequence.

- **Wait for Civil Dusk:** When checked, CCDAutoPilot will wait for civil dusk before proceeding. (Civil dusk is when the sun is 6° below the horizon.)

- **(Darks before Light Frames):** If there are active series, dark and/or bias frames will be taken at this point in the sequence.

- **Abort Darks for Light Frames: When checked, any dark/bias frames in process will be terminated at the first active target start time to allow the light frames to begin on schedule. See the Enhanced Automation(See 4.9) topic for suggested usage.**

- **Run 2: When checked, CCDAutoPilot will run whatever application is entered right before the slew to the first active target. To enter an application, hit the ..to navigate to the specific application to be run. If the application requires any arguments to follow the application, enter them manually in the arg space. To clear an entry, simply hit Cancel after hitting ..**

- **Focus before Target Run Start: If checked, the telescope will slew to the coordinates of the first target and execute a focus run using the parameters set on the Focusing page.**

- **(Light Frames): Light frames will be taken for the active target(s) specified on the Session (See 8.4)page.**

- **Park Telescope: When checked, the telescope will be parked at the park position specified in your telescope control server.**

- **Telescope Tracking Off: When checked, telescope tracking will be turned off via your telescope control server.**

- **Run 3: When checked, CCDAutoPilot will run whatever application is entered at the end of the Light Frames phase. To enter an application, hit the ..to navigate to the specific application to be run. If the application requires any arguments to follow the application, enter them manually in the arg space.. To clear an entry, simply hit Cancel after hitting ..**

- **Close Dome before Darks and Dawn Flats: If checked, the dome will be closed at this point in the sequence.**

- **Run 4: When checked, CCDAutoPilot will run whatever application is entered right before the next Dark Frames phase. To enter an application, hit the ..to navigate to the specific application to be run. If the application requires any arguments to follow the application, enter them manually in the arg space.. To clear an entry, simply hit Cancel after hitting ..**

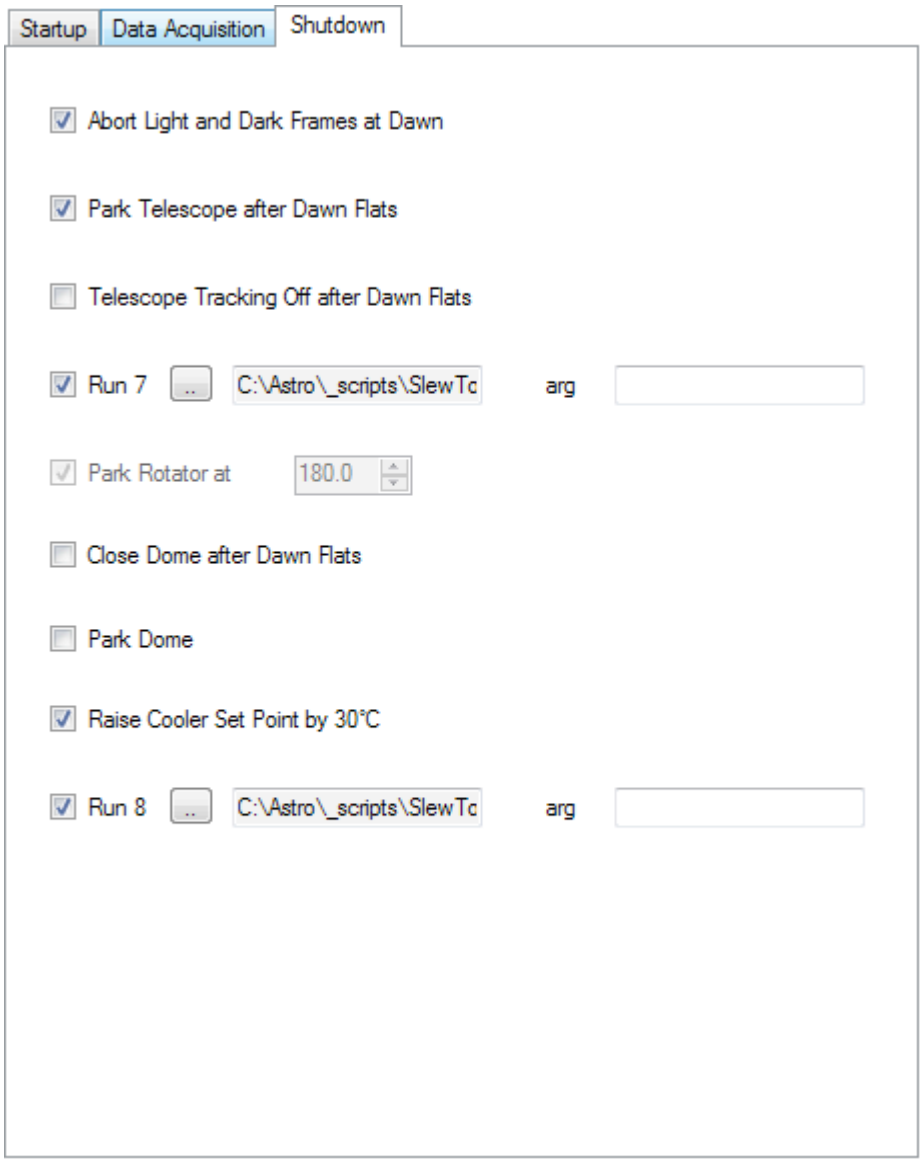
- **(Darks after Light Frames): If there are active series, dark and/or bias frames will be taken at this point in the sequence.**

- **Run 5: When checked, CCDAutoPilot will run whatever application is entered after the Dark Frames phase and before the Dawn Flats phase.. To enter an application, hit the ..to navigate to the specific application to be run. If the application requires any arguments to follow the application, enter them manually in the arg space.. To clear an entry, simply hit Cancel after hitting ..**

- **(Dawn Flats): If there are active series, flat frames will be taken at this point in the sequence.**

- **Run 6: When checked, CCDAutoPilot will run whatever application is entered immediately after the Dawn Flats phase.. To enter an application, hit the ..to navigate to the specific application to be run. If the application requires any arguments to follow the application, enter them manually in the arg space. To clear an entry, simply hit Cancel after hitting ..**

8.6.3 Shutdown



- **Abort Light and Dark Frames at Dawn:** When checked, light and dark frames will be aborted when the sun reaches the Dawn Starting Sun Altitude specified on the Preferences page, Flat Settings(See 8.14.3) tab. See the Enhanced Automation(See 4.9) topic for suggested usage.

- **Park Telescope after Dawn Flats:** When checked, the telescope will be parked at the park position specified in your telescope control server.

- **Telescope Tracking Off after Dawn Flats:** When checked, telescope tracking will be turned off via your telescope control server.

- **Run 7:** When checked, CCDAutoPilot will run whatever application is entered after the telescope is parked or tracking is turned off. To enter an application, hit the  to navigate to the specific application to be run. If the application requires any arguments to follow the application, enter them manually in the **arg** space .To clear an entry, simply hit Cancel after hitting  .

- **Park Rotator at: When checked, moves the rotator to the rotator position indicated.**

- **Close Dome after Dawn Flats: If checked, the dome will be closed at this point in the sequence.**

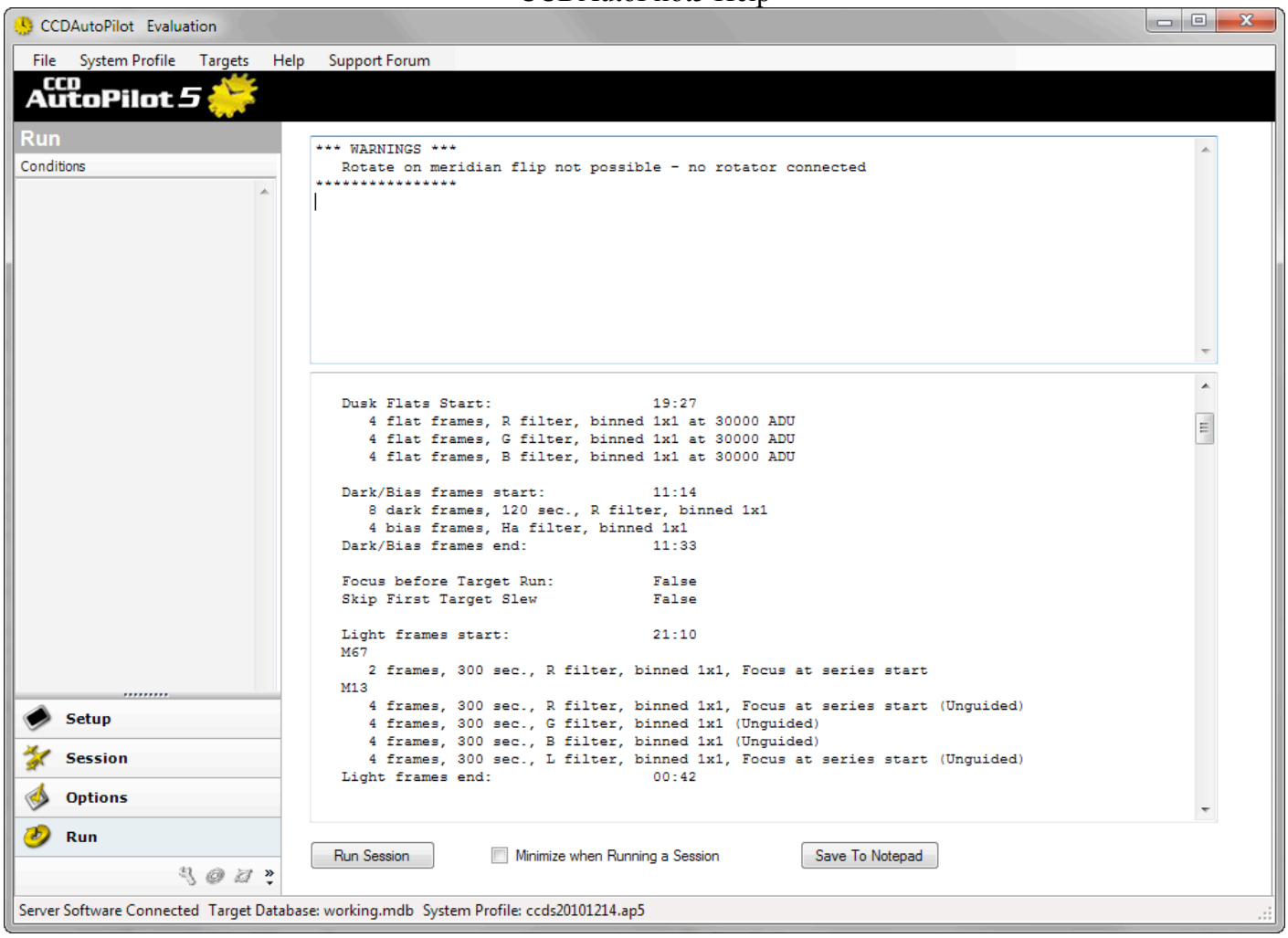
- **Raise Cooler Set Point by 30 °C: If checked, the set points of the cooler(s) will be raised by 30°C. This is to allow the coolers not to drive too hard when systems are left on around the clock. It can also be used to warm up the coolers before shutting down if desired.**

- **Run 8: When checked, CCDAutoPilot will run whatever application is entered at the end of the session. To enter an application, hit the  to navigate to the specific application to be run. If the application requires any arguments to follow the application, enter them manually in the arg space. To clear an entry, simply hit Cancel after hitting  .**

8.7 Run

8.8 Run

On this page you can review the settings for your planned session. Warnings are given that may impact the success of your session so that you can take appropriate action before continuing.



The upper window is the Warnings window. CCDAutoPilot examines your settings for any conflicts or issues that may make your session less successful. While not everything can possibly be checked, these warnings are gleaned from customer inputs over the years in the hope of making your session success more likely.

The lower window shows the review of your session. A summary of the session events, planned exposures and timing is shown for review. In addition, your equipment settings and settings for all of the controls are replicated here, grouped by function.

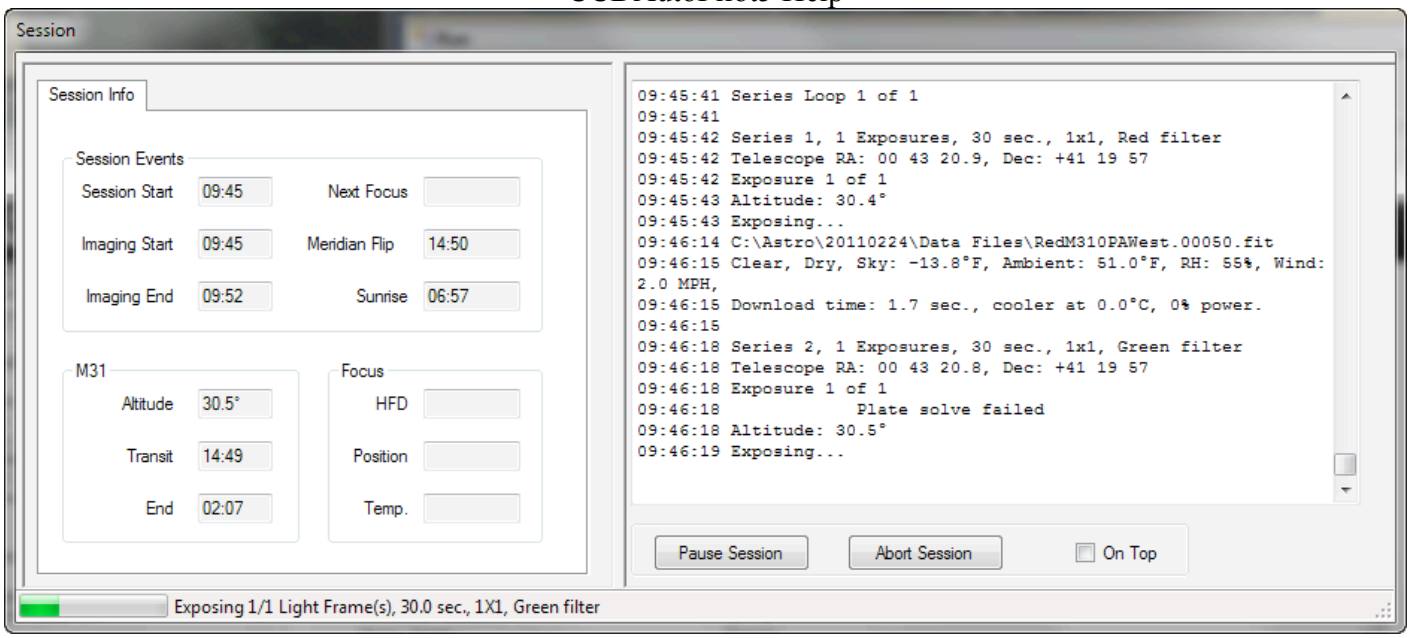
The contents of both of these windows are placed at the start of your session log for recording your settings and to aid in diagnosing a session. They are also placed on the Windows clipboard so that it may be conveniently pasted into another application.

The **Save To Notepad** button will open Windows' notepad application and paste the contents of both windows there. This is convenient if you wish to print and review the session plan before starting.

The **Run Session** button initiates the session. The Session(See 8.8.1) window will open if it is not already open and display session information.

8.8.1 Session Running

Once the Run Session button is hit on the Run page, the session window opens and the session begins. Changes can be made to a running session for nearly every setting in the CCDAutoPilot window, except the current exposure of course. It is always best to use the **Pause Session** button to make changes while the session is paused.

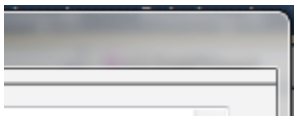


- **On Top:** When checked, the Session window is made the topmost window on the desktop. This prevents other windows from hiding crucial session information. When it is not checked, the status window's behavior is normal, i.e. it can be hidden by other windows.

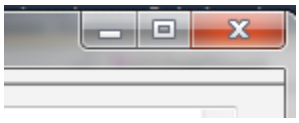
- **PauseSession:** The Pause button allows the session to be paused at an appropriate point, usually the completion of the exposure in process. Once paused, the title of this button changes to Resume and hitting it again will resume the session. This is convenient if you have to go out to the telescope, put a light on and adjust something. This is also a good time to make any changes to the session via the Main CCDAutoPilot window. When you are done, you can resume the run session where you paused.

Session Window Controls

The state of the Session Window Controls located in the upper right corner of the Session window and shown below are used to indicate session activity.



Session Running



Session Not Running

- **Abort Session:** This is used to totally abort the running session. When a session is running the Session Window Controls are removed. When hit, the session abort routines will be initiated and the Abort Session button will be grayed out. When the Session Window Controls are restored, the Abort Session routines have completed in an orderly fashion.. Be sure to wait until CCDAutoPilot has completely aborted the session in progress and is in the proper state to restart a run. If there is any doubt, close and restart CCDAutoPilot. The status window can either be left open or closed as desired.

Session Info Tab

Session Events

- **Session Start:** indicates the session start time.

- **Imaging Start:** indicates the time the light frames will begin. If the user has specified a delayed start for the first target on the Session page, this will indicate that time. Otherwise, it will indicate ASAP.

- **Imaging End:** indicates the expected ending time of the run, not including any dawn flats

- **Next Focus:** indicates when the next automatic focusing activity will take place.

- **Meridian Flip:** If the target is east of the meridian, this indicates the expected time of the meridian flip. If the target is west of the meridian, this field will so indicate. If a fork mount is being used, n/a will be indicated since there is no meridian flip with a fork mount.

- **Sunrise:** indicates the time of local sunrise

Target

- **Target: indicates the target name, as defined on the Session page. If the Loop Targets(See 8.4.1) is set greater than 1, the current loop index will be displayed in parentheses next to the target name**

- **Altitude: indicates the altitude of the target.**

- **Transit: indicates the time the target will transit (cross) the meridian.**

- **End: Indicates the end imaging time for this target.**

Focus
If no focus program is used, all these entries will indicate "n/a". Otherwise:

- **HFD: indicates the Half-Flux Density of the focused star, as reported by FocusMax. This is not necessarily the same as FWHM (Full Width Half Maximum) as normally used for stellar profile measurements. HFD is a good relative indicator of focus however.**

- **Position: indicates the focuser position, as reported by FocusMax, for your focused position.**

- **Temp: Reports the ambient temperature in whatever units (°F, °C, counts, etc.) the focuser in use reports temperature. If the focuser doesn't report temperature, then "n/a" is indicated.**

Status Bar
A status bar is provided at the bottom of the status window to indicate various activities including exposure progress.

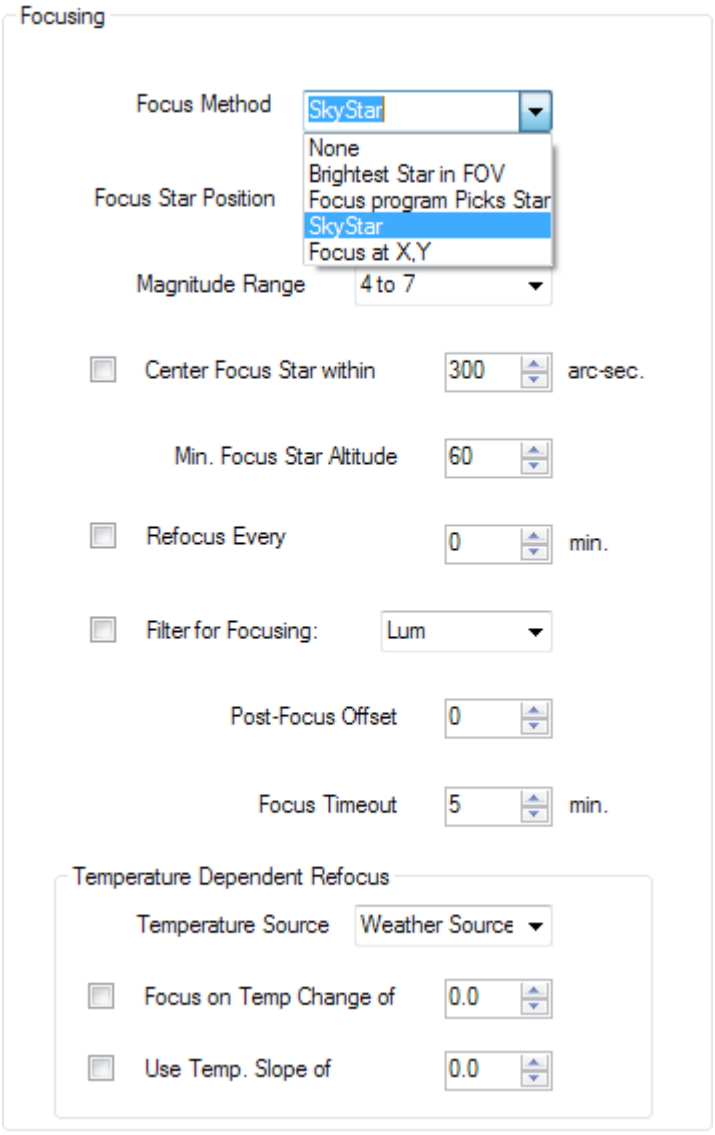
8.9 Focusing

8.10 Focusing

Here you set the various parameters for focusing during your session. There are many issues surrounding focusing and reading the Focusing Techniques(See 4.1) topic is recommended to aid in your Focusing choices. CCDAutoPilot supports three automated focusing systems: FocusMax which works with both CCDSoft and Maxim, CCDSoft's @focus2 and Maxim's internal focus routine. Which one to use is a matter of personal preference and which works best for your system. The focusing page changes slightly, depending on the focusing server choice. This topic will discuss FocusMax in detail and discuss the changes for the other programs.

For all focusing servers, When an equatorial-mounted telescope is pointed east of the meridian, any focusing activity scheduled to occur within 10 minutes of the meridian crossing will be deferred until the after telescope has crossed the meridian and the mount has flipped. This deferral does not take place with fork-mounted telescope. This focus deferral only occurs when Meridian Flip is selected.

FocusMax



Before proceeding, insure that FocusMax is set up properly for your system. Consult FocusMax documentation for specifics. Once all the software is linked to CCDAutoPilot, you can use the **Focus Now** button to verify operation. **Focus Now** uses the settings on this page to launch a mini-session that only focuses and does whatever other telescope moving might be required. Its actions are recorded as a normal log and displayed in the Session window.

Focus Methods

When FocusMax is connected, there are a number of active methods of focusing available. Active methods do not rely on predicting the focus position but actually *focus* the system at appropriate times. As such, this would be expected to give you the most optimal focus at any point in time. The trade-off here is the time to do the focusing. Depending on the method chosen, active focusing can add from 30 to 300 seconds or more, depending on the method used, camera download time etc.

- **None:** No focusing is used. This setting might be used if it is desired to use only filter offsets.
- **Brightest star in FOV:** FocusMax will choose the brightest object in the field of view. This is fine if there are no bright extended objects such as galaxies in the field but if there are, FocusMax will attempt to focus on that and will most likely be unsuccessful.
- **Focus at X, Y:** One way to avoid the above problem is to select a specific x,y coordinate for a target star. Take an unbinned image and note the coordinates of the brightest star. Enter those coordinates in the X and Y boxes. FocusMax will use that coordinate with a 100 x 100 pixel box around it to focus.

- **Sky Star:** With this technique and TheSky, CCDAutoPilot will plate solve the current location, slew the scope to a nearby star, focus there using FocusMax and slew back to the original location. If guiding was in process, it will be stopped for focusing and restarted automatically once the telescope has returned to the target coordinates. This technique guarantees a suitable star for focusing and uses the very powerful data query technology of TheSky to select stars of an appropriate magnitude to be used for focusing. SkyStar has some additional options: **Center Focus Star within:** When checked, a precision slew to the focus star will be made, insuring the focus star is in the center of the FOV and allows you to specify how close the focus star will be to the center of the imager's FOV. **Magnitude Range:** 4 magnitude ranges are provided for the focus star - 4 to 7, 5 to 8, 6 to 9 and 7 to 10. Select the range that is appropriate for your system. **Minimum focus star altitude:** Regardless of where the telescope is pointing, focusing will always use a star above this minimum altitude. As a minimum, you **must** have the Guide Star Catalog (GSC) selected as one of the Stellar Core databases in TheSky.
- **Focus Program Picks Star:** This is similar to Sky Star but it is all done within FocusMax using AcquireStar and requires the full version of PinPoint. Unlike SkyStar, whatever filter you use to focus on will be the same filter used for plate solving. CCDAutoPilot will use precision slew to correct any returning slew errors from the focus program.
- **Refocus every xx minutes:** When checked and depending on the numeric entry, the chosen focus method will be executed xx minutes after the start of the first target's imaging session. The next exposure that comes along that is xx or more minutes after the last focus will be executed. In other words, the time for an interval focus is determined before an exposure starts. If xx minutes has elapsed since the last focus, a focus run will be performed; if it hasn't elapsed, the checking process will repeat before the next exposure starts. You should set up a brief series of exposures to insure FocusMax can focus satisfactorily with all of the planned filters in place, adjusting the focus exposure to be appropriate to a given filter as described below. Make any adjustments to the FocusMax settings required.
- **Filter for Focusing:** If your filters are sufficiently parfocal, i.e. they all focus at the same point, you may choose to use one specific filter for focusing. That way you can avoid having to deal with different focus exposures for different filters. If your filters are not parfocal, you should determine and use filter offsets.
- **Post Focus Offset:** This setting can be used to minimize the effects of OTA field curvature. The intent is to "split the difference" between perfect focus at the center and focusing at the edge of the field of view. For OTA's without a field flattener and/or a large imaging chip, there can be a significant difference in the focus position between center and edge. First, determine the focus at the center of your OTA and then determine it at some point away from the center. A good starting point is 60% of the way to the corner. You can use the Focus Now button to determine these values. Average a number of focus runs at each location. Calculate the offset and enter it in the Post Focus Offset. For best results, the Center Focus Star option and SkyStar focusing should be used. After achieving focus, the post focus offset will be added or subtracted to the focus results, according to the sign of the entry.
- **Focus Timeout:** Occasionally a focus routine can end up never getting to a focus position that meets its requirements. By setting this timeout, your session will continue after the specified timeout, aborting the focus activity in progress and resetting the focuser position to where it was before the focus routine started.

Temperature Dependent Refocus

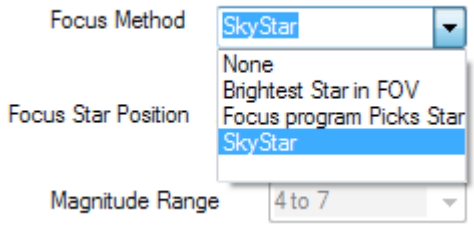
By characterizing your imaging system's performance, it is possible to refocus only when necessary. Knowing how much temperature impacts your focus, you may elect to refocus every time the temperature change is such that your focus moves out of the Critical Focus zone. Thus, having a source of temperature measurement and knowing how much of a change will adversely impact your focus, you can check **Focus on Temp Change of**, enter a suitable change amount, select the **Temperature Source**, and refocus as needed. Depending on what control programs are connected to CCDAutoPilot, the available choices will be selectable as temperature sources. Make sure you choose one if you are using this option.

Temperature Compensation

If **Use Temp. Slope of** is checked and your focuser supports temperature compensation, it will be enabled. Temperature compensation will be disabled automatically during the main exposure. At the conclusion of the main exposure, temperature compensation will be re-enabled and a 5 second delay will be initiated to allow time for temperature compensation. To use temperature compensation, the user must provide a **Compensation Slope** that appropriately characterizes the system. This value should be counts/temperature needed to maintain focus. When **Temperature Source** is changed, the reported temperature will be shown in the status bar. If "n/a" is shown, the source selected does not report temperature and temperature compensation cannot be used. There are many ways to determine the compensation slope. The basic process is to measure the focus point at different temperatures and calculate the slope. An imaging session with 10 minute exposures and a focus before every exposure during a period

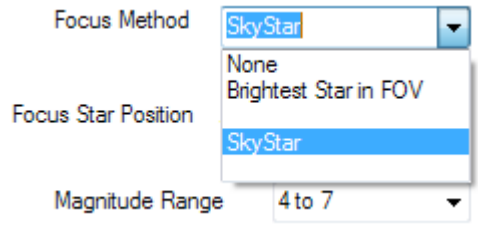
of temperature change is a good way to get the raw data. A least squares fit then gives a good slope. The compensation slope should be in units of focuser count per unit temperature. Be sure the temperature reported, °C, °F or counts used for the measurement is the same as that reported as Temperature Source. The focus starting point will be determined at the beginning of a session and the starting temperature noted. At each subsequent focus adjustment, the starting point and temperature will be redefined. Between exposures, the focus point will be adjusted, based on the current temperature and the user-supplied Compensation Slope. **Note:** If focuser temperature compensation is enabled in either your focuser or focus control program, it must be disabled when CCDAutoPilot is linked.

CCDSoft @Focus2 Differences



@Focus 2 has a limited choices of **Focus Methods** as shown above and the **Magnitude Range** is not needed since it uses its own database query to find focus stars.

Maxim



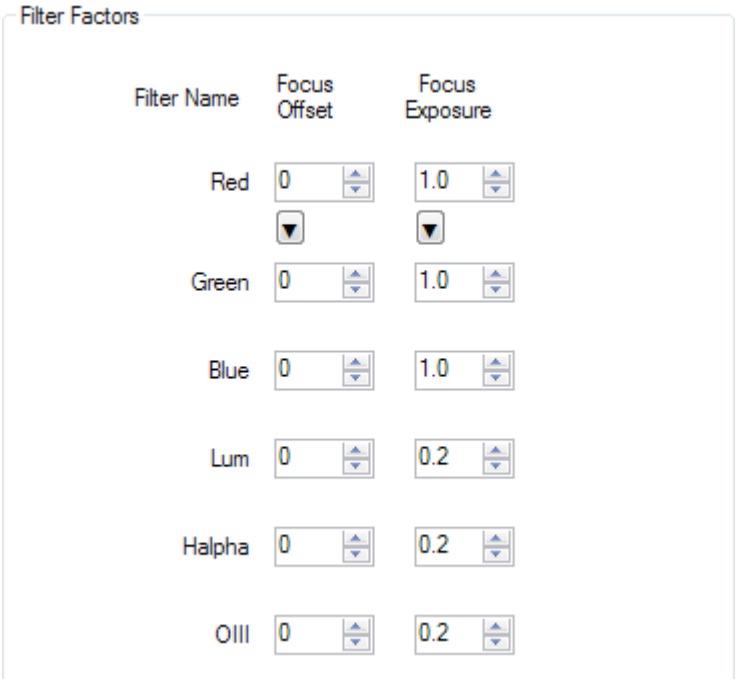
Maxim's internal focus routine fewer **Focus Methods**, as shown above.

8.10.1 Filter Factors

Filter Factors

There are some differences between the three focus programs that are described here.

FocusMax and Maxim Filter Factors

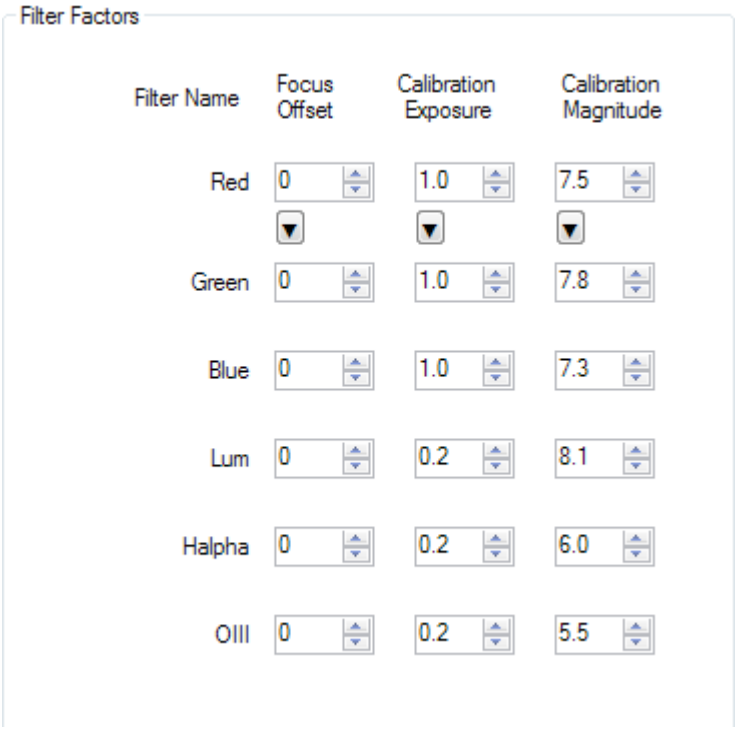


There will be as many entries here as you have defined filters in your camera server program.

- **Focus Offset:** enter how many counts you wish your focuser to move for a given filter. Normally one filter would be the reference and the others would move an amount, either + or -, relative to that reference. The reference filter should be the filter you select for plate solving - usually a clear or luminance filter. If your filters are parfocal, i.e. they all focus at the same focuser position, you would enter 0 for all the filter offsets. The ▼ button at the top sets all filter offsets to the same value as that of the first filter entry. If some filters, typically some Halpha filters, are sufficiently non-parfocal, you can speed up the active focusing method considerably by entering the offset. That way, automatic focusing will start closer to the ultimate focus position. Focus Offsets can be measured automatically using the wizard described here(See 8.14.7).

- **Focus Exposure:** As mentioned above, these fields provide a convenient entry point for the FocusMax and Maxim starting exposure. With most systems, the shortest exposure is suitable for focusing through the clear filter and the exposure time should be increased for less transparent filters. For example, you might set a 1 sec. exposure for color filters and a 2 - 4 second exposure for narrow band filters such as Halpha or OIII.

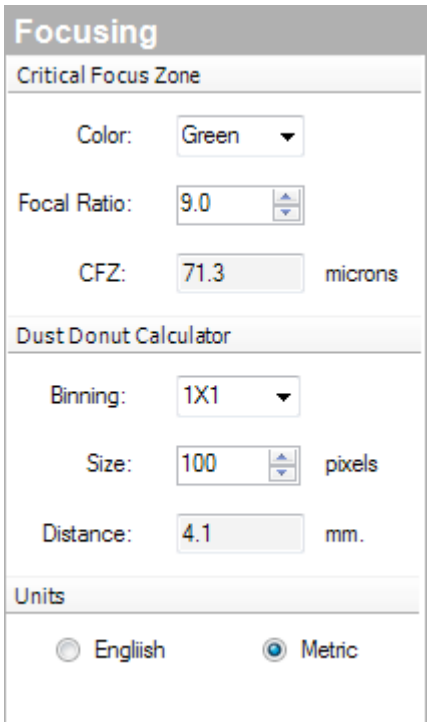
CCDSoft @Focus2 Filter Factors



There will be as many entries here as you have defined filters in your camera server program.

- **Focus Offset:** enter how many counts you wish your focuser to move for a given filter. Normally one filter would be the reference and the others would move an amount, either + or -, relative to that reference. The reference filter should be the filter you select for plate solving - usually a clear or luminance filter. If your filters are parfocal, i.e. they all focus at the same focuser position, you would enter 0 for all the filter offsets. The ▼ button at the top sets all filter offsets to the same value as that of the first filter entry. If some filters, typically some Halpha filters, are sufficiently non-parfocal, you can speed up the active focusing method considerably by entering the offset. That way, automatic focusing will start closer to the ultimate focus position. Focus Offsets can be measured automatically using the wizard described here(See 8.14.7)

8.10.2 Info Window



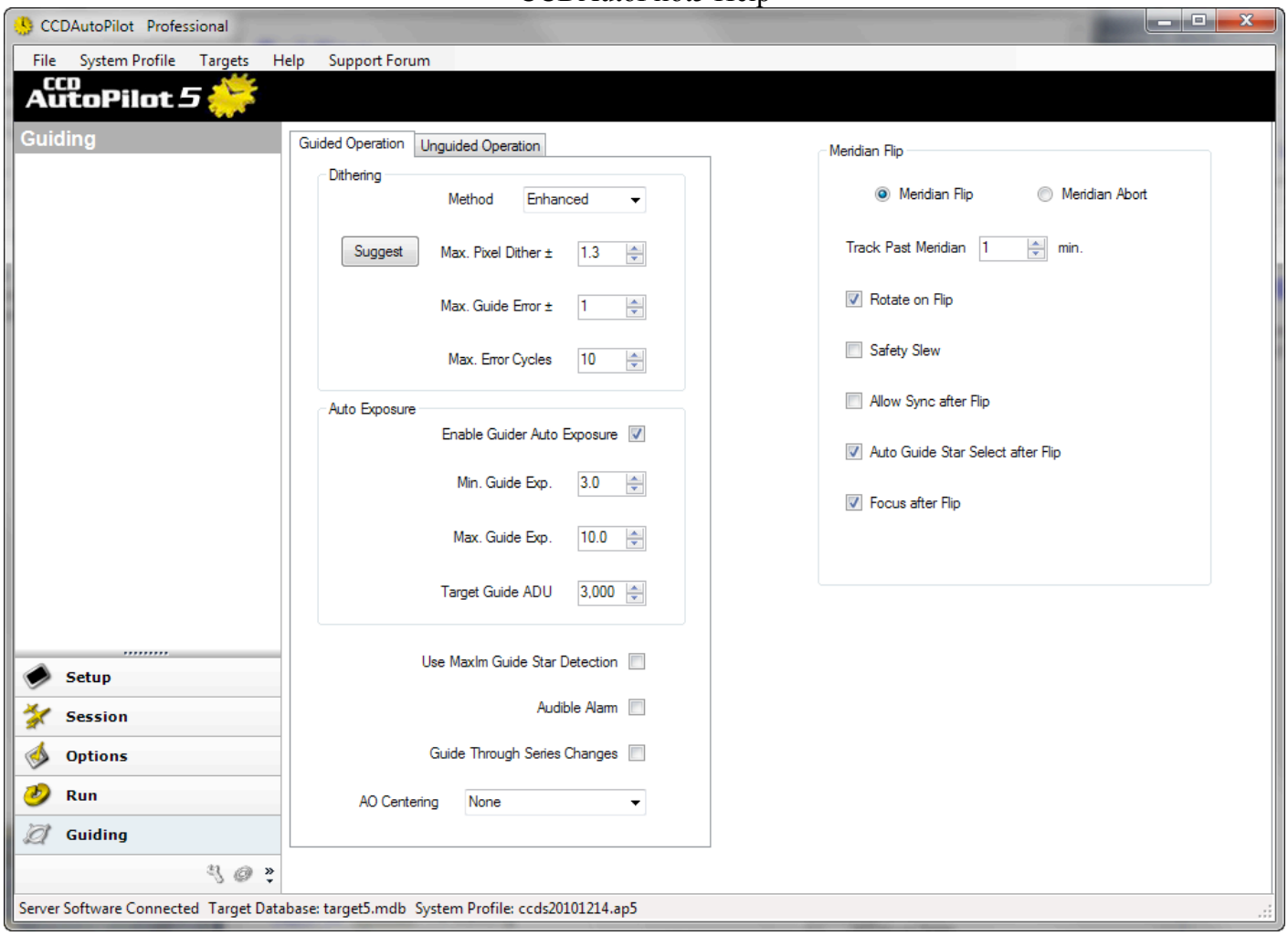
There are two calculators provided with your choice of English or Metric units. The Critical Focus Zone calculator gives the depth of the CFZ as a function of the wavelength of light and the Focal Ratio (F/#) of your system. This calculator can be useful to determine how often you need to refocus with temperature changes or even how repeatable your focusing is. It now uses the more aggressive calculation based on the Goldman/Megdal article, In Perfect Focus, in Sky & Telescope, August, 2010.

The other calculator is useful for determining where a dust particle is by measuring its resultant dust donut diameter in pixels. Simply measure the diameter of the dust donut in pixels and define the binning used. Based on the unbinned plate scale entered on the Settings page, the distance from the imaging plane to the dust particle is calculated.

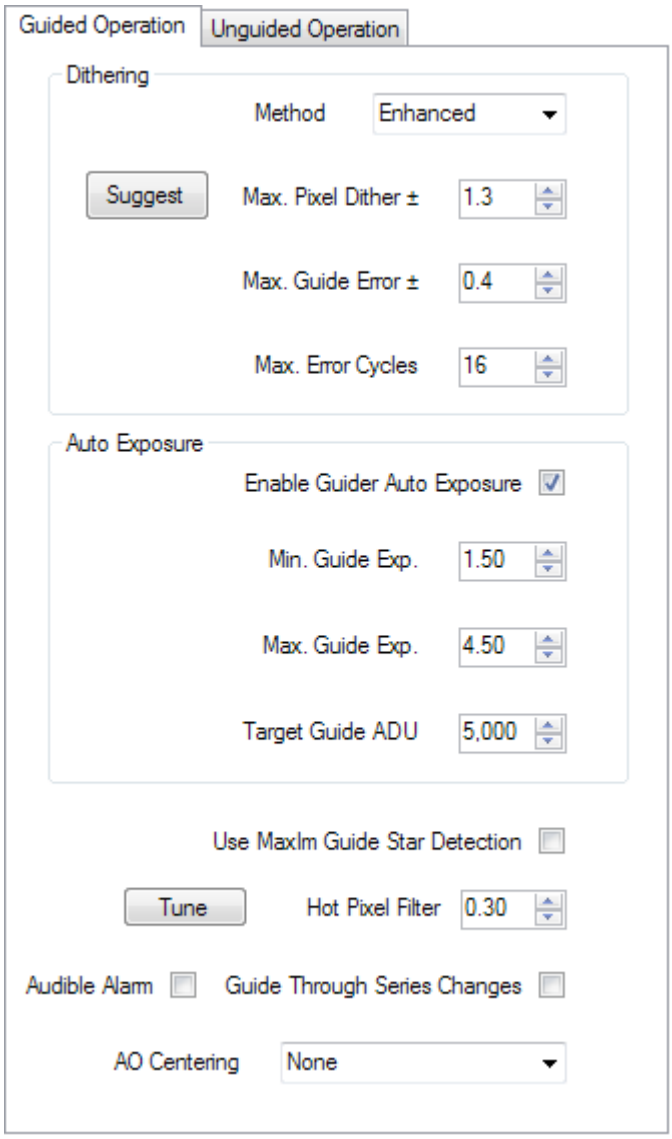
8.11 Guiding

8.12 Guiding

Here is where you set the parameters for guided or unguided operation. Click on the tab at top to change to the select the desired operation. The action choices for meridian crossing with an equatorial mount are also entered here.


CCDAutoPilot Professional
File
System Profile
Targets
Help
Support Forum
CCD AutoPilot 5
Guiding
Guided Operation
Unguided Operation
Dithering
Method
Enhanced
Suggest
Max. Pixel Dither ±
1.3
Max. Guide Error ±
1
Max. Error Cycles
10
Auto Exposure
Enable Guider Auto Exposure
Min. Guide Exp.
3.0
Max. Guide Exp.
10.0
Target Guide ADU
3,000
Use MaxIm Guide Star Detection
Audible Alarm
Guide Through Series Changes
AO Centering
None
Meridian Flip
Meridian Flip
Meridian Abort
Track Past Meridian
1
min.
Rotate on Flip
Safety Slew
Allow Sync after Flip
Auto Guide Star Select after Flip
Focus after Flip
Setup
Session
Options
Run
Guiding
Server Software Connected
Target Database: target5.mdb
System Profile: ccds20101214.ap5

8.12.1 Guided Operation



After successful initialization, CCDAutoPilot automates the guided operation parameters for optimal guiding. Regardless of where you are pointed in the sky and at what rotation your camera is, the optimal guide vectors will be developed and applied to your camera control program. Initial guide star detection is accomplished in CCDAutoPilot. Its location is determined through three exposures to avoid selecting a cosmic ray hit or other artifact via an outlier rejection routine. For automatic guide star exposure, three measurements are averaged to more accurately set the guide exposure time. And if the guide star is lost due to passing clouds, the Automatic Guide Star Recovery routine (see below) is invoked to try to recover the guide star if at all possible.

Dithering
Dithering is a process whereby the guide star location on the guider chip is moved between image exposures in either a random or optimized manner. When the guider control repositions the guide star to the new location, the image will be slightly displaced on the imager chip. When the resultant images are aligned and properly combined, hot and cold pixels, cosmic ray hits and other sensor-specific artifacts are removed, much better than any hot/cold pixel routine can ever hope to achieve. The resultant image is smoother and artifact-free. See this link for more details on this technique.
Dithering can be done either totally randomly, as determined by a random number generator, or in a controlled manner to maximize separation between each sub-exposures artifacts while minimizing the overall guide star movement. Both options are provided. The amount of the dither is user-definable. Here is a discussion on how to set the amount of dithering.

- **Dither method:** Select Enhanced (preferred), Random or None.
- **Max. Pixel Dither:** This is the peak dither value and can go +/- from the starting direction. As an example, suppose Enhanced Dithering is selected with a Max Dither of 3 pixels. The first sub-exposure will leave the guide star position undisturbed. The second will move the X position of the guide star + 3 pixels. The third will move the X position of the guide star - 3 pixels *from the first exposure.* Thus the total movement between the second and third exposure is 6 pixels but the movement relative to the first sub-exposure is ± 3 pixels. If dither is set to 0, guiding will not be stopped between exposures except for any specified focusing actions.
- **Suggest:** this button will enter a Max. Dither value, based on the parameters of your system entered on the settings page. This can be a starting point from which you can experiment if you desire.

Automatic Guide Star Recovery (AGRS)

Many times when a guide star fades, the guider drives the telescope off the target in its quest to find the guide star. CCDAutoPilot has a technique to prevent this from happening in an attempt to minimize data loss. If the guide star position is not recovered to the user-specified tolerance in a user-specified number of attempts, AGRS institutes a number of procedures in an attempt to recover the guide star. If all those attempts fail, the image is allowed to continue unguided to prevent the guide star search from driving the telescope from its intended target. AGRS is repeated at the start of the next sub-exposure so that, if the passing cloud has passed for example, the guide star is recovered and guiding continues on target. An optional Audible Alarm can be sounded to alert a nearby operator of the failed guide star recovery attempt. This has proved instrumental for some users in alerting them to an impending bad weather condition, although this should not be relied upon for equipment protection.

- **Max. Guide Error:** If the maximum error is specified at 0, AGRS is disabled; if it is any other value, AGRS is enabled. This entry specifies the value the guide error has to get down to during guider restart before the exposure is permitted to continue.
- **Max. Error Cycles:** This specifies how many tries the guider has to get the guide star error below the Maximum Error. If the guider does not get the guide error below the specified Maxim Error in the specified Maximum Error Cycles. AGRS is activated.

Automatic Guide Exposure

When Auto Guide Exposure is checked, CCDAutoPilot will set the guide exposure automatically to achieve the Target Guide Exposure you have entered within the Min. Guide Exposure time and Max. Guide Exposure time you specify. This automatic setting is done at the star of each series and after a meridian flip. If it can't get to your target level within the range you specify, it will go to the Min. Guide Exposure time if the Guide ADU is too high or to the Max. Guide Exposure time if the Guide ADU is too low.

When using Auto Guide Exposure, the Guide Exposure settings on the Light Frames page are ignored and grayed out as a reminder except in one case. If the Guide Exposure on the Lights page is 0, this is interpreted as a desire for unguided imaging for the series with a zero value Guide Exposure. If you intend to use Automatic Guide Exposure for guided imaging, be sure to enter non-zero value(s) for the series you wish to be guided *before you select Automatic Guide Exposure,* to avoid the series being unguided. Once you have a non-zero value entered, 1 sec. will suffice, select AutoMatic Guide Exposure and the guide exposure will be in the range you specify, between Min. and Max. Guide Exposure.

- **Use Maxim Guide Star Detection:** With some guiders, guide star detection may be problematic. Even though every effort is made by CCDAutoPilot to select an appropriate guide star, in some cases it may be appropriate to use Maxim's guide star selection routine. Checking this box allows this option. Note that if this option is checked, Auto Guide Exposure is not possible nor is the ability to ignore saturated guide stars. (It is generally agreed that best guiding performance is obtained with unsaturated stars. CCDAutoPilot uses technology to avoid saturated stars for guiding.)

- **Hot Pixel Filter: When using guiders without a shutter, it is not possible to take a dark-subtracted guide exposure. A hot pixel may be confused for the guide star. CCDAutoPilot's proprietary algorithm provides some rejection of hot pixels that reduces this issue. The strength of the filter increases with increasing values with 0 fully disabling the filter. The Hot Pixel Filter is only effective when CCDAutoPilot**

determines the guide star location. This filter should not be necessary when using a guider with a shutter that allows dark-subtracted images but one can certainly experiment to see if there is any advantage to using it. See Tune, below, for how to set the filter strength.

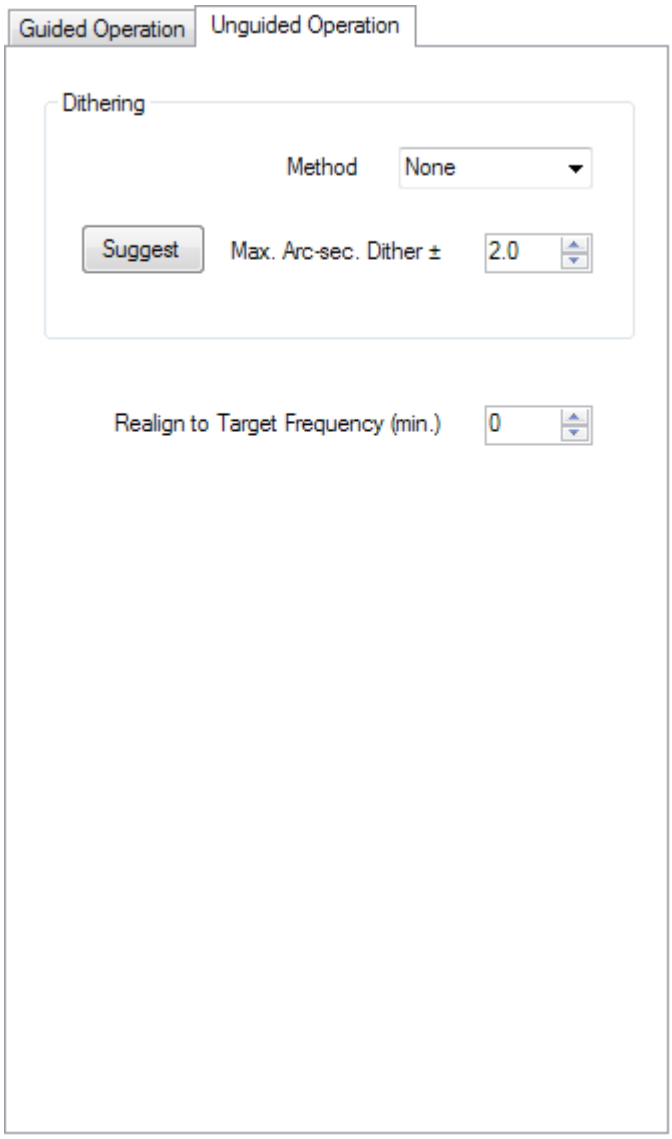
- **Tune: Start with a hot pixel filter strength of 0.1. Move the telescope as needed to place a guide star in the guider's FOV. Adjust the guide exposure so that the peak ADU is around 5,000. Note the guide star position in the camera control program. Hit the tune button to analyze the guider image. The detected guide star position will be displayed. If this position does not agree with the position of the guide star determined above, it is likely a hot pixel is being detected as the guide star. Increase the filter strength and hit Tune again. Repeat until the guide star position and not the hot pixel position is determined as the guide star. Increase another 0.1 for a safety margin. Try lower guide star ADU values to determine how bright a guide star is needed and still not detect a hot pixel in error.**

- **Audible Alarm: When checked, a somewhat annoying sound is played through your computer's speakers to alert a local operator of AGSR activation. You can replace this sound file, which is located in the program directory with the name alarm.wav with another file. Just be sure your other file is a .wav format and name it alarm.wav.**

- **Guide Through Series Changes: When checked, the guider is not stopped during exposures. The dithering must be set to 0 as well. This is useful for multi-filter photometry when disruption for dithering is undesirable. Automatic guide star exposure cannot be used when this option is selected since the guider must be stopped to measure the guide star. When using this option, be sure to set the Guide Time appropriately for each series on the Session page.**

- **AO Center: When an Adaptive Optic corrector is used for guiding, the mirror/glass position could be at some point other than 50% when slewing to a target. You can select None for no centering, Start of Each Series to center before the first exposure of a series or Start of Every Exposure to center the adaptive optic at the start of every exposure. Set to None when not using AO.**

8.12.2 Unguided Operation



During unguided operation, the same benefits that accrue during Guided Operation can be achieved. Here, the mount is moved slightly between exposures.

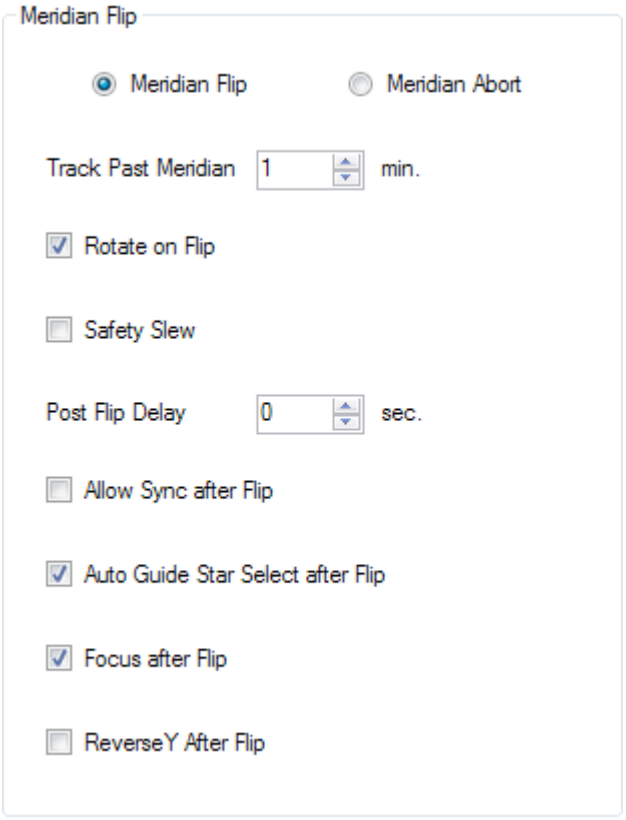
Dithering can be done either totally randomly, as determined by a random number generator, or in a controlled manner to maximize separation between each sub-exposures artifacts while minimizing the overall guide star movement. Both options are provided. The amount of the dither is user-definable. Here is a discussion on how to set the amount of dithering.

- **Dither method:** Select Enhanced (preferred), Random or None.
- **Max. Pixel Dither:** This is the peak dither value and can go +/- from the starting direction. As an example, suppose Enhanced Dithering is selected with a Max Dither of 3 arc-sec. The first sub-exposure will leave the mount position undisturbed. The second will move the mount +3 arc-sec. in RA. The third will move the mount - 3 arc-sec.*from the first exposure.* Thus the total movement between the second and third exposure is 6 arc-sec. but the movement relative to the first sub-exposure is ± 3 arc-sec. If dither is set to 0,the mount will not be moved between exposures.
- **Suggest:** this button will enter a Max. Dither value, based on the parameters of your system entered on the settings page. This can be a starting point from which you can experiment if you desire.

Periodic Realignment

When a long series of unguided exposures are taken, the mount will gradually track off the target. By using this feature, the telescope is periodically realigned to the target coordinates. If any periodic focusing using SkyStar is implemented, target realignment will occur during that process. If that is used, additional periodic realignment will occur only as long as the time between SkyStar focus runs has exceeded the realignment period.
Realign to Target Frequency (min.): If 0 is entered, this function is disabled. If a non-zero value is entered, the telescope will be realigned to the target coordinates via a precision slew after the current exposure completes and after the specified interval has elapsed.

8.12.3 Meridian Crossing



When tracking a target in the east with an equatorial mount, eventually the meridian is approached or even crossed. While this is of no concern with a fork mount, a decision is required for equatorial mount users. There are basically two choices. **Meridian Abort**, whereby data acquisition for this target is halted and CCDAutoPilot moves on to the next target, or **Meridian Flip**, where CCDAutoPilot makes the changes necessary to pick up the target after flipping the mount on the west side of the meridian.
Automatic meridian flipping essentially uses software to turn an equatorial mount into the functional equivalent of a fork mount. This is achieved by allowing the telescope to track a target up to the meridian, stop the exposure, move the telescope to the other side of the meridian and then continue tracking. If a rotator is employed, the camera is rotated by 180°, the guide star is reacquired and guide calibration is appropriately adjusted. All this is accomplished automatically. Automatic meridian flipping depends on successful plate solving and Initialization.

- **Track Past Meridian: If the value entered is positive**, this indicates the number of minutes your mount can track past the meridian and defers the flip for your specified number of minutes. Depending on the above two settings, you may be able to get another exposure in before meridian crossing and eliminate the wait time for the meridian flip. Observatory users using DDW or ASCOM for observatory control should insure their shutters permit crossing the meridian by the PM Tracking time since dome tracking is disabled 2 minutes before a meridian flip. AutomaDome has no such limitation since it integrates tightly with TheSky. **If the value entered is negative**, the mount backs up 1 hour in RA in the east and the session waits for the specified number of minutes. It can be used if your mount has some ambiguity in slewing to a location whose RA has passed the meridian. By setting Meridian Tracking to -10 or so, the target RA will be 10 minutes past the meridian before meridian flip is enabled. Some

experimentation may be required for the smallest negative value that will work. For some mounts, this may need to be used in conjunction with Safety Slew, below.

- **Rotate on Flip:** If checked and a rotator is connected to CCDAutoPilot, the meridian crossing event will also trigger a rotator movement by 180°. Thus the images on the west of the meridian will be the same orientation as on the east side of the meridian.

- **Safety Slew:** Some mounts, notably the Gemini, will not flip even though the target has crossed the meridian. Checking Safety Slew will slew the mount one hour past the meridian, which will force the flip, and then back to the target. This should eliminate the need for the AM stop offset setting and it should be set to 0.

- **Post Flip Delay: The session will pause for the entered time before proceeding. This is useful to allow domes that do not have direct synchronization with the mount to "catch up" to the mount. Some domes depend on a text file written periodically to determine where the mount is pointing for dome synchronization.**

- **Allow Sync After Flip: If this option is checked, an image is taken and plate solved after a meridian flip. The mount is then sync'd to the center of the solved image. The correcting slew is then from this reference. Recommended for portable setups or for setups with poor pointing accuracy. If this option is cleared, there is no sync and the correcting slew is made from the plate solved position. This option should be cleared for permanent setups with good pointing accuracy as may be obtained with a suitable Tpoint model. If checked, any Tpoint models should be disabled as repeated syncing into a Tpoint model is not recommended and will result in pointing inaccuracies. Use either Allow Re-sync or Tpoint but not both.**

- **Auto Guide Star Select After Flip: If checked, an automatic detect of the brightest star in the field will be used to guide. If unchecked, the run will pause until you select a guide star and tell it to continue.**

- **Focus After Flip: When checked, the focus method chosen on the Focus page will be executed immediately after the meridian flip and before the next exposure.**

- **ReverseY After Flip: In very rare circumstances, it may be necessary with some guide cameras and using a Guide Scope (only) for guiding to select this option. Most properly configured systems should have this option unchecked.**

Tips on efficient meridian usage
With the various time settings, you can increase your meridian usage efficiency. Track Past Meridian is the amount of time your mount has to track past the meridian before it (the mount) knows it is time to flip and will do so. Let's assume you have determined your mount can safely track past the meridian for 15 minutes. Set the Track Past Meridian to 12 minutes for a safety margin. Now, assume you are taking 10 minute sub-

exposures at the time the mount approaches the meridian. Assume your meridian crossing is at 22:05. Here is a schedule of events you might see:

21:50 Take 10 minute exposure
22:00 Take 10 minute exposure
22:05 (Time to flip - deferred)
22:15 Flip meridian
22:18 Take 10 minute exposure
Now, if PM Tracking were set to 0, this would be the result
21:50 Take 10 minute exposure
22:00 Wait for meridian flip
22:05 Flip meridian
22:09 Take 10 minute exposure
Here are some excerpts from an actual log with PM Tracking set at 10 minutes:
>>> Here is the target information
20:02:28 Target: M1
20:02:28 Rise: 13:51 6 Feb
20:02:28 45° E elevation: 17:32 6 Feb
20:02:28 Transit: 20:50 6 Feb
20:02:28 45° W elevation: 00:09 7 Feb
20:02:28 Set: 03:50 7 Feb
20:05:49 Solved RA: 05 34 30.2, Dec: +21 59 17
20:05:49 Target RA: 05 34 30.2, Dec: +21 59 17 , PA: 358.4
20:05:49 Meridian flip after 20:51 Tue 6 Feb
>>> The mount would have flipped at 20:51 without the buffer time
>>> The exposure completed after the meridian flip time but before the 10 minute buffer elapsed.
20:43:31 Exposing...
20:54:15 D:\Astronomy\070206_M1\Clear356E_M1_00006.fit
>>> And then the mount flipped immediately.
20:54:18 Waiting for meridian flip time...
20:54:18 Meridian flip starting...

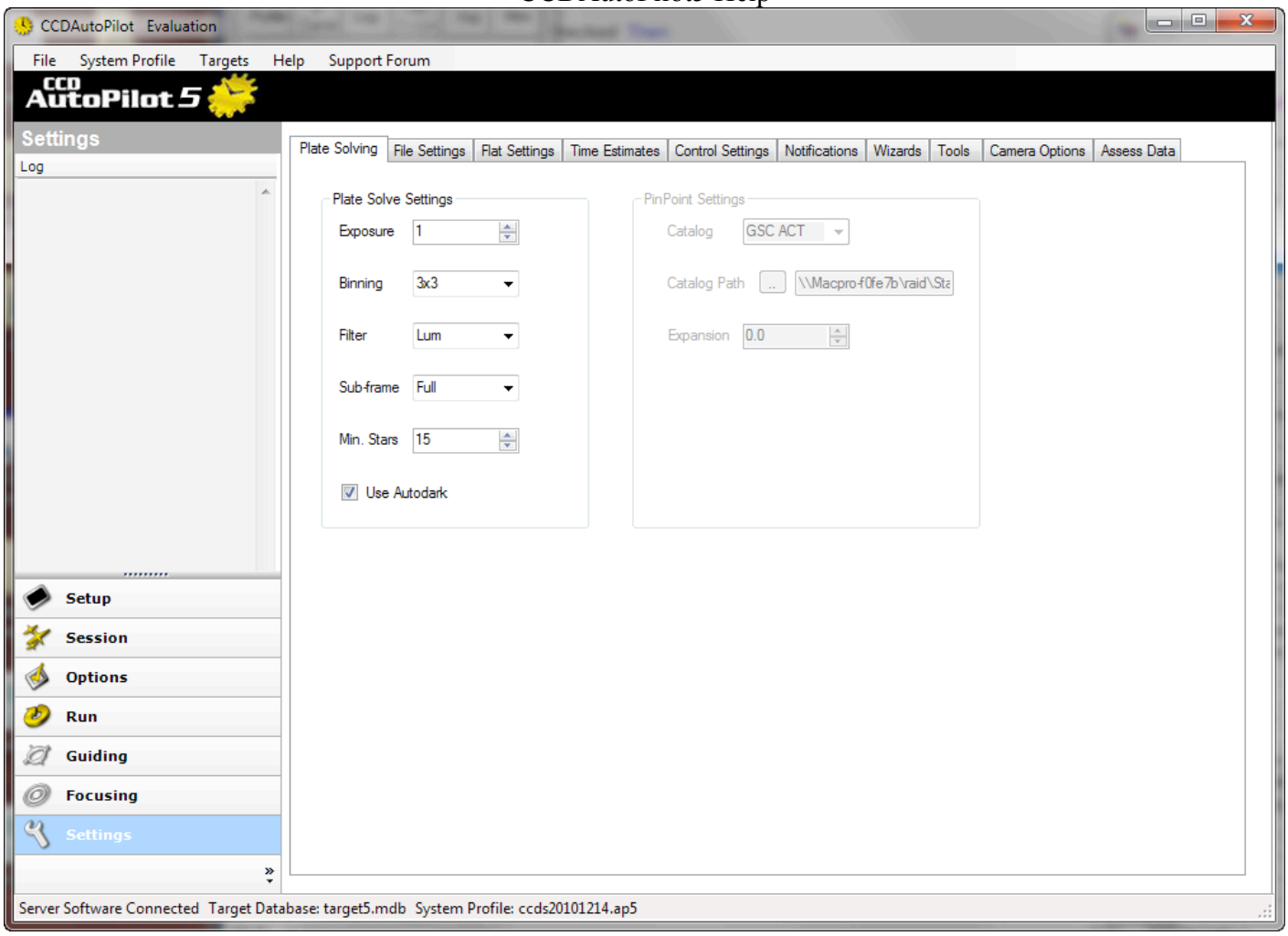
If your mount is capable of longer tracking past the meridian, the flip can be deferred longer, for example in the case of an Astro-Physics mount which can track for a number of hours past the meridian, depending on telescope, camera size and orientation, declination, etc.

Warning: It is up to the user to determine the proper Track Past Meridian. In addition to consulting your mount's documentation, you should also experiment at various declinations, while watching the mount. If you rotate your camera, you should also verify this setting at various camera rotations.

8.13 Settings

8.14 Settings

Here is where you can customize CCDAutoPilot to meet your needs. Each tab is discussed in the next topics



The Log window on the left is used to record certain actions of tools and wizards on this page.

8.14.1 Plate Solving

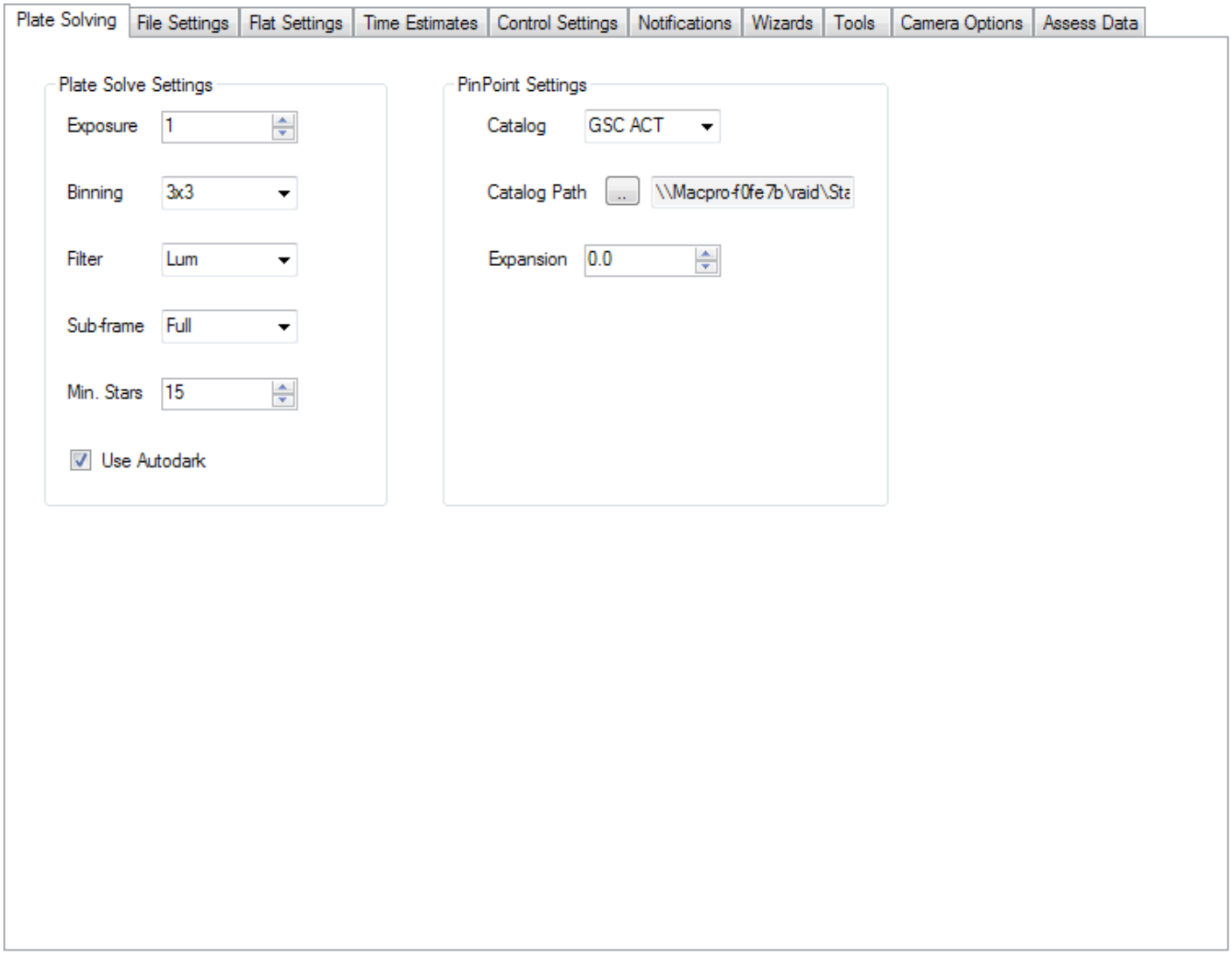


Plate Solve Settings

- **Exposure:** Enter the exposure time in seconds for plate solve exposures.

- **Binning:** Select the binning desired for plate solve exposures

- **Filter:** Select the filter desired for the plate solve exposure. Usually this is the most transmissive filter such as luminance or clear

- **Sub-frame:** If you have a wide field system, selecting a sub-frame may result in faster plate solving.

- **Min Stars:** This sets the minimum number of stars required for a plate solution to be accepted. Setting this number too low may lead to a false solution. 15 represents a safe minimum.

- **Use Autodark:** When CCDSoft is used, the plate exposures are auto-dark subtracted. Unchecking this box disables auto-dark.

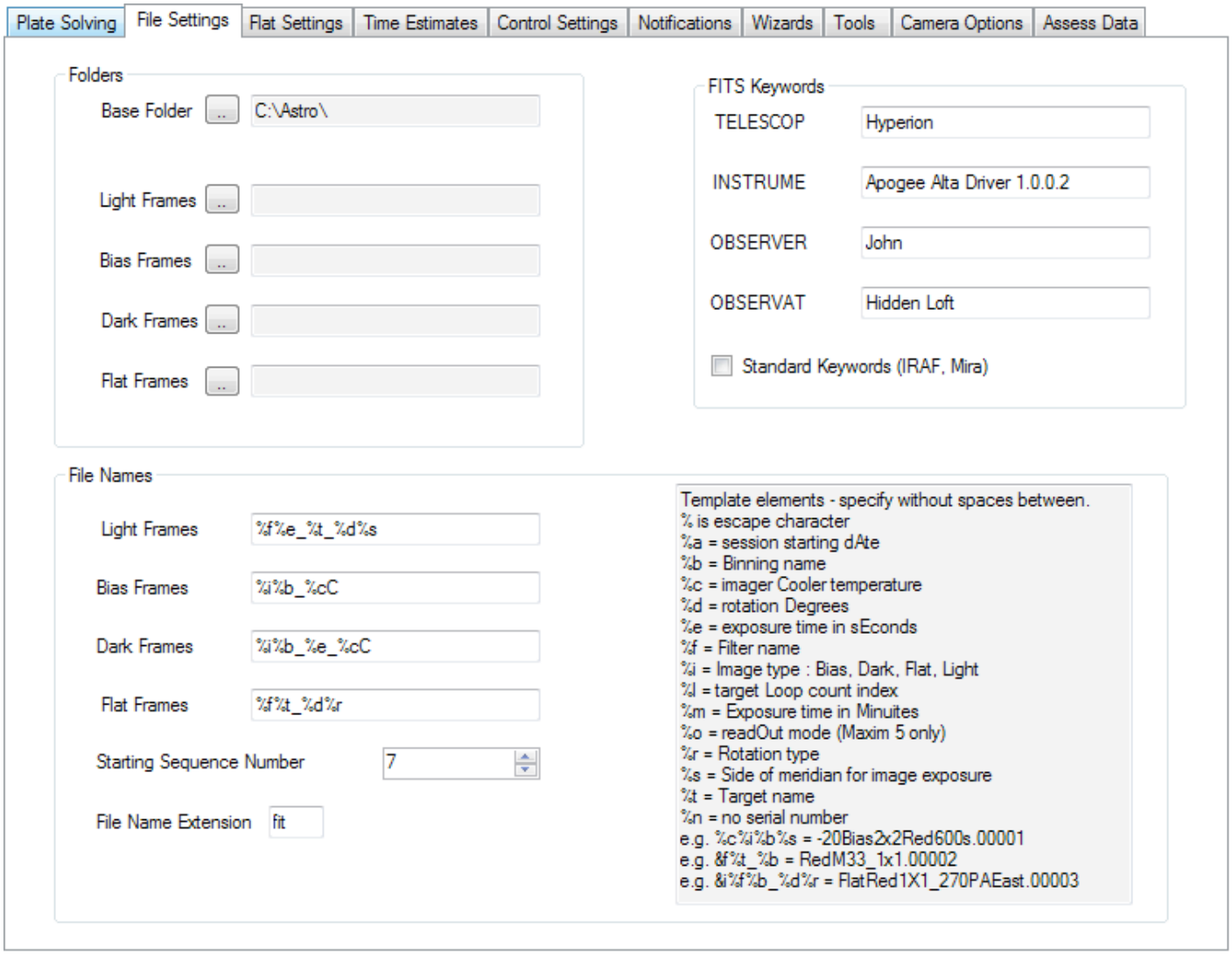
PinPoint Settings

- **Catalog:** Select the desired stellar catalog to be used for plate solving. For most users, GSC-ACT will serve very well but other catalogs are also supported.

- **Catalog Path:** Press the  to navigate to the root folder of your chosen stellar catalog. This catalog must agree with the catalog selected above.

- **Expansion:** Sets how much beyond the imager FOV PinPoint will search for a solution. If your pointing is not precise, increasing this value can make plate solutions more probable albeit with increased solve times.

8.14.2 File Settings



Folders

The folder structure consists of a base folder and individual folders which can be customized for different frame types. If the field is blank, the default settings are used. If you want to clear a folder's path, hit the ..button and then select Cancel when the window opens. If the base folder is blank, the default base folder is
`(My)Documents\CCDWare\CCDAutoPilot5\Images\`
If the light frame folder is blank, the light frames folder is
`<base folder>\yyyymmdd_<target name>\Data Files`
If any of the bias, dark or flat folders are blank, all calibration files will be placed into
`<base folder>yyyymmdd_<target name>\Calibration Files`

File Names

If the description field on any series on the Session page is not blank, then the file name will be defined by that Description, followed by a 5 digit sequence number, followed by an extension, typically .fit.

If the Description field on the Session page is blank, then the file names are defined by the appropriate template, followed by a 5 digit sequence number, followed by an extension, typically .fit. File name templates

can be used for each frame type. A '%' character is not legal as part of a file name but a '%' character followed by a letter will replace the '%' character and the following character by specific information as defined below:

- **%a enters the session starting dAte as part of the file name**
- **%b enters the Binning for the specific exposure**
- **%c enters the imager's Cooler temperature for the specific exposure**
- **%d enters the target position angle Degrees for the specific exposure**
- **%e enters the exposure time in sEconds for the specific exposure**
- **%f enters the Filter name for the specific exposure**
- **%i enters the Image type: Bias, Dark, Flat, Light for the specific exposure**
- **%l enters the target Loop count index**
- **%m enters the exposure time in Minutes for the specific exposure**
- **%o enters the readOut mode for the specific exposure (Maxim only)**
- **%r enters the Rotation type: PAEast, PAWest, Rotator for the specific exposure. This is applicable to flat frames only**
- **%s enters the Side of the meridian: E for east or W for west. for the specific exposure**

- **%t enters the Target name for the specific exposure. This variable is not recommended for calibration frames as dusk flats and darks taken before the light frames will have a null entry for the target and darks after light frames and dawn flats will have the last target acquired as the target name.**

- **%n *prevents* a serial Number from being entered. Caution: this is used in very special situations and should not generally be used as subsequent exposures will overwrite the previous one.**

If any text is entered in a template that is not preceded by a '%' character or after the first character after the '%' character, it will be entered exactly as entered for all file names for the given frame type.

If the backslash character, '\' is entered, a new folder will be created whose name is the text preceding the backslash.

You can experiment with different templates by entering the text in the space for each frame type and hovering the mouse over the space. You will see a sample file name in the tool tip window. This way you can check out the file templates before committing them to a session.

- **Starting Sequence Number: This represents the starting sequence number that will be used for a session. There is no need normally to reset this for each session but it certainly can be reset if desired.**

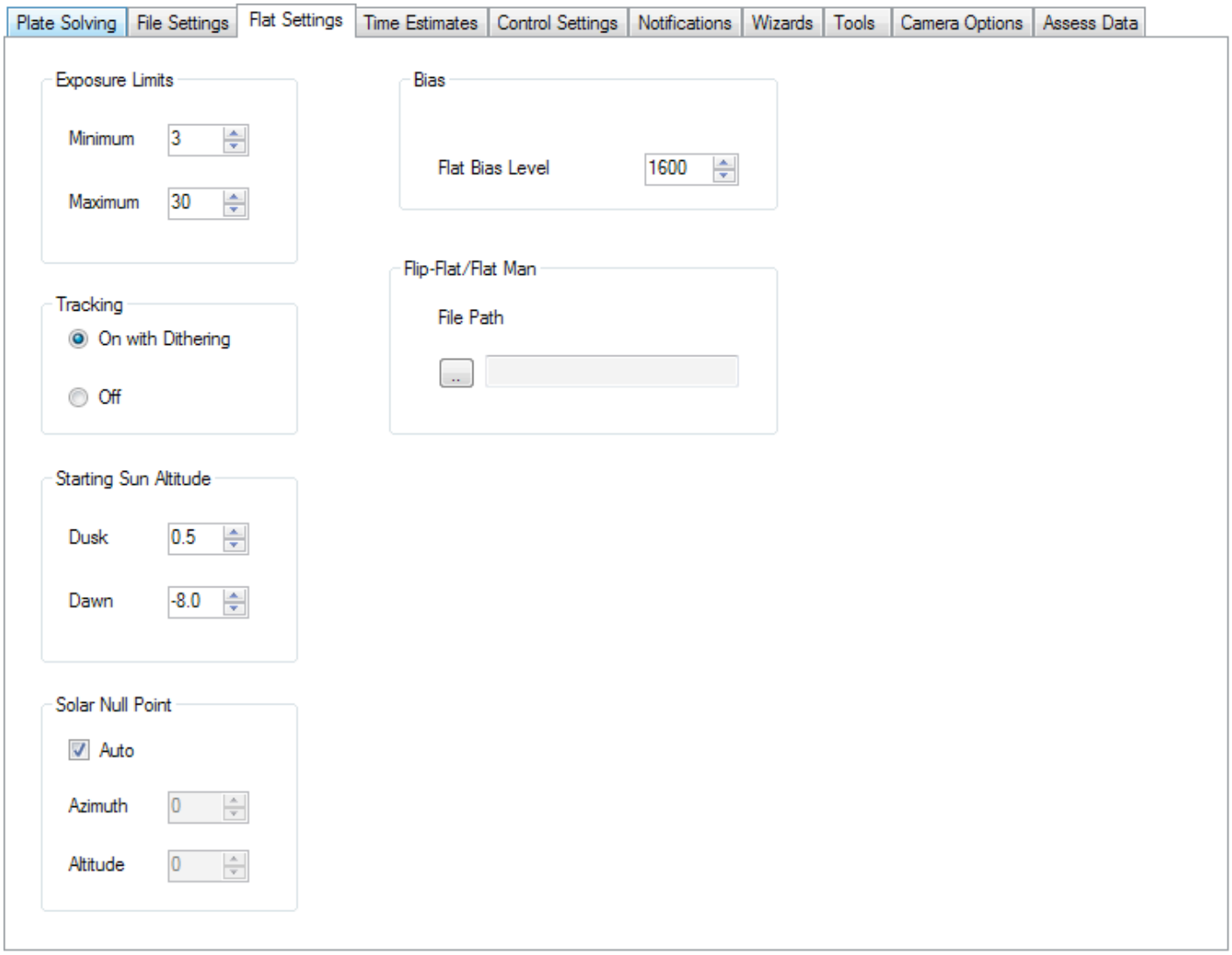
- **File Name Extension: This normally ".fit" but can be changed if needed by your processing application.**

FITS Keywords

These keywords are entered in the FITS header for every frame. If the INSTRUME keyword is left blank, the camera server will enter the name of the driver used.

- **Standard Keywords: is checked, the FITS Keyword IMAGETYP will use professional for light frame, dark frame, bias frame and flat frame will be used - LIGHT, DARK, BIAS and Flat, respectively. If cleared, the SBIG standard will be used, Light Frame, Dark Frame, Bias Frame and Flat Field respectively. It is recommended that the Standard keywords be used.**

8.14.3 Flat Settings



Exposure Limits

Set a **Minimum** exposure limit to prevent any shutter effects from distorting the flats. Set a **Maximum** exposure limit such that a bias frame is sufficient to calibrate the flat without having to worry about matching or scaling dark frames.

Tracking *(Sky flats only)*

Selecting **On** will move the mount between flat exposures. When using the twilight sky as the flat light source, stars may appear. By moving the mount between exposures, the stars can be eliminated in the master flat by suitable rejection combining techniques such a Sigma Reject. Selecting **Off** will turn off tracking. Any stars that appear will be trailed for the length of the exposure.

Starting Sun Altitude *(Sky flats only)*

These settings are the sun altitude at which to begin sky flat exposures for **Dusk** and **Dawn**. The values shown are good starting points but you may adjust them based on your own experience by reviewing the log.

Solar Null Point *(Sky flats only)*

When **Auto** is checked, the telescope will be slewed to that point in the twilight sky that has a minimum gradient, needed for good flats. When unchecked, you can enter your own altitude and azimuth for sky flats.

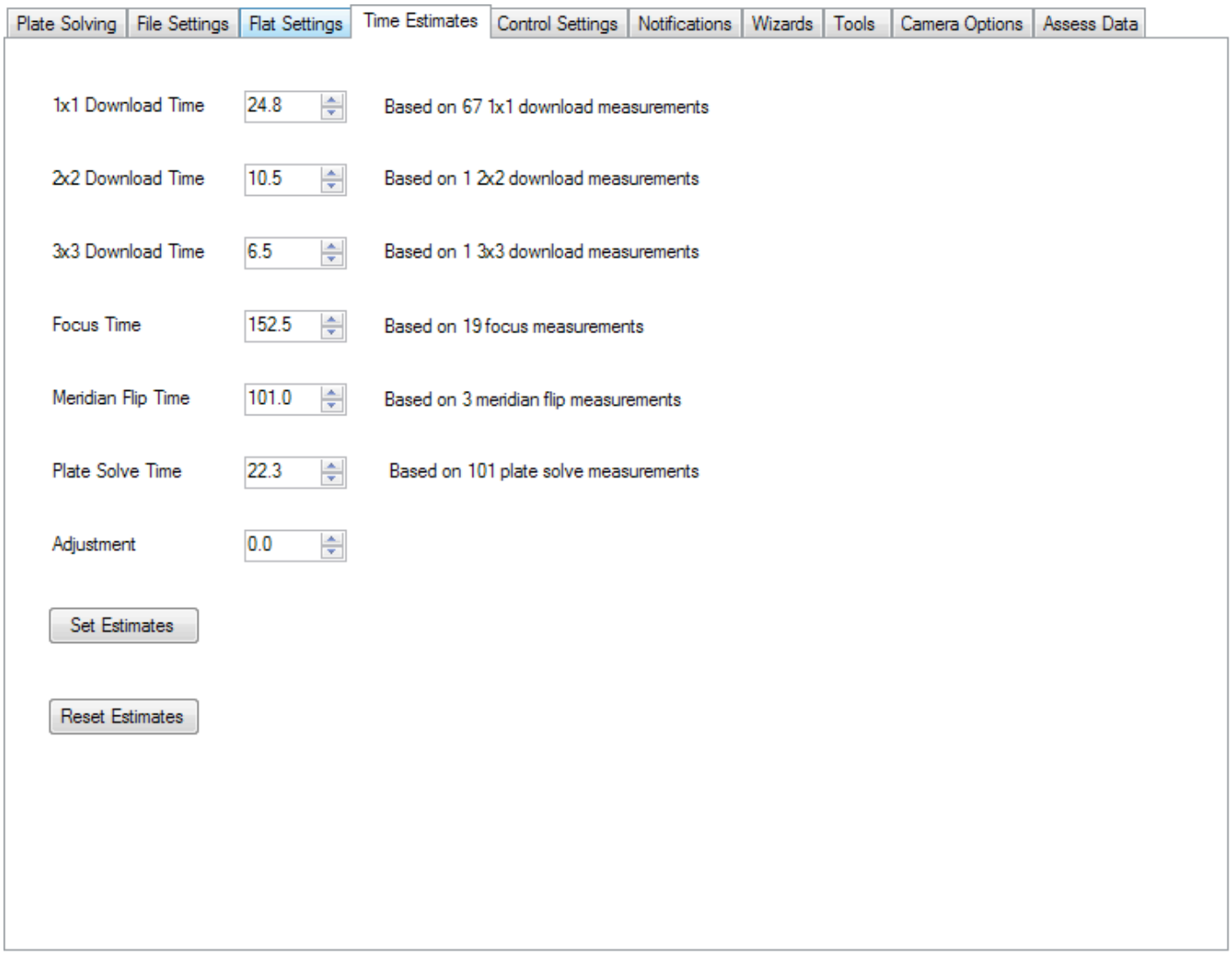
Bias

Enter the average bias level, if known, for your camera. This improves exposure convergence to the desired target ADU and is especially important when a dim flat source is used. If the average bias level is not known, then enter 0.

FlipFlat/FlatMan

- **CCDAutoPilot has integrated support for this flat panel. All that is needed is to use the**  **button to point to the AACmd.exe file, usually located at `C:\Program Files\Alnitak Astrosystems\Alnitak Astrosystems Controller\` To clear an entry, simply hit Cancel after hitting**  **.**

8.14.4 Time Estimates

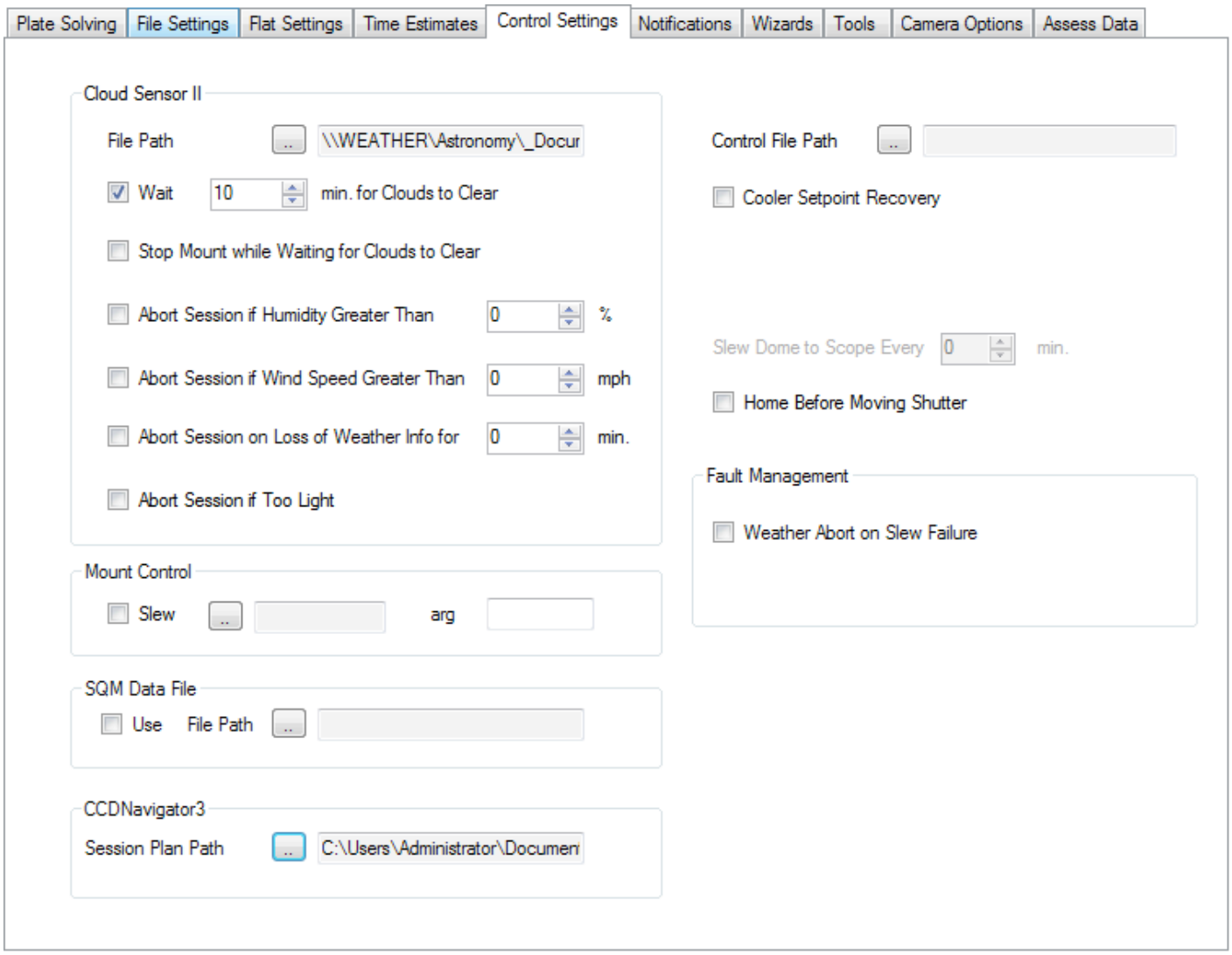


A key aspect of planning is the estimation of various event timings that occur during the course of an imaging session. These events are shown above. One can either enter estimates or let CCDAutoPilot develop them using its internal learning algorithm. The more sessions are run, the more accurate the estimates become. At the end of each run, the actual event history is compared with the estimates and the values are adjusted. Any differences are shown in the adjust box. As additional sessions are run, the magnitude of this adjust box decreases. When a run estimation is made, these event times are used to make the session estimated times more accurate. Note that download time estimates are based on light frame downloads only.

The **Reset Estimates** button is used to reset all estimates to 0 and start the learning process again from scratch. The **Set Estimates** button is used to enter an estimate where none exists or to enter a revised value.

In general, these settings are best made automatically.

8.14.5 Control Settings



Weather Sensor

- CCDAutoPilot uses the single line data file of the Boltwood family of cloud sensors and other cloud sensors that conform to this file structure. With this facility, multiple observatories can share a common cloud sensor as long as it is networked to each observatory. Set up the cloud sensor to write the single line file. Use the **File Path** .. **button to navigate to the location where this file is written. To clear an entry, simply hit Cancel after hitting** .. **. The remainder of the settings depend on whether a version I or version II cloud sensor is being used. The run abort condition is set if the cloud sensor reports very cloudy or rain.**

- **Wait for Clouds to Clear: When checked, if clouds come in and the cloud sensor is not "very cloudy", light frame acquisition will pause for the time specified waiting for the clouds to clear. If it clears before the specified time, the run will resume, if not the Run Abort Condition will be set.**

- **Stop Mount while Waiting for Clouds to Clear: When checked, mount tracking will be turned off while waiting for the clouds to clear.**

The following are Professional Edition features only.

- **Abort Session if Humidity Greater Than: When checked, the run abort condition will be set if the humidity exceeds the specified level.**

- **Abort Session if Wind Speed Greater Than: When checked the run abort condition will be set if the wind speed exceeds the specified level**

- **Abort Session on Loss of Weather Info: When checked, the run abort condition will be set if the weather monitoring thread fails or the cloud sensor/weather system stops updating for the specified time. See the Cloud Sensor Notes(See 12.7).**

- **Abort Session if Too Light: When checked, the run abort condition will be set during light frame acquisition if the sky is too light, i.e. the Cloud Sensor reports the Too Light condition (3). This is useful to set to terminate the session after dawn if an incorrect user setting allows the light phase to continue too long.**

Run Abort Condition
Should any adverse weather condition be set, including rain or water on the rain sensor, CCDAutoPilot will attempt to perform the certain Shutdown steps on the Options page - turn off tracking, park the telescope, park the rotator if one is used, close the dome and run the final application (Run 8 only) - whether these are checked or not. Any scheduled calibration frames, except for flats using the sky as a flat light source, will be acquired. The guider will be stopped if running. The camera cooler will be warmed up at the end of any calibration frame acquisitions only if checked on the Options page, Shutdown tab. A failure of any of these attempts will not impact subsequent steps.

Caution and Disclaimer
Both the Cloud Sensor documentation and common sense advise against relying on this device to protect valuable equipment. It is mainly intended as a monitor of sky conditions. See the Cloud Sensor documentation for details. CCDAutoPilot responds to changing sky conditions as a convenience to the user and in no way should be considered a fail safe approach. The most reliable usage, again without guarantees, is to have a direct connection between the Cloud Sensor and the dome control hardware emergency close switch with no intervening software. The dome controller should be on an uninterruptible power supply (UPS) to be able to close the dome in the event of a power failure.
None of this is any substitute for an attendant.

Mount Control
Some mounts benefit from running a custom application whenever the mount moves to the target or crosses the meridian. This application can be specified here.

- **Slew: When checked, CCDAutoPilot will run whatever application is entered after the mount has slewed to the target either at the beginning of a target session of after crossing the meridian. To enter an**

application, hit the .. to navigate to the specific application to be run. If the application requires any arguments to follow the application, enter them manually in the arg space. To clear an entry, simply hit Cancel after hitting ..

- SQM Data File: When checked, use the .. button to navigate to the Sky Quality Meter data file, as written by the SQM reader application. When active, the sky quality, as measured in mag. / arc-sec ^2 is added to the FITS header with the keyword MPSAS.

- CCDNavigator3 Session Plan Path: Use the .. to navigate to the folder that contains the session plan. To clear the entry, again hit the .. and press Cancel. See the Enhanced Automation(See 4.9) topic for suggested usage.

Control File Path *Professional Feature Only)*

- Use the .. button to navigate to the Control File Path.To clear an entry, simply hit Cancel after hitting .. See the Control File Editor(See 10.1) topic for details on this file structure.

- Cooler Setpoint Recovery: Some camera coolers, Apogee for example, have firmware that increase the cooler setpoint if the percent power used by the cooler exceeds a predetermined level. Since the evening generally cools down, this artificial increase in cooler setpoint becomes less necessary. Checking Cooler Setpoint Recovery will try to reset the imager cooler temperature to that entered on the Options page, Startup tab whether Set Imager Cooler is checked or not.

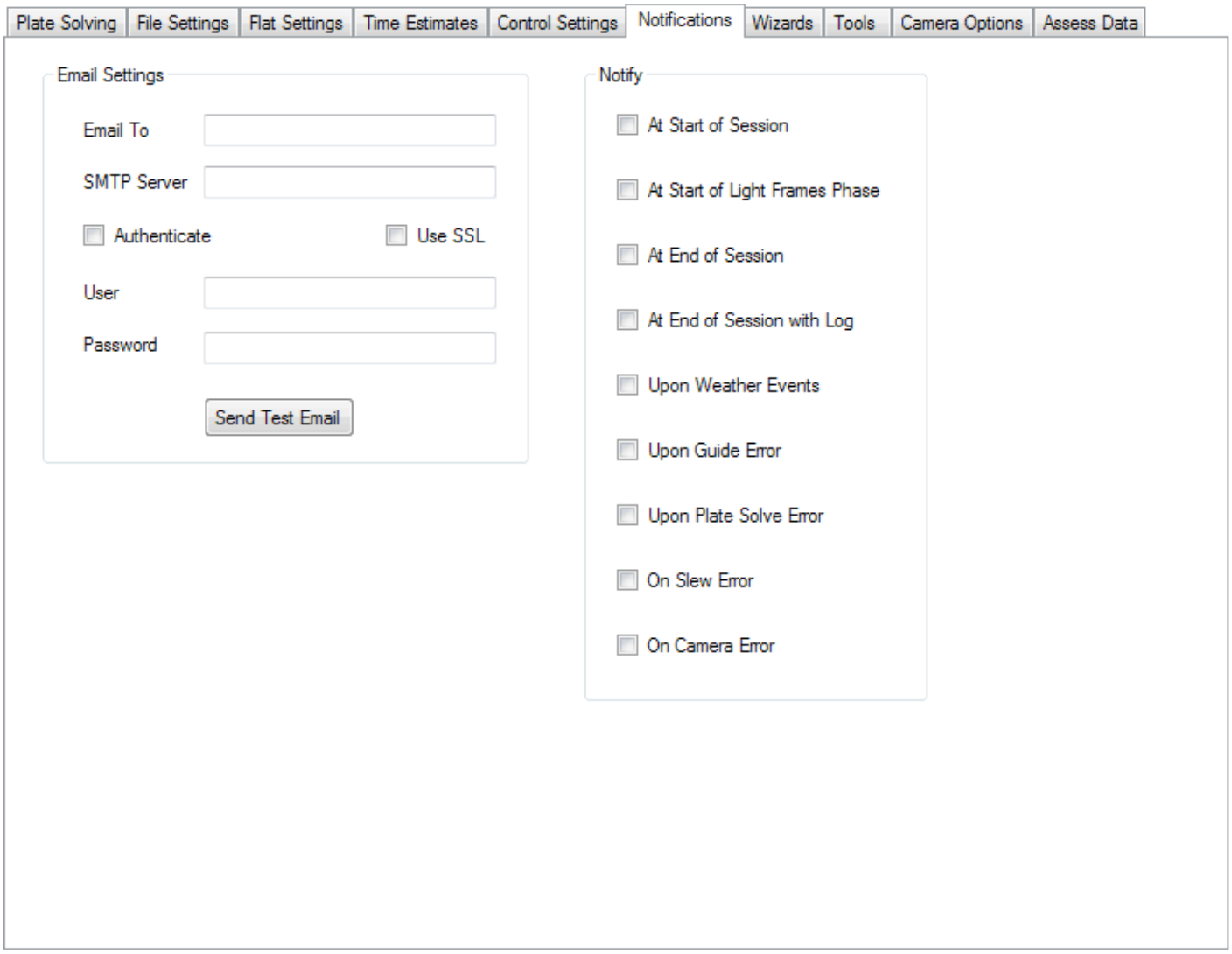
- Slew Dome to Scope (AutomaDome and TheSkyX (X2) only): The setting determines how frequently CCDAutoPilot should adjust the dome slit position to the telescope. (There is no need for any auxiliary VB script to maintain this alignment as CCDAutoPilot does this internally.) This time should be chosen such that the telescope doesn't move out of the slit when tracking a long exposure. For most systems, 4 min. or so should work fine. If more frequent adjustments are desired, the dome/telescope system should be checked over an extended period of time (hours) to verify proper centering and tracking.

- Home Before Moving Shutter: Some domes need to be at the home position in order to provide power to open and close the shutter. This class of domes should have this box checked. If the shutter power is provided independently so that homing is not required, this box may be unchecked and the dome will not home before opening or closing the shutter.

Fault Management

- **Weather Abort on Slew Failure: If there is a slew failure for whatever reason in TheSky6 or TheSkyX, the Run Abort Actions(See 8.14.5) will be executed. If the slew failure prevents the mount from moving at all, the mount may not be able to go to the park position. Caution: Before engaging this option, be sure your dome or roof can clear the telescope with the telescope in any position. If this is not the case, do not check this option.**

8.14.6 Notifications



Email Settings *(Professional Feature Only)*

Email notification is possible of significant events during the course of a session. In concert with the Control File(See 10.1) and the Notify settings, you can receive an email notification of a number of events. Enter an email address to which you want the notifications sent. TIP: If you enter the email address for your cell phone's SMS text message, you can receive a text message. You can enter more than one email address as long as they are separated by a comma ',' but no spaces or any other punctuation. You can test these settings using the **Send Test Email** button.

In order to receive these notification, you must have a valid email account established on the observatory's computer and CCDAutoPilot must be properly configured. As a minimum, you will have to enter the SMTP server, which is the same that is entered in your email client's account setup. If you need to enter a port other than the default standard which is port 25, enter the smtp server name followed by a colon ':', followed by the port name. For example: `smtp.mail.net` for a standard port and `smtp.mail.net:505` for a non-standard port 505. If your server requires

you to use Secure Sockets Layer, check the SSL box. CCDAutoPilot will use the default credentials (UserName and Password) you have entered in your email setup for that account. Be sure to test your settings by using the **Send Test Email** button. If you get an Authentication Error, proceed to enter your UserName and Password as described next.

Notify

With the Email Settings properly configured and tested, you can receive notification for any of the events shown in the Notify box. Of particular use for remote observatories is **At End of Session with Log**. It is very gratifying to receive the log of a successfully completed session when you awake!

- **At Start of Session:** Sends an email when the session starts. This is useful when using a programmed session start.

- **At Start of Light Frames Phase:** Sends an email when the light frame data acquisition begins.

- **At End of Session:** Sends an email when the session completes.

- **At End of Session with Log:** Sends an email when the session completes and attaches the log for the session.

- **Upon Weather Events:** Sends an email if any of the weather abort limits set in the Weather Sensor(See 8.14.5) box are hit.

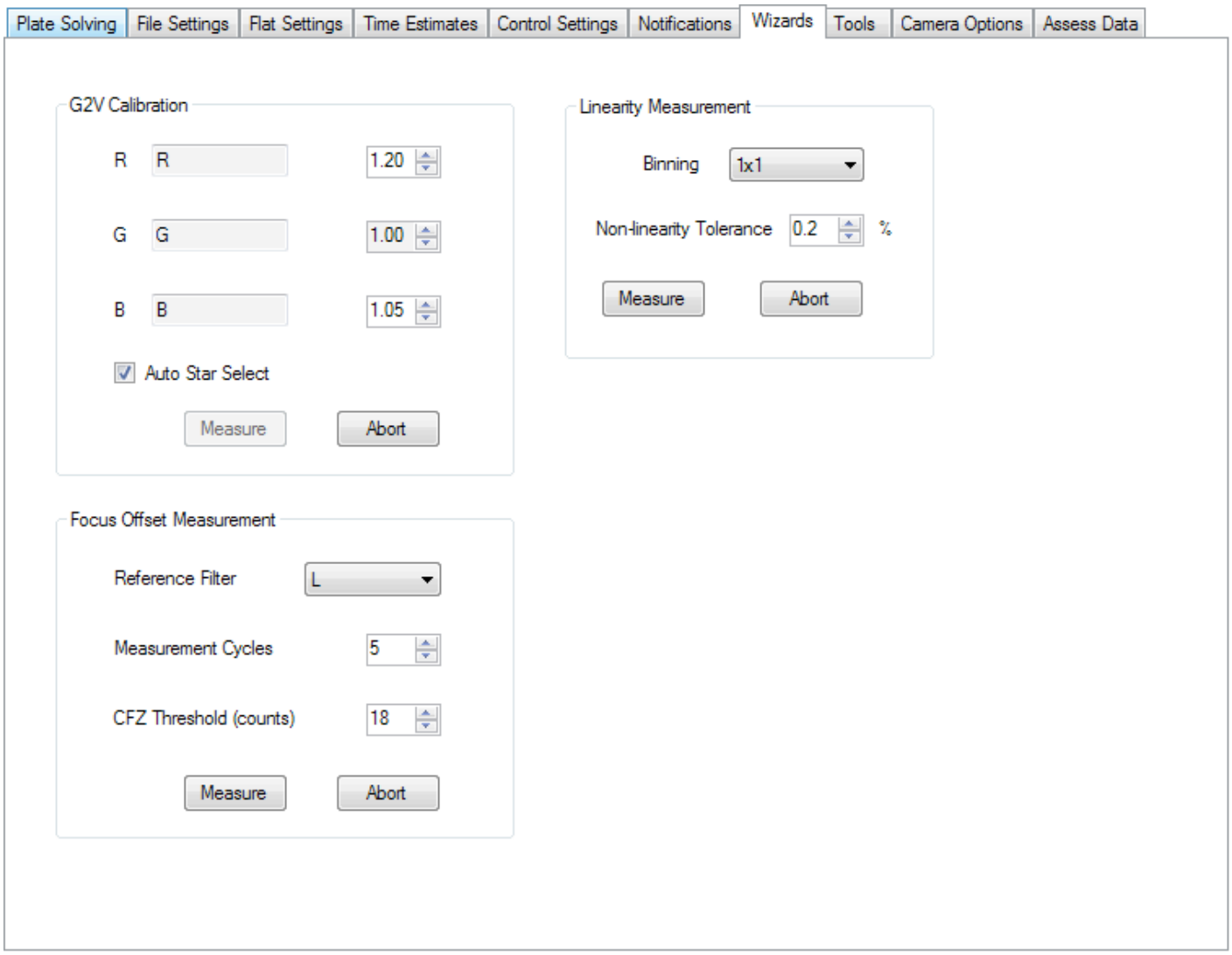
- **Upon Guide Error:** Sends an email if the guider fails to start for any reason.

- **Upon Plate Solve Error:** Sends an email if plate solving fails. May be an indication of clouds.

- **Upon Slew Error:** Sends an email if the mount fails to successfully make a Precision Slew.

- **Upon Camera Error:** Sends an email if the camera server is unable to take or save an image.

8.14.7 Wizards



G2V Calibration Wizard

CCDAutoPilot can automatically measure your RGB Ratio, sometimes called a G2V ratio for the spectral signature of a sun-like star. This is a widely accepted method of determining your color combine ratios when assembling your final color image from RGB filtered data.

To begin, first select the R; G; and B; filters. The G: filter will be used as the reference. Typically in English, R: will be Red, G: will be Green and B: will be Blue. If using a BVR filter set, then R: would be R, G: would be V and B: would be B. Then proceed as follow, depending upon your telescope control program.

TheSky6, ASCOM/TheSky6, TheSkyX, ASCOM/TheSkyX: Point your telescope to a point in the sky near the zenith. If Auto is checked, CCDAutoPilot will locate a number of G2V stars and slew to the first G2V star. If you are initialized, it will center the star in your FOV. If you don't check Auto, you will have to manually slew to a known G2V star. CCDAutoPilot will then automatically adjust the exposure to meet its measurement criterion, take a number of flux measurements through each filter, correct the measurement for atmospheric extinction and show the resultant combine ratio. You will be asked to inspect the first image for each star to insure there is not a close double in the image. If there is, simply move on to another star; if not, allow the measurement to proceed. You can measure additional stars if you wish.

ASCOM: Automatic selection of G2V stars is not possible. Therefore manually slew the telescope to a known G2V star then hit the Measure button.
CCDAutoPilot will automatically adjust the exposure to meet its measurement criterion, take a number of flux measurements through each filter, correct the measurement for atmospheric extinction and show the resultant combine ratio. You will be asked to inspect the first image for each star to insure there is not a close double in the image. If there is one, please select and slew to another star.

In general, it is advisable to measure a few G2V stars. The expected measurement accuracy is +/- 0.1. It is also worthwhile measuring on different nights. High, thin clouds can reduce blue transmission, leading to erroneous results.

At any time during the measurement, you can terminate the run via the **Abort** button.

A log of measurements will be displayed in the log window to the left. When completed, you are given the opportunity to save the log to notepad. It is also available on the Windows clipboard to paste into another application.

Focus Offset Measurement Wizard

Focus offsets were discussed earlier(See 4.1). This wizard provides an easy way to determine your offsets. Begin by pointing the telescope to a suitable focus star. Choose one that is bright enough for your range of filters The settings on the Focusing(See 8.10.1) page will be used to run the focus routine. Verify successful manual focus on this star with your most transparent and least transparent filter in place before beginning the wizard. Adjust the settings on the Focusing page if necessary.

For most usable results, you will need to know your Critical Focus Zone (CFZ). Use the info window calculator on the Focusing (See 8.10.2) page to determine the CFZ in appropriate units. Then move your focuser a known distance, noting the starting counts and ending counts. From these data, you can calculate your CFZ Threshold in counts. For example, assume you are using an F/9 system. Selecting the blue color (smallest CFZ), we see the CFZ is 58.3 microns. Assume you move your focuser 10 mm and the focuser counts change by 1000 counts over that movement. Then your CFZ in counts is 1000 X .0583 / 10 or 5.8 counts. Any change under 6 counts is immaterial. By setting the CFZ Threshold to 6 in this example, you tell the wizard to put offsets on the focusing page that exceed this threshold and enter 0 for any offsets that do not exceed the threshold. This eliminates unnecessary focuser movements during filter changes when the offsets are not significant. If the CFZ Threshold is entered as 0, focus offsets will be reported and optionally entered on the Focusing page as measured.

Select the Reference Filter and choose the number of Measurement Cycles you want performed. A minimum of 5 measurement cycles is recommended and more are preferred. CCDAutoPilot will set the filter and focus using that filter, repeat for each filter in the filter set and then repeat the cycle for the specified number of Measurement Cycles. If a focus fails for whatever reason, it will keep trying until is achieved, before moving on to the next filter. After each cycle the focus offset will be calculated. When the measurements are completed, CCDAutoPilot will calculate the median offset for each filter from your chosen reference filter and optionally enter the *median* offsets in the Focus Offset column of Filter Factors(See 8.10.1) on the Focusing page. The *mean* of the filter offsets is also calculated without consideration of the CFZ setting as a cross-check. With a sufficiently large number of measurements, the median and the mean should converge.

At any time during the measurement, you can terminate the measurement via the Abort button.

A log of measurements will be displayed in the log window to the left. When completed, you are given the opportunity to save the log to notepad. It is also available on the Windows clipboard to paste into another application.

The wizard will measure the difference between the minimum and maximum focus position of the reference filter. For an absoluter focuser and under good seeing conditions, this difference should be minimal, certainly below the CFZ Threshold. If it exceeds that threshold, you will know that the focuser is not repeatable and may be slipping. Some focusers home on power up, in which case, you should compare focus positions for a known star and filter manually to verify repeatability through a power cycle. If it still is not repeatable, you

should not rely on any logged filter positions as respresentative from night to night. If the slippage is so excessive as to impact offset repeatability, you may not be able to rely of filter offset focusing strategies.

Linearity Measurement Wizard

All CCD cameras are linear over a range and then saturate or depart from linearity. Flat field frames should be exposed to as high an ADU level as possible, while staying within the linear range, to maximize the flat field frame's signal-to-noise ratio. This wizard will help determine that ADU level, which can then be used as the Target ADU for flat fields.

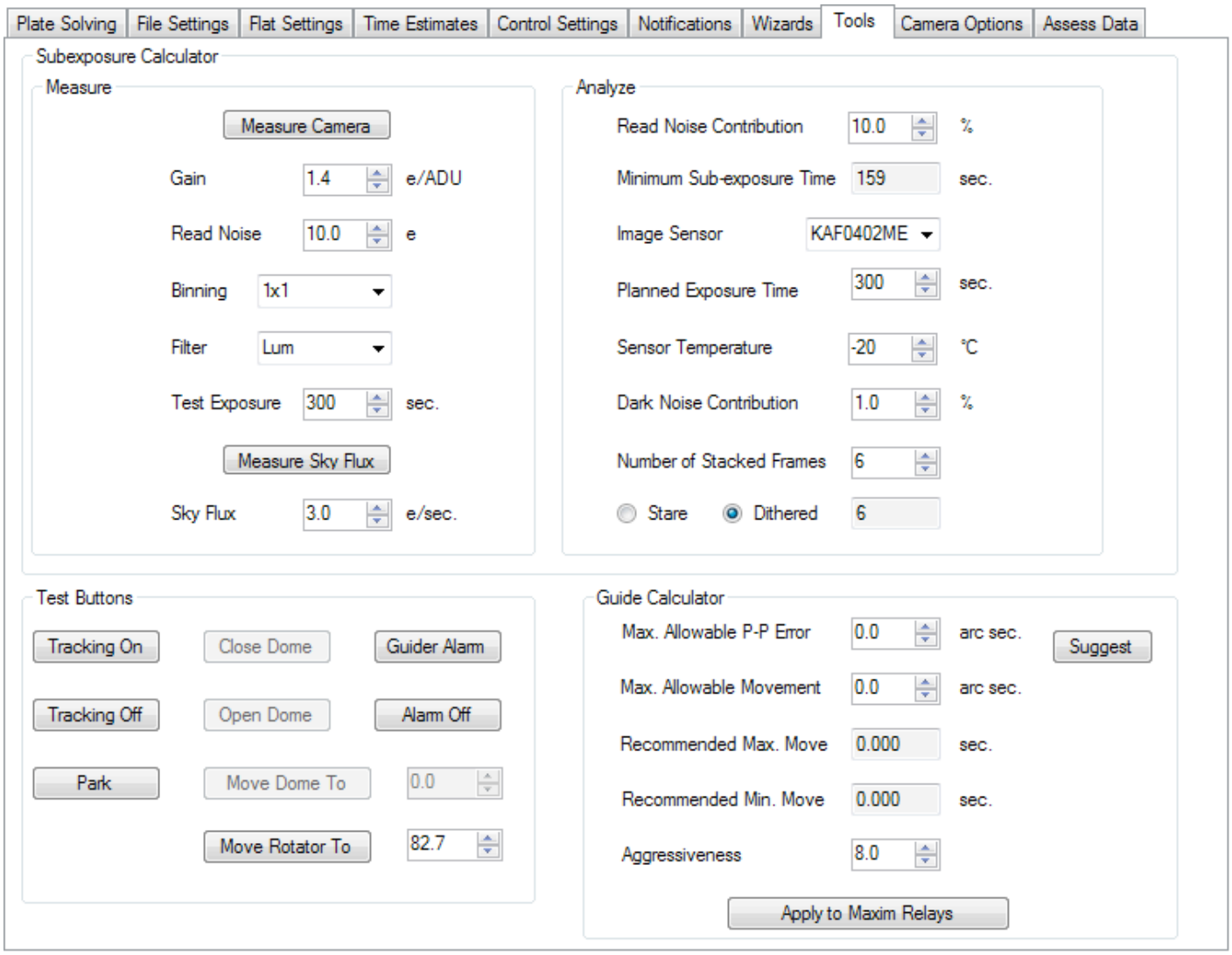
To measure the linear range, point our camera/OTA to a suitable constant illumination light source. For accurate measurements, the light source must be constant. To verify the stability of the light source, adjust the light source brightness so that a 20 sec. auto dark exposure gives approximately 20,000 ADU. Take 10 images or so and measure the average ADU. Compute the difference between the highest value and the lowest value. The smaller the difference, the more constant the light source is. If the light source has some variation, then set the Non-Linearity Tolerance as needed to account for the light source variability. For example, assume you see a variation in the 10 images of 100 ADU. Then 100/20,000 = 0.5%. So to include this variability, you should set the Non-Linearity Tolerance to 1%. With such a light source, this is the best tolerance with which you can determine the departure from linearity, called the turnover point.

Adjust the light source brightness so that the center of the image measures 5,000 ± 400 ADU with a 5 sec. auto-dark exposure at the desired binning. Once the source brightness is adjusted, hit the Measure button. CCDAutoPilot will take a number of auto-darked exposures in 5 sec. increments and record the exposure and ADU/sec. in the log window to the left. At the end of the measurement, a recommendation as to the maximum linear ADU will be made. It is a good idea to examine the raw data along the way as well. When the ADU/sec. decreases significantly at higher ADU, the CCD is going non-linear. If you acquire data at more than one binning, it is recommended that this measurement be repeated for other binnings used.

At any time during the measurement, you can terminate the measurement via the Abort button.

A log of measurements will be displayed in the log window to the left. When completed, you are given the opportunity to save the log to notepad. It is also available on the Windows clipboard to paste into another application.

8.14.8 Tools



Sub-Exposure Calculator

As discussed in Imaging Strategies(See 4.), characterization of the imaging camera and site sky glow can aid in determining sub-exposure duration. The Sub-exposure calculator consists of two parts, Measurement and Analysis.

Measure

First, the camera read noise and gain must be measured. Many vendors supply values for these terms but it is good to measure your specific camera. The read noise measurement requires no special setup but the gain measurement does. For the gain measurement, you will be asked to somewhat uniformly illuminate your imaging camera to approximately 20,000 ADU by adjusting the exposure to reach that level. If you are not prepared to do that, you can accept the camera manufacturer's value and proceed.

Before measuring the camera, select a binning and a filter. I suggest your first measurement be at 1x1 and you use a clear filter. Hit the Measure Camera button. You will be prompted through the steps for the measurement. When complete, there will be an entry for Read Noise and, if measured, Gain. In theory, read noise should be unchanged when binning, if the binning is done in hardware and there are no other noise sources introduced by the binning process. With some cameras, this is not the case.

The next step is to measure your sky flux. Try an exposure of 180 to 300 sec., depending on your ambient light. This measurement will take some time as a light exposure and an auto-dark exposure will be taken. Once the exposures are complete, the Sky Flux will be displayed at e/sec. You can also determine this manually by using a calibrated previous exposure through the filter of interest. Simply measure the average ADU level of an area free of stars. The sky flux is simply that average ADU times the gain as measured, divided by the exposure time in seconds.

Gain, read noise and sky flux are the key ingredients necessary to proceed to the Analyze box.

Analyze

Select the contribution to total noise you wish to assign to the camera read noise. This is a percentage of the noise that will be contributed by the sky flux. The underlying concept is to expose long enough so that the noise from the sky flux overwhelms the read noise such that the read noise contributes the indicated percentage to the total noise. A good starting point is 5%. Entering a Read Noise Contribution value automatically calculates the minimum sub-exposure duration in sec. For more details and analysis, see my paper on *Sub-Exposure Times and Signal-to-Noise Considerations*.

Next, choose your image sensor. If necessary, consult your camera documentation or vendor for your sensor type. If your sensor is not available, you can add it if you have the necessary data. See here(See 12.4) for the file structure. Enter your planned sub-exposure time. Select your Sensor temperature, Dark Noise contribution and the number of sub-exposures in your stack to get the number of mean combined darks you need. (Because any master dark is subtracted from each sub-exposure, it is correlated. This means any noise that is in the master dark eventually will appear if the stack is deep enough, just as faint details appear when the stack size is larger.) Experiment with changing your Sensor Temperature and Dark Noise Contribution. As you further cool your camera, you will see the number of darks needed slowly decreases. Now warm up the camera. The number of darks will increase slowly at first then faster. You want to be in the area where it increases slowly if possible. For more details and analysis see my paper on *Sub-Exposure Times and Dark Frames*.

Compare Stare mode to Dithered mode. "Stare" means undithered. You can readily see the impact of dithering on the required number of darks.

It should be mentioned that the number of darks is based on a min./max clip combine. You would normally use this combine method to eliminate cosmic ray hits and similar random artifacts.

Caveat: This is a bit of a simplification of a very complex topic. Narrow band imaging, extremely dark skies, etc. will mandate much colder camera operation since the sub-exposures will become longer. Nevertheless, this is a good starting point for determining a starting point for your sub-exposures, camera operating temperature and number of darks.

Test Buttons

These buttons cause the indicated actions to be performed. They may be used to test communications to the ultimate hardware through the various software layers before committing to an automated session. It is recommended these buttons be used whenever hardware changes or a suspicion of things not going right arises.

IMPORTANT: CCDAutoPilot can only send the Tracking Off and Park command to your telescope control program. It is your responsibility to verify that your mount behaves properly when it receives these commands. Please take advantage of the test buttons to verify proper communications with your mount and dome. Hit these buttons one at a time to test whether your chosen telescope control program turns off tracking or parks the mount. If you don't get the expected results, consult the manufacturer of your telescope control program for support. CCDAutoPilot sends standard commands for tracking off and park in accordance with ASCOM and TheSky's defined interfaces. Watch the status panel below the buttons for reports of activities.

- **Tracking On: This button should turn the mount tracking on.**

- **Tracking Off: This button should turn the mount tracking off.**

- **Park: This button should send the mount to its park position. With most telescope control programs and/or mounts, this park position must be pre-defined by the user.**

- **Close Dome: This button should close the dome shutter.**

- **Open Dome: This button should open the dome shutter.**

- **Move Dome To: The current dome azimuth is reported to the right. Change the value, hit Move Dome To and confirm the dome does indeed rotate to the entered position.**

- **Move Rotator To: The current rotator position is reported to the right. Change the value, hit Move Rotator To and confirm the rotator does indeed move to the entered position.**

- **Guider Alarm: This gives an example of the alarm that sounds when guiding fails and the AGRS cannot restore it.**

- **Alarm Off: This turns off the alarm.**

Guide Calculator

This calculator allows you to determine your optimum minimum and maximum move parameters for your system. Proper setting of these parameters is important for optimal guiding. When connected to your camera control program, the guide calculator will automatically determine whether DirectGuide (CCDSoft only) or camera relays is in use and calculate minimum and maximum recommended moves automatically. These parameters can be loaded into your camera control program. For more information, see the online Guide Calculator.

- **Max. Allowable P-P Error: Here we try to determine when we want your mount to actually make a correction. If your guider error is only .05" arc-seconds, there is no need to make an correction. If your min move setting is set to low, then you guider relays will move the mount every guider cycle. This can result in mount oscillations or chasing atmospheric turbulence. My best suggestion in setting this value is about 75% the image scale in which you are imaging. For example, if you are imaging at 1.2" asp, then set this**

value to 0.9" asp. This way a guider correction is only sent when the centroid of the guide star is 0.45" asp off in either the X or Y axis from the selected guide star position.

- **Max. Allowable Movement: This value is not required to achieve great autoguiding, but it does protect us from some extreme situations that could ruin a sub-exposure. For instance, if a cosmic ray hit is sensed on the autoguider CCD, this could cause your autoguiding software to think that the centroid of the star has moved many, many pixels from center. Therefore it is going to attempt to correct the mount for this error. If you have no max move setting, this will result in a very large correction and a ruined exposure. If you have a limit to the size of the correction, i.e. max move, then this effect can be mitigated by not allowing a large correction. Setting this value too low may result in under correction, so its best to set this value about 2X - 4X larger than the above 'Peak to Peak Maximum Allowable Error' setting.**

- **Suggest: Hitting this button will cause recommended settings to be entered for the above two values and represents a good starting point. If you are unsure of what to enter, hit the Suggest button.**

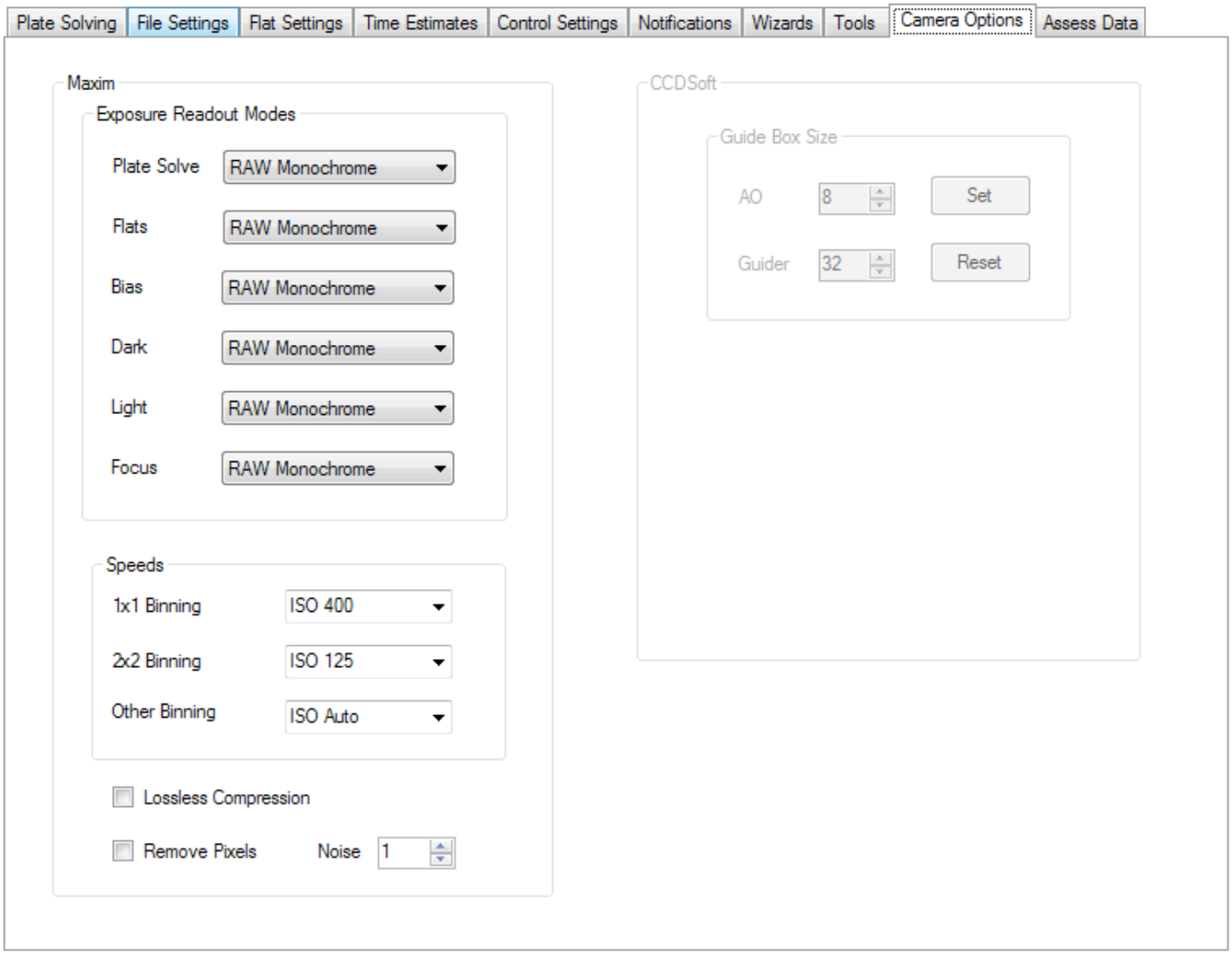
- **Recommended Min. Move: Based on the above entries, this is the recommended minimum move amount for your guider.**

- **Recommended Max. Move: Based on the above entries, this is the recommended maximum move amount for your guider**

- **Aggressiveness: With the recommended minimum and maximum move, this is the recommended aggressiveness setting for your guider**

- **Apply To <guider>: Hitting this button will automatically enter the recommended values into your camera control program. The button name will indicate your camera control program (CCDSoft or Maxim) and the corresponding guide method (Relays or DirectGuide for CCDSoft, Relays or MicroGuide for Maxim).**

8.14.9 Camera Options



Maxim Camera Options

Depending on your specific camera, different **Exposure Readout Modes** may be available. These choices will be available when Maxim is connected to your actual camera hardware and CCDAutoPilot is linked to Maxim. Depending on the choices available, you may elect to choose different readout modes for different exposures. For example, assume your camera has two readout modes: Normal and Fast. The Fast mode might have more read noise. (Hint: Use the Sub-Exposure Calculator to measure all modes.) For things like Focusing, plate solving and even flats, you may elect to use the Fast mode. But for Light frames, you use Normal to minimize read noise. Don't forget to use Dark and Bias frames with the readout mode that matches your light frames and flat frames.

Depending your specific camera, different **Speeds** may be available. This allows you to set specific ISO speeds or, in the case of QSI cameras, different gains for different binning choices.

- **Lossless Compression:** When checked, all FITS data files, light frames, dark and bias frames and flat frames are compressed using Maxim's proprietary lossless compression algorithm. This makes file sizes considerably smaller than uncompressed files but they can only be opened in Maxim and not any other program. If this option is checked, Data Assessment cannot be used.

- **Remove Pixels (Maxim):** When checked, CCDAutoPilot will automatically execute Maxim's Remove Bad Pixels process for all frames, Light, Dark, Bias and Flats, taken during the session. See the Maxim help file for details. The Bad Pixel Map in Maxim must be pre-defined and unique for each binning. For example, a bad pixel map for 1x1 binning **must** have the name "Map1", for 2x2 binning, the name **must** be "Map2", for 3x3 binning, the name **must** be "Map3". Any other name will not be accepted by CCDAutoPilot.

- **Noise:** This represents the small amount of Gaussian noise that is added to the interpolated images to improve appearance. See the Maxim help file for more details.

Remove Pixels Usage Note

When this feature is configured and checked, it will be applied to all frames, light, dark, bias and flat. If you already have library dark and bias frames taken without this option and want to use them with light frames acquired with this option checked, then you should run your masters through Maxim, apply the appropriate bad pixel map and save the master to a new name. If you don't do this, your calibrated image might not look correct. For example, assume you have a bright column that you remove with the bad pixel map. This column will not show up in your light frame but if it is in your dark frame, you will have a black column in your reduced image. If you run your master dark through the Remove Bad Pixels routine manually in Maxim, save that dark and apply it to your light frame taken with the Remove Pixels option checked, your calibrated image should look proper.

If you select this option, you should make bad pixel maps for all binnings that you use, including those you use for plate solve exposures. That way, hot pixels will be removed and the plate solving routine won't mistake a hot pixel for a star.

While there are many ways to develop a bad pixel map, one way is to use a master bias. It should be made up of 20 - 40 individual bias frames, the more the better. Move the information windows around to measure the level (ADU's) of the bad pixels you want to remove. Hit the AutoGenerate button and use the threshold adjustments in Maxim to define the pixels that should be replaced. Next, process the bias frame to see what pixels will be removed.

It is strongly recommended that you experiment with this feature before committing it to an evening's session.

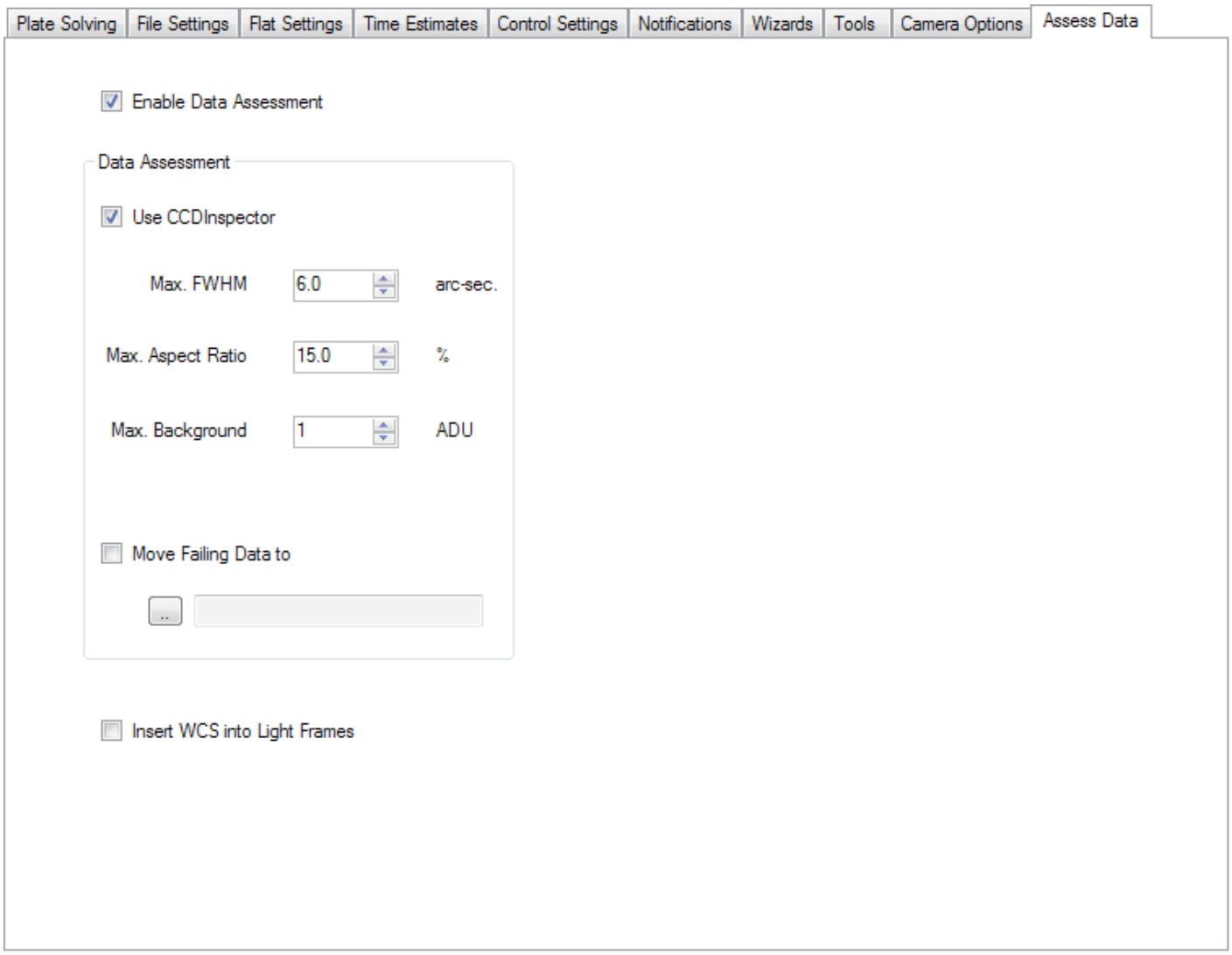
Enabling this feature **modifies** your original data by the Remove Bad Pixels process **before** it is saved. There is no way to "undo" this modification. Science users should carefully consider whether this option is appropriate for your data requirements. You can evaluate this by not checking the option and manually running it through Maxim's "Remove Bad Pixels" process.

CCDSoft Camera Options

This setting allows adjusting the size of the guide star box. This is the image that is visible when the guider is operational. The settings must be set before guiding is enabled. You can set either the AO guide star box or the conventional guider guide star box. Changing during guiding will not have any effect

- **Set:** Enters the values shown for the guide box size.
- **Reset:** Resets the guide box size to the default values of 8 for the AO and 32 for conventional guiders.

8.14.10 Assess Data



Data assessment consists of measuring key light frame exposure parameters during a session. By setting criteria here, frames failing to meet the defined criteria can be so noted in the log and optionally moved to another folder for subsequent examination. Data assessment works with goals to insure only those light frames that meet the defined criteria count toward the goals set on the Session page.

As a minimum, the average Full Width Half Maximum (FWHM) of the frame is measured as a first order quality assessment. This measurement requires either PinPoint or TheSkyX be available and used for Plate Solving. With CCDInspector 3.0, additional measurements of Aspect Ratio, a measure of tracking and/or guiding, and Background, to measure the level of sky glow, can also be measured,

- **Enable Data Assessment:** When checked, data assessment will be performed either during a session or via the Assess Data button on the Options Page.
- **Use CCDInspector:** When checked, CCDInspector will be used to assess the light frames
- **Max. FHWM:** When a suitable value is entered, all light frames whose average FWHM exceeds the entered value will be noted as having failed.
- **Max. Aspect Ratio (CCDInspector only):** When a suitable value is entered, all light frames whose average Aspect Ratio exceeds the entered value will be noted as having failed.

- **Max. Background(CCDInspector only):** When a suitable value is entered, all light frames whose average Background exceeds the entered value will be noted as having failed.

In order to pass CCDInspector's screening, all three measurements must be below their corresponding values. If it is desired to not consider one parameter, Background for example, simply set the value high.

Frames that are noted as failed will not be considered against the goal. There is an additional option:

- **Move Failing Data to:** When checked, failing frames will be moved to the folder specified. Use the  button to specify the folder to which the failing data will be moved. If the path is blank, the failing data will be moved to a \Failed|\ folder off the Base folder. Assume the Base Folder is C:\Astro and all other Folders on the File Setting tab are blank. Then the failed folder will be `C:\Astro\20110228\Data\Failed\` Of course this folder location can be customized as well.

- **Insert WCS into Light Frames:** When checked, WCS data will be written to the FITS header as well. This option is available only when PinPoint is selected for plate solving. Note that this will require additional time during a session as a plate solve will have to be made for each data frame and then added to the FITS data. For other than scientific purposes, this is best left unchecked.

9. Other Applications

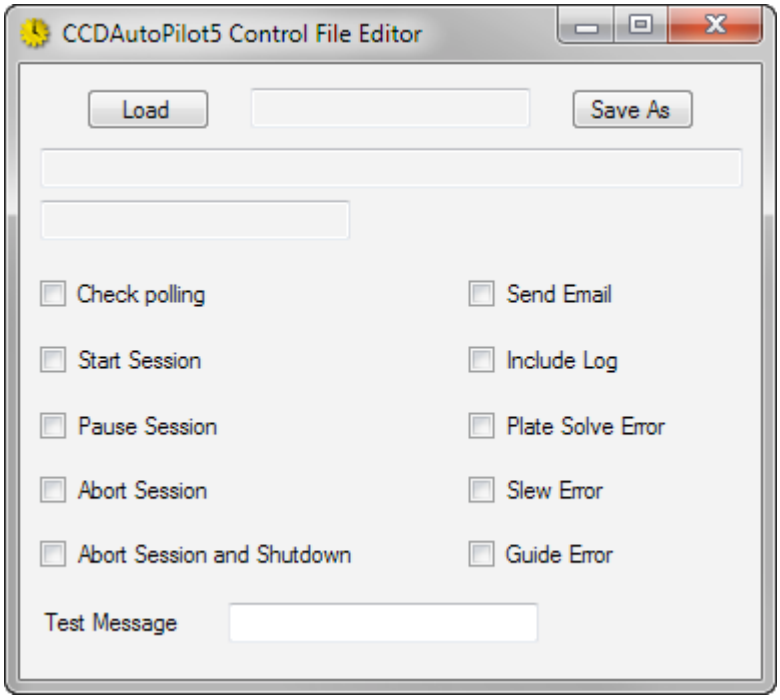
10. Other Applications

CCDAutoPilot comes with a number of applications that are discussed in the following sub-topics. These tools can help with evaluating and troubleshooting sessions.

10.1 Control File Editor

Professional Edition Feature

The Control File facility allows a number of additional options that are useful for more sophisticated remote observatories, whether remote is in your back yard or across the globe. This file can be created or modified by any text editor. The Control File Editor provides a convenient way to create the control file as well.



- **Load:** Loads an existing file for editing
- **Save:** Saves the open file or creates a new one
- **Test Message:** Enter up to a 20 character string that will accompany any email messages or log entries as desired
- **Characters 1 through 6 (CCDAP5):** These characters must be "CCDAP5". This string of characters is used to validate this as a control file.
- **Check Polling (Character 8:** If Y, the following field must be updated more frequently than the CCDAutoPilot polling time of 6 sec. This option is useful for sophisticated observatory control systems to insure communication between a client application and CCDAutoPilot. If the following field is not updated within the polling interval, the current run is aborted. If this character is anything other than Y, the next field is ignored.
- **Character 10 through 20:** This string can be generated by a Now(days) function in the client program. As long as this string changes between CCDAutoPilot polls, the run will progress if Character 8 is Y.
- **Start Session (Character 22):** If Y, the run will start when the Run Session is pressed on the Run Session page of CCDAutoPilot. If set to anything other than Y, the session will not start until the character changes to Y.
- **Pause Session (Character 24):** If Y, the run will pause in the same manner as when the Pause Session button is pressed on the Status window. When set to anything else, the run will resume as when the Resume Session button is pressed on the status window.
- **Abort Session (Character 26):** If Y, the run will be aborted as if the Abort Session button is pressed on the Status window.
- **Abort Session and Shutdown (Character 28):** If Y, the run will be aborted as if a cloud sensor had triggered the Run Abort Conditions. Additionally, the imager cooler will be warmed up.
- **Send Email (Character 30):** If Y, an email will be sent using the Email address and SMTP server settings on the Preferences page. Any other character and no email will be sent.
- **Include Log (Character 32):** If Y, the current log will be attached to the email sent as above. Any other character and no log attachment will be included.
- **Plate Solve Error (Character 34):** If Y, any plate solve error will result in a message "Plate solve error" being sent to the email address, assuming character 30 is Y. Any other character will result in no message.
- **Slew Error (Character 36):** If Y, any slew error will result in a message "Slew error" being sent to the email address, assuming character 30 is Y. Any other character will result in no message.
- **Guide Error (Character 38):** If Y, any automatic guide star error failure will result in a message "Guide star not recovered. Imaging unguided." being sent to the email address, assuming character 30 is Y. Any other character will result in no message.
- **Reserved Identifier (Character 48)**

- **Message (Characters 50 through 70):** Up to 21 characters can be appended to any messages sent from the above events.

Format

The control file consists of a single line file that may or may not be updated continuously as the need arises. When Use Input File is checked on the Preferences page and a suitable file is entered by the File/Path button, this file will control CCDAutoPilot.

Here is the general structure of that file:

```
0         1         2         3         4         5         6         7
12345678901234567890123456789012345678901234567890123456789012345678901234567890
CCDAP4 N 01234.67890 y N N N N N N N N            Test Message........X
       |              | | | | | | | | |           |
Y=Check+              | | | | | | | | |           |
                      | | | | | | | | |           |
Y=Enable start++++++++ | | | | | | | |           |
                       | | | | | | | |           |
Y=Pause, else resume++++ | | | | | | |           |
                        | | | | | | |           |
Y=Abort run+++++++++++++++ | | | | | |           |
                          | | | | | |           |
Y=Abort Run and Shutdown++++ | | | | |           |
                            | | | | |           |
Y=Send Mail++++++++++++++++++ | | | |           |
                              | | | |           |
Y=Send Log++++++++++++++++++++ | | |           |
                                | | |           |
Y=Report plate solve error++++++++ | |           |
                                   | |           |
Y=Report slew error+++++++++++++++++ |           |
                                     |           |
Y=Report guide star recovery error++++           |
                                                 |
Reason/text message (21 characters)+++++++++++++++
```

The top line indicates character position, starting with 1 and going through 70. The character positions have meaning as defined below:

Usage

By the judicious choice of these options, you can arrange for any number of notifications and control. Some examples:

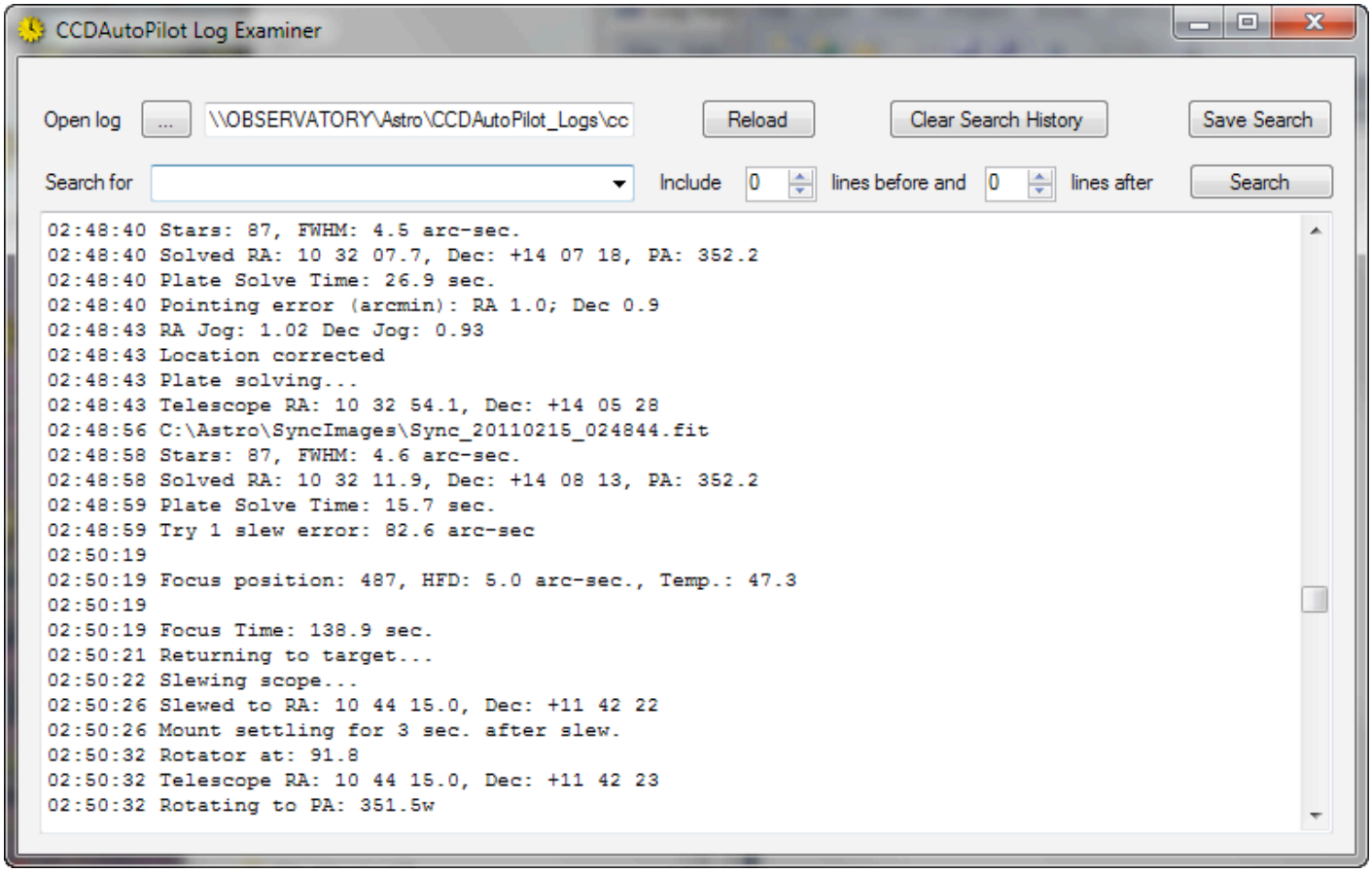
Assume you have a sophisticated weather and observatory control system such that if primary power is lost, you have enough UPS power to secure the system. You might use the Abort function to abort the run. Then, assuming your observatory is properly constructed, you can close the slit and gracefully power down the system. You can be notified of this by email or text message, along with any additional text, identifying the reason for the change

You can your email address of your phone's text message subscription to receive notification of any plate solve or guide star failure.

Note that, independent of this control file, you can elect to be notified via email of run completion and receive the log as an attachment by checking the appropriate boxes on the Preferences page.

10.2 Log Examiner

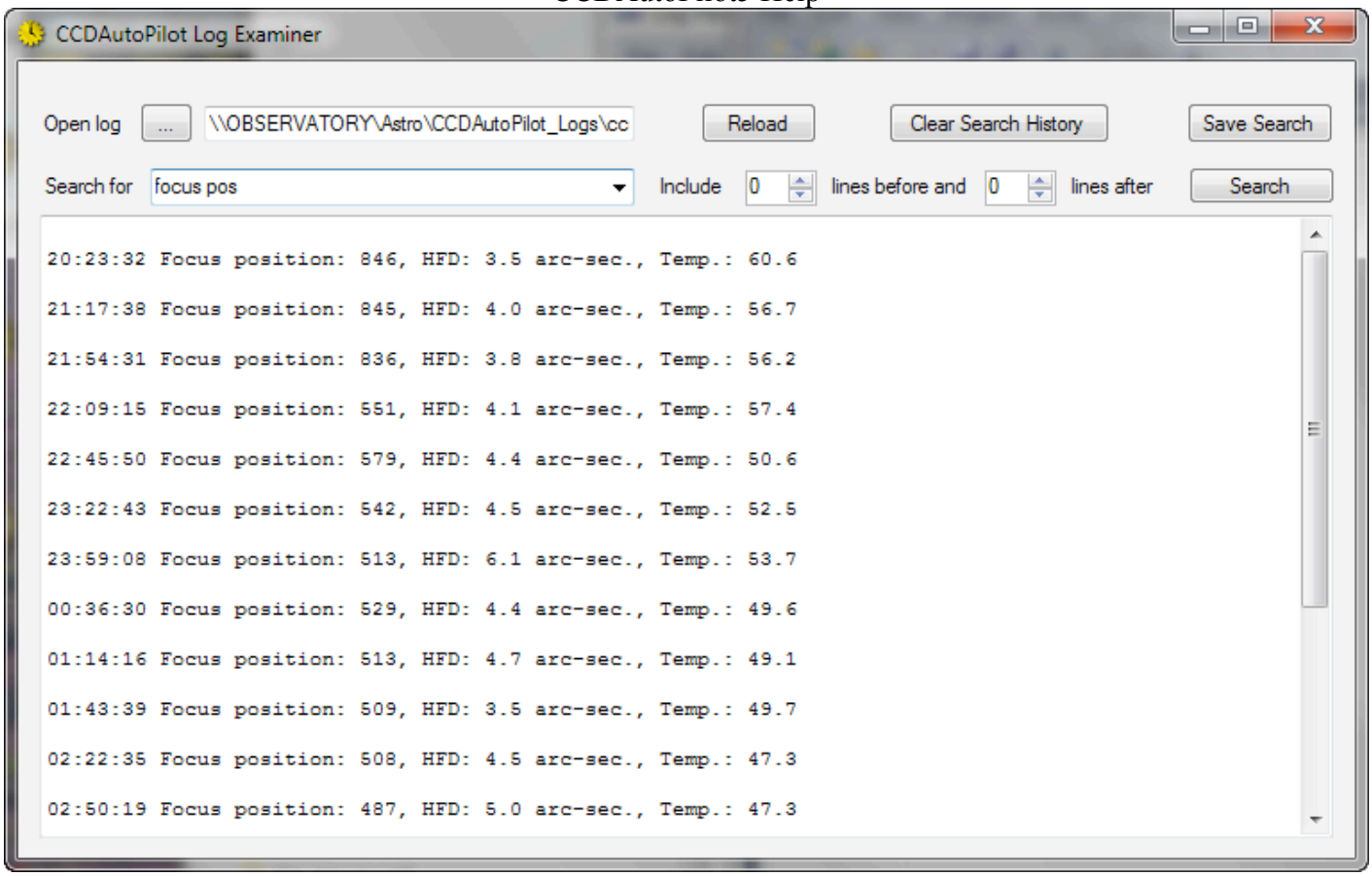
CCDAutoPilot logs have a lot of information in them and it can be a bit tedious to find what you are looking for. The Log Examiner allows you to search for a specific set of characters (called a "string") and report all instances of that string. Since what you are looking for may require some lines before or after your search string, that can also be selected. Up to 10 search strings are saved. You can even save the search results.



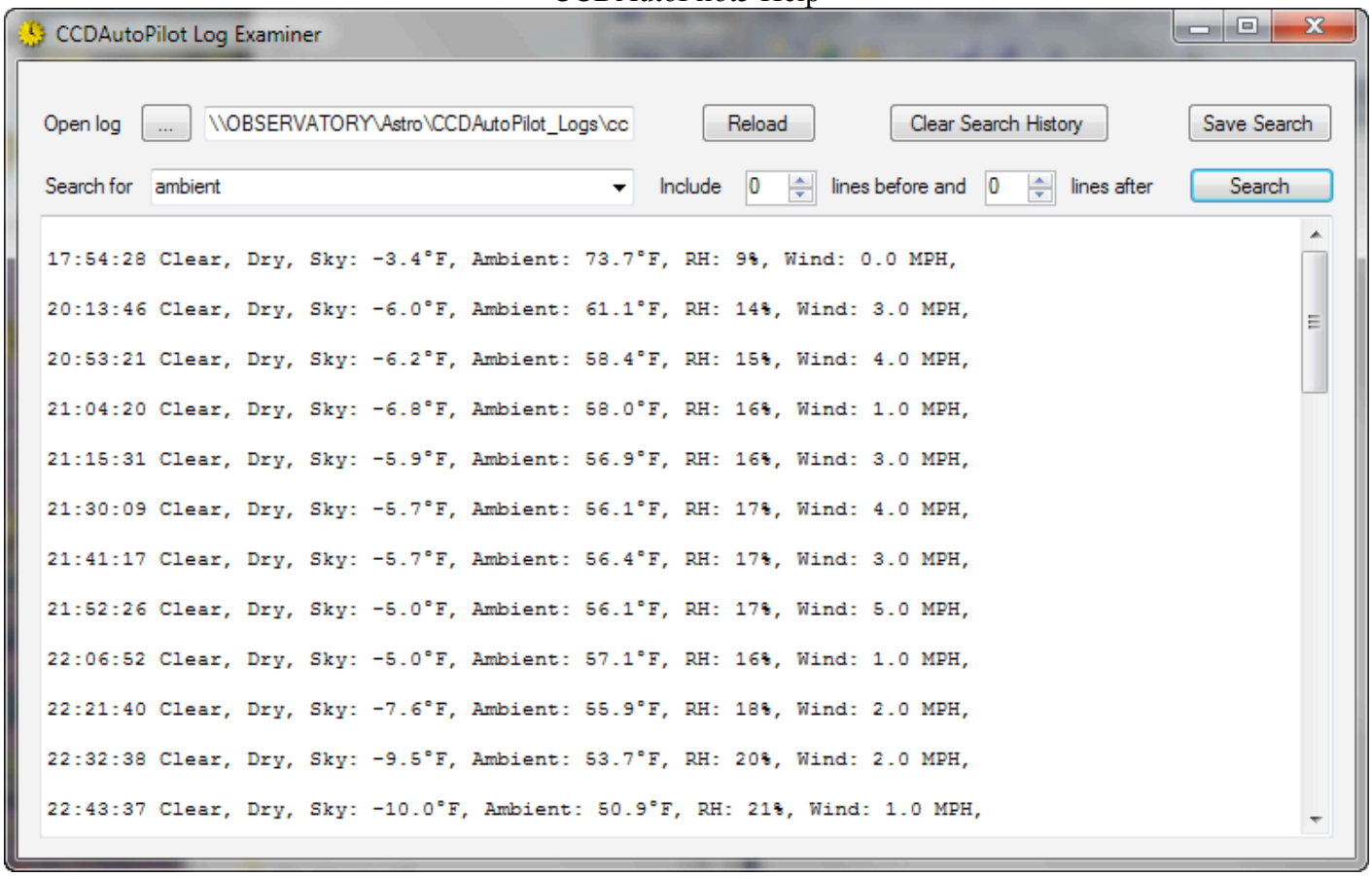
- **Open log:** This opens a window from which you can navigate to and select the log you wish to examine. Once the log is selected it is displayed in the text window.
- **Search for:** Enter the search term you wish to use for the search. You can enter the number of lines before and after the search term,
- **Search:** This searches the log for all instances of the search term and displays any lines before or after the search term you have specified.
- **Save Search:** Allows you to save the search to a new file. The default file name will be the same as the original log file with "_sort" appended to the log file name. Of course you can name it anything you wish.
- **Reload:** Reloads the original log file, replacing the search display.
- **Clear Search History:** Clears the saved search strings.

Examples

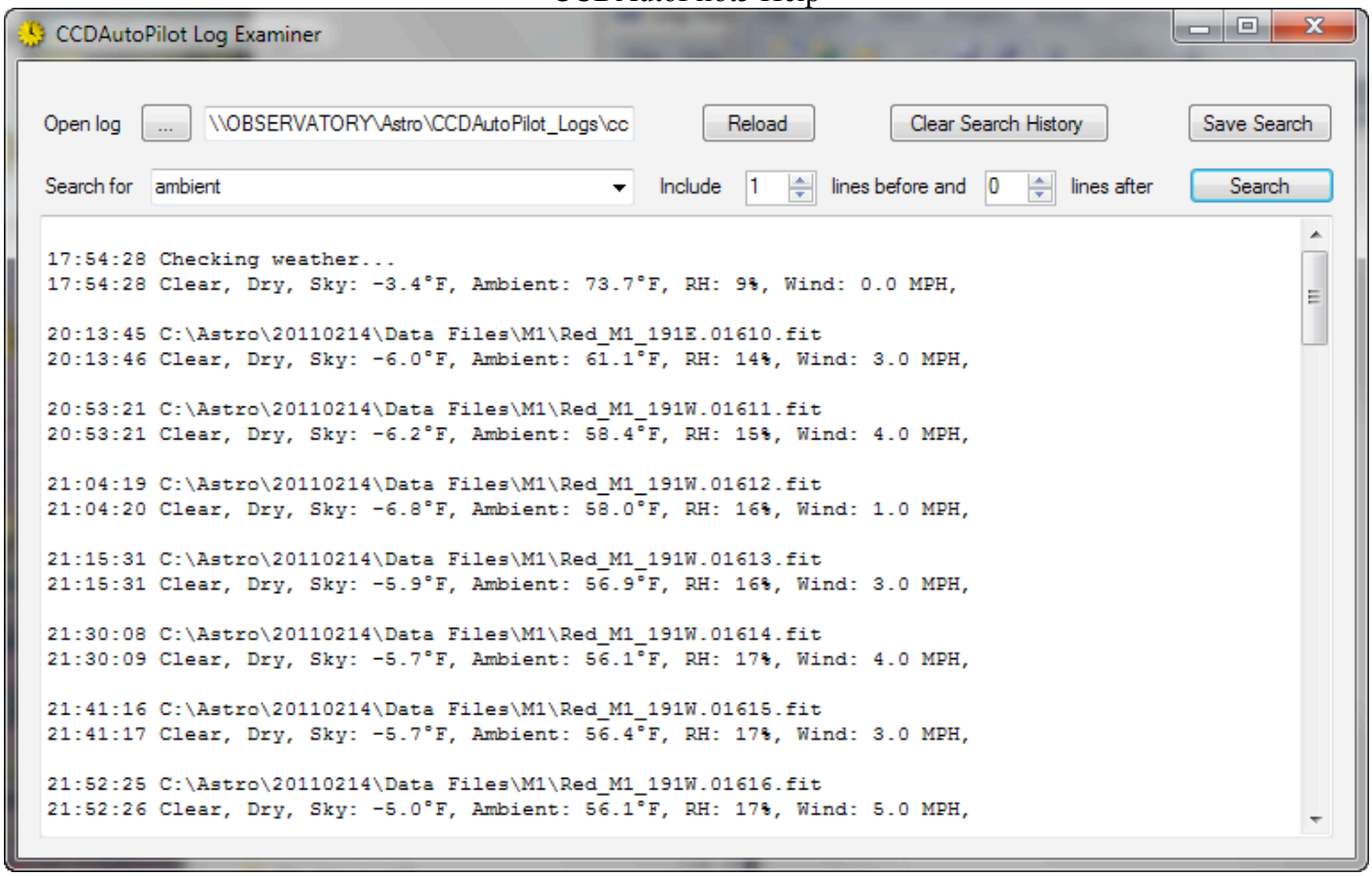
Suppose I want to see how focus changes over the course of a session. If I enter "focus pos" as a search string, this is what I would see:



Suppose I want to see how the weather changes during a session (I am using a cloud sensor). Here I enter "ambient" as the search term:



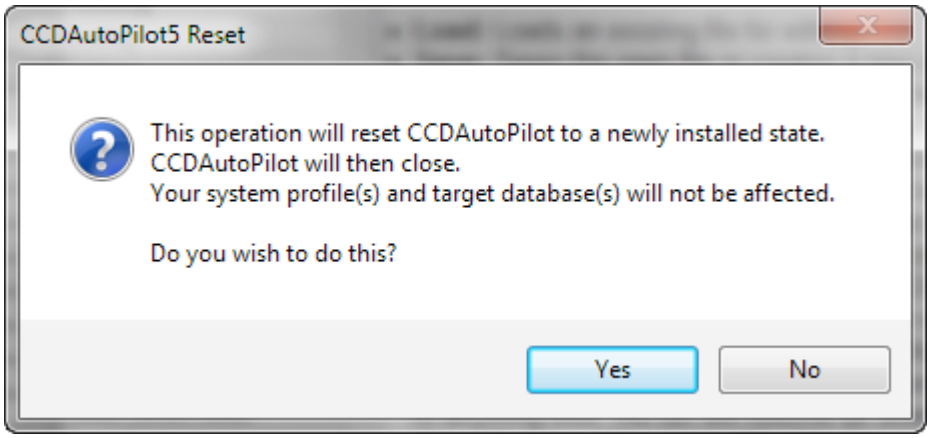
Now I want to see what the weather was like after each exposure. I can select my previously entered search term "ambient" from the search pulldown but specify 1 lines before.



As you can see, there are many repeating events and relationships that can be extracted from the log by the Log Examiner. In fact, you can use Examiner to scan logs from other programs as well, for example FocusMax logs to similarly collect events and relationships.

10.3 CCDAutoPilot5 Reset

This program is used to restore the CCDAutoPilot to a default installation, as if it had just been installed and CCDAutoPilot has never been run.



You will be asked to confirm reset before proceeding. Your system profile and target database will not be affected by the reset.

11. Troubleshooting

12. Troubleshooting

Important: If some or all of your control programs are not started, CCDAutoPilot will attempt to start them in what should be the proper order. Depending on your PC's performance, they may or may not start properly. If things don't seem to be operating properly, start them manually before starting CCDAutoPilot. For example, assume you are using RoboFocus to control your focuser, FocusMax for focusing and CCDSoft to control your camera. Load and start RoboFocus, confirming it connects to and can control your focuser hardware. Next Load CCDSoft, confirming it connects to your camera. Take a short image to be sure. Next, load FocusMax since it must control both RoboFocus and CCDSoft. Finally, load CCDAutoPilot.

If you haven't read Introduction to Automation(See 4.6) yet, I strongly recommend you do.

Step-by-step

1. Make sure the .NET 4.0 framework extended edition is installed. You can verify its installation by going to Control Panel, Add/Remove Programs and making sure there is an entry for "Microsoft .NET Framework 4 Extended". If that entry is not present, please install it before proceeding. See the Application Requirements(See 2.3) topic for a link to the Microsoft download location.

2. Insure installation of all programs required for your operation is proper and functional by testing them standalone. See the Application Requirements(See 2.3) topic for links to all programs. Make sure you are using the latest version of CCDAutoPilot. The most recent version information and change history can be found here.

3. Verify you have the minimum version level for the above programs. CCDAutoPilot will warn of out-of-revision programs and prevent operation. See the Application Requirements(See 2.3) topic for minimum version requirements. Of course, higher version numbers can be used. Program version numbers can generally be checked by the Help | About menu on the individual program. For programs that do not support this feature, you must locate the program's .exe file, right click on it, select properties and select the version tab.

4. Before connecting CCDAutoPilot to any of your programs, be sure the programs are able to properly control their related hardware. Can you take an image with your camera control program? Can you slew the telescope with your telescope control program? Can you control your focuser and focus with your focuser program? Does your rotator program control your rotator? Does your dome control program move your dome?

5. Connect to CCDAutoPilot and use the test buttons on the Preference page, Tools Tab(See 8.14.8) to verify CCDAutoPilot is able to control the appropriate hardware *through* your programs.

6. On the Session Page, Light Frames phase(See 8.4.1), create a target using the Get function with TheSky or the Add a target manually. Select the target if it is not selected using the Row Header. Right-click and select Slew To Target Uncorrected. Does the mount slew properly?

7. Set up a single, short exposure on Session Page, Light Frames phase(See 8.4.1). Run a short session to confirm the telescope slews to the target and takes a short exposure.

8. Add other functions and complexities gradually, verifying proper operation with each addition.

When things don't go as expected

While every effort has been made to trap invalid user entries, some slip by. These are addressed as they are identified but with over 600 controls, there is a lot of opportunity for bad entries or combinations. Here are some techniques to help resolve such a problem.

- **Global Error Handler: CCDAutoPilot traps and handles many potential errors during the course of a session. Occasional setup and input errors can lead to errors as well (unhandled exceptions). Should the latter error occur, CCDAutoPilot will present a window with choices on how to capture the error information. Next, CCDAutoPilot will attempt to run a script named RunOnError.vbs(See 12.1) located in**
- **(My)Documents\CCDWare\CCDAutoPilot5\ if it exists. Finally CCDAutoPilot will close. If the error is repeatable and the next steps don't resolve the issue, feel free to post the error file to the CCDWare support forum for assistance.**

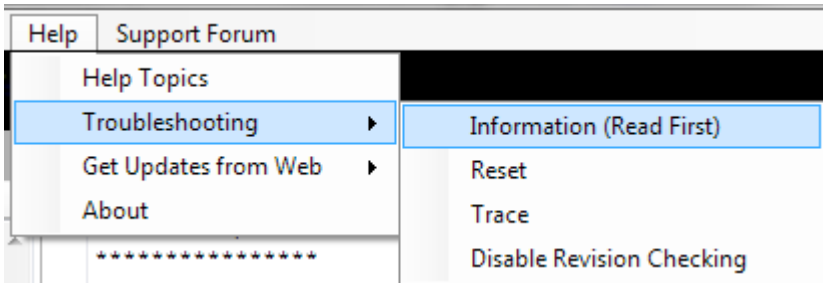
- **Reset: If CCDAutoPilot fails to load, selecting CCDAP4 Reset(See 10.) from the Start menu resets all key data as if CCDAutoPilot were never installed (except for the trial period status of course). Your system profile(s) and target list(s) are not affected. You can also access this function from CCDAutoPilot's Help/Reset menu item.**

- **Create a new System Profile: From the System Profile menu, select New to create a new system profile. Of course you will need to re-enter all your settings but often this resolves the issue of a bad setting.**

- **Task Review: Open Task manager and select the Processes tab. If you click on the Image Name table header, the processes will be sorted in alphabetical order for easy viewing. Verify that one and only one process is running for each server program you have operating. If you see more than one process, then proper automation is not possible. You should either reboot your PC (easiest) or close all programs and use the End Process button to stop any server programs that remain running. This can happen when a run is aborted and the abort process is not allowed to complete. After hitting the Abort button on the status window, remember to wait until the main window restores (re-opens). This minimizes the chance of multiple processes in task manager.**

- **Hardware: If things suddenly stop behaving properly or you experience heretofore unexplained hangs, it is most likely a hardware problem. Check all USB connections. Make sure you do not depend on connector retention force to hold the cable in place but rather strain relieve all USB cables so you can pull on them without unplugging them. As a diagnostic, bypass any hubs, especially if not of commercial (usually more expensive) quality. Office quality hubs can be problematic unless you operate your observatory with electronics in a temperature controlled environment between 10° and 35°C. The same is true of serial-USB converters. Insure proper voltages are being delivered to your cameras and other equipment.**

Troubleshooting Tools



- **Information (Read First): links to the Troubleshooting Overview.**

- **Trace: The Trace facility provides diagnostic information for various phases of CCDAutoPilot operation. While the Session window and the attendant log provide event logging during an active run, there are possible occasions when things don't go as expected before starting an actual session. The trace facility can be used whenever things don't seem to be "working right" before running a session. Trace also provides more detailed information *during a session*. When Trace is enabled, all plate solve frames are saved, not just the failed ones. This can be handy to diagnose plate solving issues but be aware that leaving Trace enabled will consume more disk space as all plate solve frames are saved. When this topic is selected, CCDAutoPilot's trace facility is turned on and CCDAutoPilot closes. When CCDAutoPilot is next started, the trace facility is engaged and a trace file will be written in the CCDAutoPilot4 data directory. The data directory is located at My Documents\CCDWare\CCDAutoPilot5 (XP and Prior) and Documents\CCDWare\CCDAutoPilot5 (Vista/Windows 7).A new file is written each time CCDAutoPilot is started. The file has a file name of `Trace<yyyymmdd>_<HHmmss>.log` and will record any error messages. When Trace is enabled, all plate solving images ("Sync_Image") are saved, whether successful or not. Trace being on is indicated by a check next to the Help menu selection. To turn Trace off, select this topic again. CCDAutoPilot will close and Trace will be disabled when CCDAutoPilot is next started. Contact support for interpretation of any messages in the trace file.**

- **Remove and Reinstall CCDAutoPilot: While this should not be necessary. it has been shown to help resolve some unique issues. This should be used in conjunction with the CCDAutoPilot Reset Tool. First remove CCDAutoPilot then run the CCDAutopilot Reset Tool. If possible, it is a good idea to reboot your PC before reinstalling.**

Support

If none of the above resolves the issue you are having, please use the CCDAutoPilot support forum, which is also accessible from the Help menu. If you have problems during a run, be sure to post the related .log file as an attachment. If you are having problems that prevent a run from starting, post the error log file described above(See 12.). The more detail you include in your problem report along with the suggested attachments, the more quickly the issue can be resolved.

12.1 RunOnError Scripts

In the unlikely event of an unhandled exception or other program error, CCDAutoPilot will attempt to run a script called RunOnError.vbs, if it exists. There is only one location checked for the existence of this script:
`(My)Documents\CCDWare\CCDAutoPilot5\`

A script is a simple text file that addresses server programs through Windows Scripting Host. A script is written in notepad or other simple text editor, (**not Word!**) and has the extension .vbs instead of .txt. If you want to use this recommended back up facility, here are some sample scripts. Simply copy the text between the ***'s (but not the ***'s) and paste it into notepad. Save the file as RunOnError.vbs, initially to the desktop. Double click on it to make sure it has the desired result. Once you are satisfied, move it to `(My)Documents\CCDWare\CCDAutoPilot5\`

Park the mount with TheSkyX:
***
```
dim tele
set tele = CreateObject ("TheSkyXAdaptor.RASCOMTele")
tele.connect
tele.Park
set tele = nothing
```
***

Park the mount with TheSky6:
***
```
Dim tele
set tele = CreateObject ("TheSky6.RASCOMTele")
tele.Park
set tele = Nothing
```
***

If you want to add more to this, for example close a roof or dome, that can be added. Google Windows Scripting Host for more info and see the documentation for your server programs.

12.2 Plate Solving Notes

Plate solving is a technique that measures precisely where the telescope is pointing by taking a CCD image and then using various pattern matching techniques, matches the stars in the image to a given star catalog. Knowing approximately where the telescope is pointing and the system image scale, plate solving algorithms can calculate the center of the image to sub-arc-second accuracy. Successful plate solving is **essential** for automated imaging.
In order to be successful, three things are required: telescope coordinates, known image scale and sufficient catalog stars in the image.

- **Telescope coordinates:** CCDAutoPilot gets this information from the mount via the chosen telescope control program. Generally the coordinates must be within one or two FOV's and is easy to do. Problems with plate solving are generally not related to telescope coordinates. The telescope coordinates, RA (OBJCTRA) and Dec. (OBJCTDEC), are written into the image's FITS header for any images acquired by CCDAutoPilot. (see note below.)
- **Image scale:** CCDAutoPilot gets this information generally from the FITS header. Image scale is calculated from the pixel size (XPIXSZ), binning (XBINNING) and imager focal length (FOCALLEN). These keyword values are written into the image's FITS header for any images acquired by CCDAutoPilot. A successful initialization will cause these values to be properly written, based on the Imager Settings information. See note below.
- **Star Catalog:** When using TheSky6, catalog selection is automatic. In the recommended default setup, GSC, Tycho and UCAC are used. TheSky6 starts with the GSC and proceeds to more dense catalogs as needed. When using PinPoint, the chosen star catalog must be defined by the user and only one at a time is available. Fortunately for most uses, the GSC is sufficient. Very narrow FOV's may need to use USNO A2.0. This has more faint stars but may fail on wider FOV's.

Note: If you are using image data that was not acquired by CCDAutoPilot, as for example using the "From FIT" button on the targets page, these parameters must be correct in the fits header. If CCDAutoPilot is not initialized, then the FITS header information may not be correct. Camera control programs typically provide for entering most of the data based on the camera driver. However, the user must enter the correct focal length for the imaging system in the appropriate setup section. Failure to do this will cause plate solves to fail.
Assuming all of the above, then the next issue is the plate solve exposure parameters. The goal is here is to get a sufficient number of stars in the image. For most users, a binning of 2x2 or 3x3 is more than sufficient and will both speed plate solving time and increase sensitivity. Of course, use the most transmissive filter, usually the clear or

luminance filter. Sub-framing is appropriate for wide FOV's both to speed plate solving, and in the case of CCDSoft/TheSky plate solving, to insure success. CCDSoft/TheSky has a maximum FOV limit of 1 square degree. Set a suitable sub-frame to get below this limit. While PinPoint doesn't have such a limit, sub-framing may make it a bit speedier. Lastly, the exposure must allow sufficient stars for reliable plate solving.

Using CCDSoft and TheSkyX Professional

TheSkyX, when used in combination with CCDSoft, gives greatly improved plate solve performance over TheSky6. The 1 square degree limitation no longer applies. A number of 10° x 10° FOV's have been successfully solved very rapidly with TheSkyX. You may need to adjust the residual tolerance in CCDSoft to get successful wide angle plate solves. Unfortunately the only way to access this initially is via the results window after a successful plate solve in CCDSoft. I suggest you use a quarter frame exposure with CCDSoft, solve the plate and increase the residual from its normal 0.5 arc-sec. to something like 5 arc-sec. if you are doing wide field imaging.

Using TheSkyX Professional

TheSkyX has a standalone plate solving system that not require CCDSoft and can in fact be used successfully with Maxim. Whether used with Maxim or CCDSoft, you may have to adjust the Detection Threshold in TheSkyX for optimal results. In TheSkyX, see Tools/Image Link/Setup, Setup Button. A good starting point for this setting is 10. For best results, select Unknown Image Scale (really!) and enter your image scale when testing.

Determining plate solve exposure parameters

A good starting point is 5 sec., binned 3x3, through a clear filter. Take some images manually first and use your desired plate solve program. For CCDSoft, use Tools/Insert WCS AutoAstrometry. You will need to manually enter your image scale. For PinPoint with Maxim, use Analyze/PinPoint Astrometry. For PinPoint with CCDSoft, use Visual PinPoint to solve saved CCDSoft exposures.

Experiment with different exposures and note the number of stars used in the solution. You will need at least 10 and more is always better. Adjust the exposure to achieve a good number of stars. Move to a star-poor region of the sky and repeat the test a couple of times to insure good results. Adjust exposure times as needed. If your FOV is small and you are using PinPoint, you may need to use the USNO A2.0 catalog.

During a CCDAutoPilot session, the number of stars used in the solution is shown in the log for every plate solve. Examine your log to make sure you have a sufficient number of stars for reliable plate solving and adjust your plate solve parameters appropriately.

12.3 Mount Notes

Make sure your mount is capable of responding to either or both Park and Tracking commands issued by CCDAutoPilot through the Telescope Control Program's automation interface. This can be verified by using the Test Buttons(See 8.14.8). If those buttons don't have the desired result, there is no way CCDAutoPilot can cause those actions to happen. Check the mount driver software. Many times there is a later revision that may address some missing functionality.

Specific hardware notes

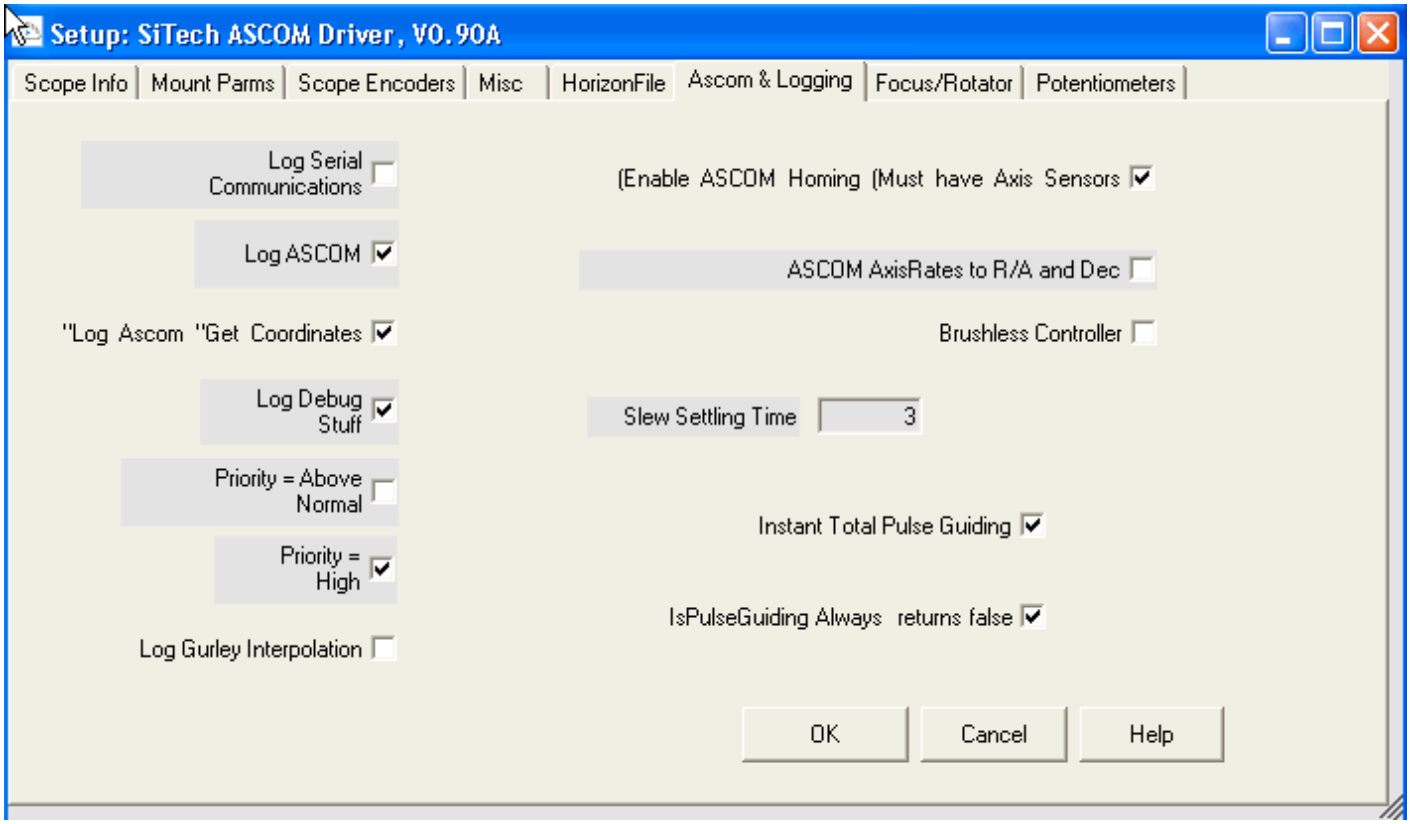
- **Gemini:** To allow proper meridian flip operation, check the Safety Slew box on the Guiding page. See Meridian Crossing (See 8.12.3)for details. Alternatively, on your Gemini controller, set the Goto Limit to exactly the meridian - 90 degrees.
- **Paramount GT1100:** For the original Paramount, check Safety Slew on the Guiding page. See Meridian Crossing(See 8.12.3) for details.
- **ASA Direct Drive:** When using Maxim with Telescope(PulseGuide) for guiding, turn off AutoSlew in the mount's control software.

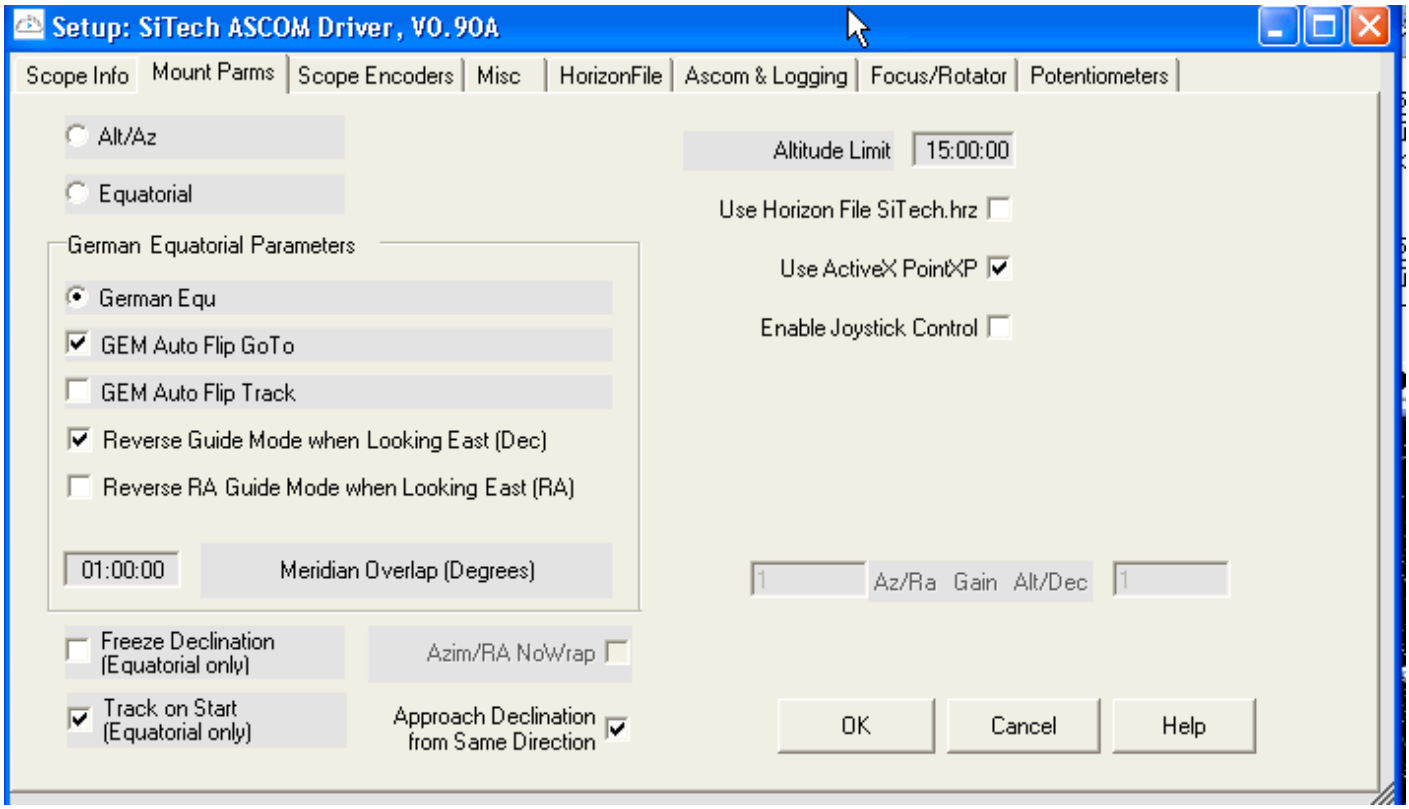
Scitech Mount Setup (Courtesy of Peter Kalajian)

Some specifics on Sitech Ascom driver using ascom.siTechdll.telescope as the ascom telescope. First of all, note that these instructions assume that you have set up Maxim using "telescope" as the guide mode and have the "instant total pulse guiding" and IsPulseGuiding always returns false" checked in the tab Ascom and logging in the SiTech controller configuration setup.

In the second image below, you can see that the Reverse Guide Mode when looking east (dec) is checked. This overrides the default settings in CCDAutoPilot which assume that the mount acts dumb when it comes to meridian flips, but this is the only way it works. You need to calibrate in the east.

Note that to calibrate, you need to uncheck the two pulse guide checkboxes referred to earlier, but once you have a good calibration in CCDAutoPilot, then make sure to check them before you actually guide.





Paramount MX/ME

For proper meridian flipping, be sure to set the Flip Hour Angle to 0 in TheSkyX. (Telescope tab, Tools/Bisque TCS, Parameters)

12.4 Camera Notes

CCDAutoPilot gets its filter and binning information from the Camera Control Program when it first connects with your actual camera connected. It will save that information in the system profile so that you can use that profile for session planning. However, the camera control program automation interfaces do not allow changing the filter names or binning back. At this point in their development, the only alternative if you have different cameras with different filter sets or names is to manually enter them in the camera control program. Hopefully that will change in the future. When it does, CCDAutoPilot will be updated to handle it.

Camera Sensors

The Sub-exposure calculator needs to know sensor characteristics for your camera. A starting list is provided in a file called sensor.ini, located in the CCDAutoPilot4 program folder, typically `C:\Program Files\CCDWare\CCDAutoPilot5`. There is space for 32 entries. While it will be updated from time to time, you can enter your own data if you wish. The file should be edited in notepad or similar text editor, not Word. Make a backup copy before editing, just in case something goes wrong. The four entries are separated by a comma with no spaces and must be numeric data. The last entry should be a blank line. The four entries are:

- **Sensor name**
- **Dark signal in e/pixel/sec**
- **The temperature in Centigrade at which the dark signal is measured**
- **The dark signal doubling temperature in Centigrade times 10. In other words, if the dark signal doubling temperature is 6, this entry should be 60.**

Some sensors have been superseded by new versions by the sensor manufacturer. The new version typically has the same or better performance characteristics as the one it replaces. Some examples are:
KAF11002 replaces KAF11000
KAI4021 replaces KAI4020

Specific Hardware Notes

SBIG STL with Remote Guide Head and Off-axis guider

When using an SBIG STL-series camera with the SBIG remote guide head and an off-axis guider such as the Astrodon MOAG-A, be sure to orient the remote guide head so that its connector is closest to the STL body, as shown at left. Select "Off-axis Guided" for the guide method.

FLI ProLine and Apogee Alta cameras
Some large format sensors benefit from having a selectable readout mode to reduce residual bulk imaging (RBI). See the Camera Options(See 8.14.9) topic for more information.

Maxim v5.05/5.06.
There is a bug introduced in Maxim v5.05 that resets the guider binning to 1 upon program restart. If you simply change the binning to 2, the guider will be sub-framed to 1/4 of the active sensor, resulting in possible loss of guide star. When starting or restarting these versions of Maxim, be sure to reset the guider binning to 2 and hit the reset button to get your full guide chip again. Diffraction Limited is aware of this issue and it was resolved in Maxim 5.07.

Operating with AO devices and Maxim
Maxim uses a somewhat unique method to determine mount bumping. Depending on the camera and AO involved, some adjustments may be required to get successful mount bumping. This may require a combination of using Maxim's Orientation (Camera Control Window, Setup tab, Options button, Orientation box), along with possible adjustment to CCDAutoPilot's Guider Method (Settings page, Guider box). Unfortunately, trial and error may be required. Contact CCDAutoPilot support for help if needed.

SBIG STF-8300 OAG Package

When using this package, select Self-Guided for Guide mode. Even though it is an off-axis guider, there are two mirrors in the guider optical path, which makes it look like Self-Guided to ccdautopilot. Setting the guide mode to Self-Guide will accommodate this.

12.5 Focuser Notes

If a focuser works properly through the focus program, it should work fine through CCDAutoPilot. If you are using temperature to determine when to focus, make sure you select the proper temperature source on the Focusing (See 8.10)page.

Specific Hardware Notes

Optec Focuser: Be sure to turn off the Optec's temperature compensation. The focuser can not be remotely commanded if it is turned on. If temperature compensation is desirable, use CCDAutoPilot's internal temperature compensation routine.

12.6 Rotator Notes

When using an automated rotator, it is critical that the rotator rotate in the proper direction. If Test Rotator Direction(See 8.2.3) is checked on the Setup page, the rotator direction will be checked as part of the initialization process and you will be notified if the direction is incorrect. Some rotators have no way to change them and are coded as such. Others are settable and settings must be made so that operation is in the correct direction. References to direction are viewed from the camera end and should be as follows:

Specific Hardware Notes

- **RCOS PIR:** This is fixed by design. CCW rotation should result increasing position counts or degrees.
- **Optec Pyxis:** There are setup options. The option should be chosen in which CCW rotation results in increasing position counts or degrees. For the 2" Pyxis, this is normally the Reverse direction and for the 3" Pyxis, this is normally the default direction. See the Pyxis control software help file for specifics.
- **Astrodon TAKometer:** By design intent, CCW rotation should result in increasing position counts or degrees. If the rotator position is negative, it should get less negative; if it is positive, it should get larger. For example, CCW rotation should result in the position moving from -150 to-140 or 30 to 40. If this is not the case, try loading factory defaults to see if this solves the issue. Direction may also be changed by the RoboFocus Control Box, which drives the TAKometer. Unlike other rotators, the TAKometer must be accurately calibrated to give good results. Follow the instructions in the TAKometer documentation. Once you have completed calibration, rotate the TAKometer to +180 and note the rotator's position, perhaps against a fixed reference. Then rotate to -180. The rotator should come to the same point If it does not, re-calibrate as needed. Ideally, you should get within ±1 degree.

12.7 Cloud Sensor Notes

CCDAutoPilot accesses the Cloud Sensor via the Single Line Data File, as described in the Boltwood Cloud Sensor documentation. In order to access the cloud sensor data, you must set up a file name and location for this data file. Then, CCDAutoPilot must be told where this file is located from the Settings page, Control Settings tab(See 8.14.5). This file can be located on a PC different from the one CCDAutoPIlot is running on, allowing multiple observing sites at a single location to use the same Cloud Sensor.

When Abort on Update Loss is checked, the run will abort if the cloud sensor stops providing updated data for the time period indicated. For most dedicated cloud monitoring programs, this update time should be set to 30 sec. In some cases, as for example the WeatherWatcher described below, this time should be longer.

Specific Hardware Notes

Boltwood Cloud Sensor: Make sure your temperature settings for cloudy and very cloudy are set properly to indicate the appropriate conditions. You may need to adjust these settings seasonally.

CloudWatcher: The CloudWatcher supports complete networked operation such that each client can set their own thresholds for what constitutes cloudy and very cloudy. This equipment provides Cloud Sensor I functionality, i.e. monitoring of sky temperature to determine cloudy conditions and a rain sensor.

WeatherWatcher: When integrated with CloudWatcher and an appropriate commercial weather station, a Cloud Sensor II compatible Single Line Data File can be used for CCDAutoPilot input. This configuration adds humidity and wind speed from the weather station to cloud and rain monitoring from CloudWatcher. Because weather stations update their data less frequently than CloudWatcher, you may need to adjust the timeout in Abort on Update Loss. You should set the time to be 3 times the weather station update time. For example, if the weather station fastest update is once per minute, set the timeout to 180 sec.

12.8 Dome Notes

CCDAutoPilot makes every attempt to work with available domes. Some automation interfaces are more robust than others. Use the test buttons(See 8.14.8) to verify CCDAutoPilot can operate the dome rotation and open and close the shutters. If those buttons don't have the desired result, there is no way CCDAutoPilot can cause those actions to happen. If you are using AutomaDome, don't set the update time too short. Longer times, 8 - 10 minutes or so, seem to give more reliable operation.