

AG Optical-Thermal Control System Manual

(Version 2.0.0.4.3)

Introduction

The AG Optical Systems Thermal Control System (TCS) consists of:

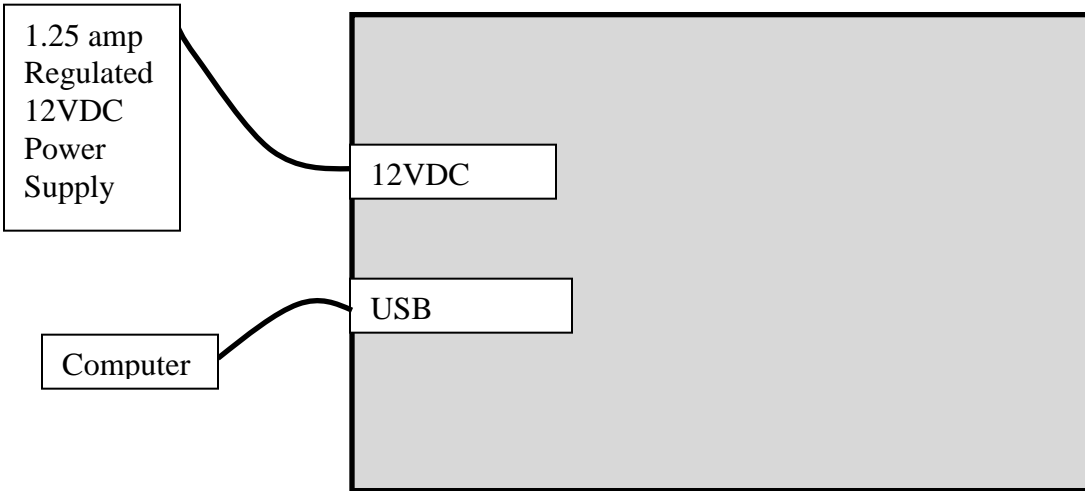
- TCS Control Box
- AGO Thermal Manager software application (Windows compatible)
- Primary mirror cooling fans
- Primary mirror heater
- Secondary mirror heater
- Primary mirror temperature sensor
- Secondary mirror temperature sensor
- Ambient temperature sensor
- Cabling

The system is designed to maintain the temperature of the primary and secondary mirrors to above ambient air temperature by automatically turning on and off the heating and cooling elements of the TCS according to a set of parameters set by the user. Given the wide variability of factors affecting the thermal behavior of the telescope system, AG Optical System designed the TCS to be a simple but effective system that the user can easily monitor and adjust to achieve the best possible performance for their specific telescope system.

The AG Optical Thermal Control System consists of hardware that uses temperature sensors that reads the ambient temperature as well as the surfaces of the primary and secondary mirror to heat and cool the mirrors that is controlled by an application on your computer. Both mirrors can be heated to warm their surfaces and the primary mirror can be cooled using the fans. Multiple sensor reads are made every ten seconds, and a weighted smoothing function that incorporates a moving average together with a median noise filter is used for a stable display and readout.

Minimum System Requirements: XP, Win7 or later.

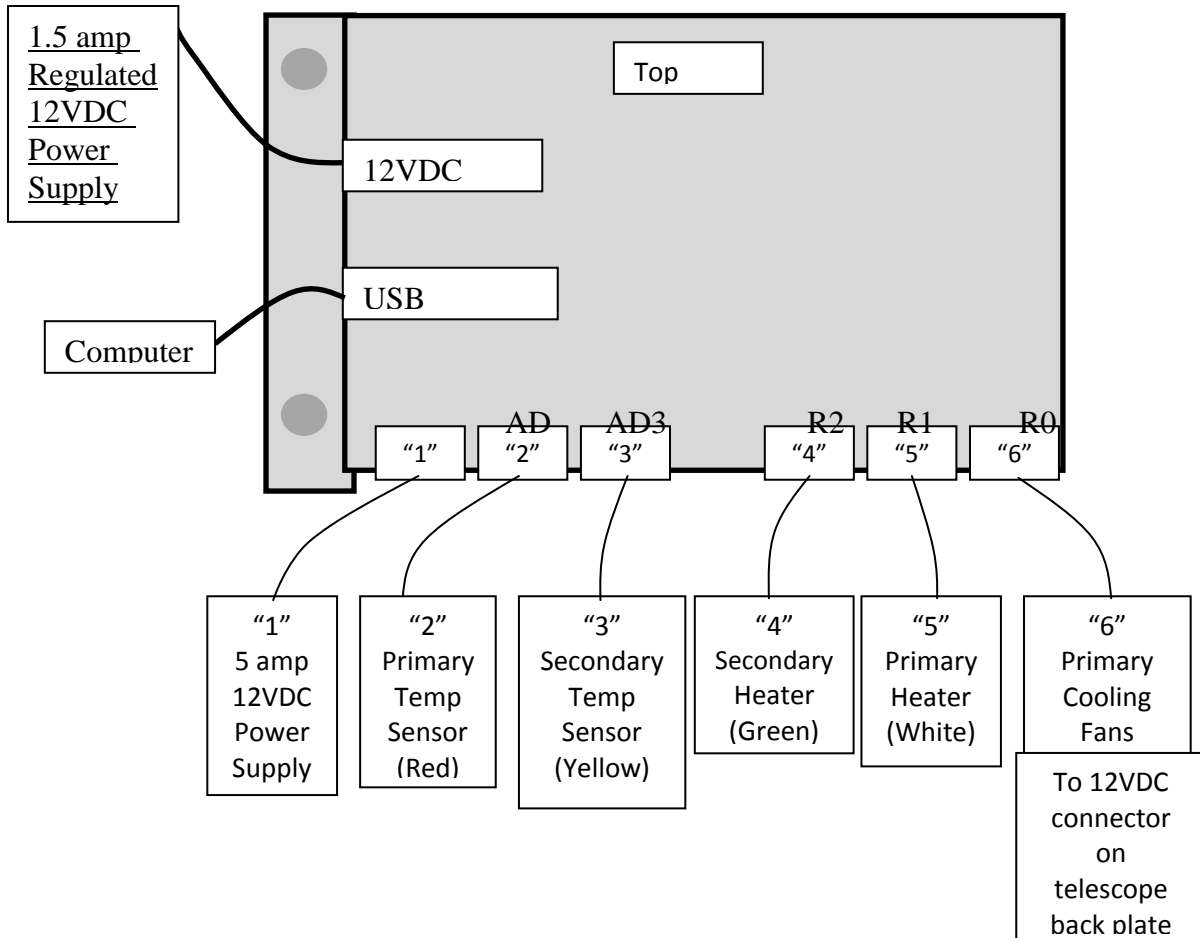
Hardware requirements. Be sure to power the Thermal Control Box using a high quality, regulated 12vdc power supply with at least 1.25 amps capacity. The USB connector and 12 VDC power port are located on the back plate side of the TCS Control Box.



Connect the TCS Control box to a 1.25 or higher, regulated 12vdc power supply. Connect the USB port to your computer or hub that is connected to your computer.

Wiring Diagram

Below is the wiring diagram describing how the various thermal control system elements are connected. A simple numbering and color scheme (1 through 6) is used to ensure each element is properly connected to the TCS Control Box.....Yellow connects to Yellow, Blue to Blue, etc. Some of the connection points are located on the telescope back plate.



Seventeen inch and larger iDK models have four cooling fans installed on the carbon fiber mirror shroud. These fans greatly reduce internal air currents by scrubbing the boundary layer of warm air on the face of the primary mirror. The 12vDC center pin positive power connector and speed control knob for the shroud fans is located on the back plate and is identified by the letters “Sh”.

The other power connectors on the back plate are for the primary cooling fans and TCS temperature control elements (if applicable).

Hint: It is suggested that you use two separate power supplies for the TCS Control Box. A quality, 12VDC regulated power supply capable of supplying at least 1.25 amps should be used for the power source for the TCS Control Box (underlined in the diagram above). A separate 12VDC power supply capable of supplying at least 2.5 amps should be used to power the cooling fans and heaters. Damage to the control board may occur if a non-regulated or non-switched power supply is used.

Software Installation. Before installing the application, be sure to plug the power cable to supply power and the USB cable to the AGO-Thermal Control System Board and the computer. Wait a few seconds and then run *Setup*. On first startup, you will see a warning that the TCS hardware is not connected, and asks if you wish to select the COM port from the Configuration Menu or exit. If the board is powered and the USB cable is connected, click on “Yes” and you will see the TCS Main window. From there, click on "Settings" from the top-menu, and then click on "Serial Port Configuration" and select the correct COM port. Otherwise, click no to connect the cables and restart TCS. If the correct port is selected from the Serial Port Configuration window, click on “Connect” text will change to “**Connected**” if the proper Com Port was selected. After the application finds the port, the main window should start up and be operating in “Off” mode. The status bar should also correctly display the assigned port to which it is connected. If, by some chance, you select an incorrect com port it will not connect and will display a warning that the TCS board could not be found. Once a correct serial port is connected,

it will use that same serial port when you restart the application without further need to reselect the Com Port. If, for some reason that port changes (which could occur if you plug other USB devices that use a serial port before you connect the TCS hardware and a different serial port is assigned, simply go to the Serial Port Configuration page and select the correct serial port again.

Hint: When you connect a USB cable to the TCS hardware and your computer (or hub, if that is connected to your computer), a com port is assigned to the TCS hardware. If you are not sure what com port the TCS hardware should use, remove the USB cable, then left mouse-click on the Start button (on Win7; using Win8 change to Classic Mode), then right-click on “Computer” and click on “Manage” and then click on “Device Manager”. If you see “Ports (COM & LPT)”, click on “Ports” to see the ports installed and then plug in the USB cable. The new com port should appear. If “Ports (COM & LPT)” is not listed, plug in the USB cable and it will appear. Click on “Ports (COM & LPT)” and the Com port created will be shown. Select that com port from the Select com Port Configuration page in TCS.

Start the application. Start the application by clicking on the AGO-Thermal Control

System icon:



The application has three modes:

Off: turns off all relays and sensors and stops temperature readings;

Auto: starts an automatic routine to read sensors and monitor and controls the temperature of the mirrors by turning on heaters or the primary mirror fan; and

Manual: allows the fans and heaters to be controlled manually.

By default, TCS starts up in “Off” mode. Each mode is described below.

Off. All sensors and relays are disabled and OFF. The manual controls are not enabled.

Auto. In *AUTO* mode, the manual controls are not enabled. The ambient temperatures are monitored, and if needed, the Primary is heated or cooled with the fans. The secondary can

only be heated. While in **AUTO** mode, there are three variables that can be modified to fine tune the time the fans or heaters are on, or when they come on or off based on temperature. On the Configuration window, you will find these three settings. The display will show the status of each relay as well as the status bar. The changes are effective immediately when entered and are saved upon exiting the application. If you wish to have the application start up in Auto mode each time TCS is started with no user interaction, simply click the “AutoStart” checkbox from the Configuration page. The next time TCS is started, it will then start in Auto mode, using the Threshold and Duty Cycle and all other settings saved from the previous session. Note that in Auto Mode, it must cycle through one cycle before any heat or fans will begin. For example, if you have the ON or OFF cycle to 60 seconds, the heater or fans will not turn on for the first 60 seconds. Note the Status bar will indicate “Auto Control ON” when Auto is selected. There also will be short delay while TCS initializes, which is also indicated on the Status menu. A flashing "heartbeat" star is displayed each time the temperatures sensors are read.

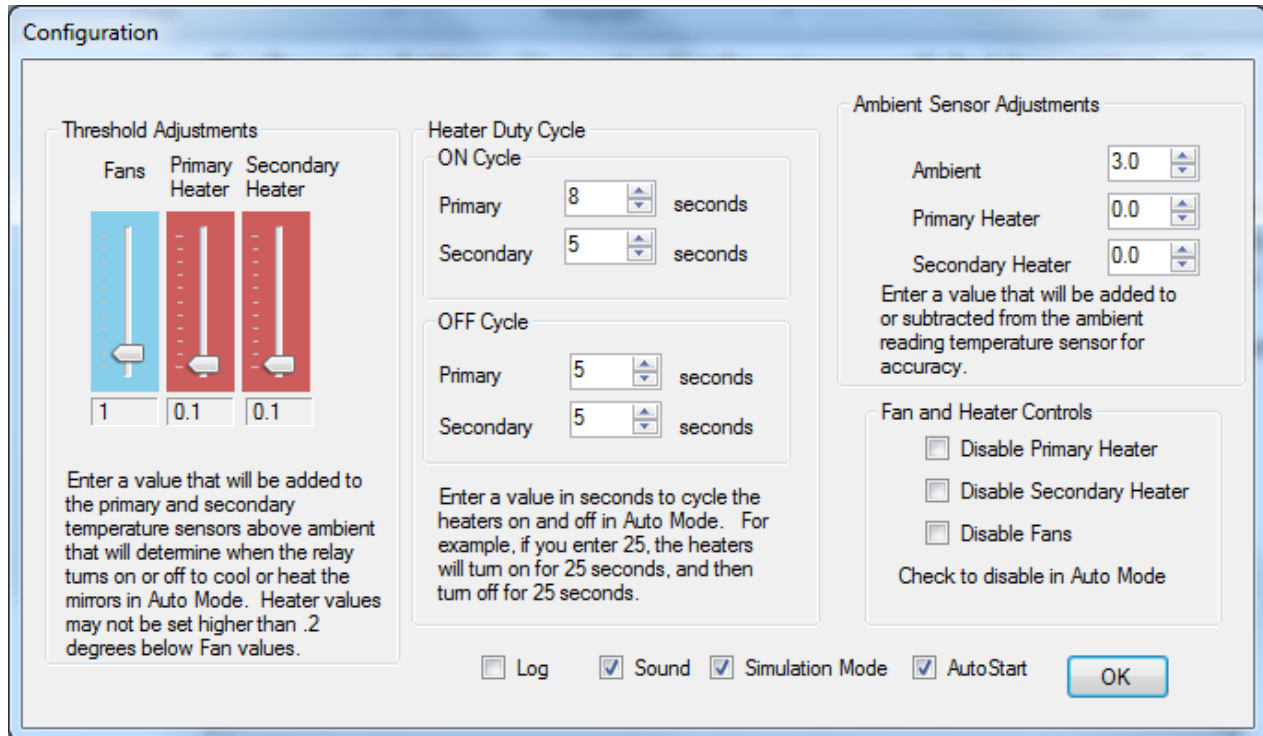
Manual. In Manual Mode, the Manual controls are enabled as are the temperature sensors, and clicking on the control turns on the relay, and clicking it again turns it off. The display will show the status of each relay. Fans and Primary Heaters may not be on at the same time; however, the primary fans and secondary heater may both be on at the same time in case the primary has not cooled down as fast as the secondary mirror.

Hint! If you manually turn on the heaters, be aware they may warm the mirror excessively if you forget to turn them off.

Settings. Clicking on Settings controls the Auto-Timer, Configuration, Enable/Disable Logging, Serial Port Configuration, MiniTCS, and Temperature settings.

Auto-timer Settings. If you want the Auto Control features to be enabled and disabled at a set time, from the Settings Menu, select Auto-timer. There you simply enter the Start Time and End Time and click “Auto-Timer Set”. While waiting for the Start Time to begin, you may use the three controls as you normally would do (Off, Auto, and Manual). A red warning on the Main Menu will be displayed advising an Auto-timer job is pending. At the start time, no matter what mode is selected, the mode will change to Auto. You can use this feature to turn on the heaters in the morning and then off later in the day automatically, for example, after an imaging run at a designated time and without any user interaction to prevent dew. While running, whatever configuration settings you

have selected will be used during the run. You may change these settings as well during the before or during an auto-timer automated run.



Configuration Settings. If you select Configuration you will find three settings that make adjustments to tune the auto settings for accuracy.

Threshold Adjustments. Threshold settings simply set the temperature that the heaters and fans use to determine when the heaters or fans are engaged or disengaged. Default is ambient. In other words, if the settings are at their default setting of 0, the heaters will turn on to warm the mirror until they are brought up to the ambient air temperature, or turn the fans on to cool the mirror down to ambient. The same works for the secondary, except it only can heat the secondary to ambient. Then, the heaters or fans turn off until there is a need to heat or cool the mirror(s) again. There are three settings. One, in blue, is to set the temperature the fans will turn off. There are two in red that determine the temperature the

heaters will heat the mirror before turning off. You may not set the heater threshold setting lower than .2 degrees above the fan setting for the Primary Heater setting to keep them from both being engaged at the same time. You may set the Secondary heater setting up to 10 degrees higher than ambient, no matter what the Primary is set for as it is independent of the Primary settings.

On the main window, when Auto is selected, the Target Temperatures as adjusted by the Threshold settings are displayed to make it easier to both understand and set the desired temperature ranges of the fans and heaters. The ambient temperature is always displayed in green. The primary mirror temperatures are displayed in blue if the temperature of the mirror is below the target temperature and in green if it equals or is between the target temperatures for the heater and fans as set forth in by the threshold settings on the configuration page. The secondary is displayed in blue if it is below the ambient plus threshold temperature settings as set forth in by the threshold settings on the configuration page, and green if it exceeds the target temperature. That way, you can quickly see how well the target temperatures are being maintained.

If you leave the threshold settings at 0.00 for all three settings, if the mirror is warmer than ambient the fans will come on and cool the mirror until it reaches the ambient air temperature. If the mirrors are cooler than the ambient temperature, then the heater will come on and heat the mirror until ambient is reached. When the primary reaches ambient, if weather conditions are stable, there is a possibility that the heater and fans will cycle back and forth. If the temperature is falling or rising usually this is not an issue. To keep the primary heater and fan from cycling back and forth where the air temperature is fairly stable, it is recommended that a setting of at least .4 or so for the primary heater and .1 for the fans be set as the threshold settings. This creates a "dead band" of .3 which should be enough to keep the devices from cycling, and keep the mirror above ambient to keep dew from forming. If not, increase it accordingly - simply increase the fan values by .1 or so and the positive values for the primary heater until the cycling stops. Setting the primary fans within .2 degrees of the heater is not allowed, and the heater temperature will be adjusted to the minimum difference. You may increase this difference, but not reduce it beyond .2 degrees. The goal is to set the values so that the temperature of the mirror is what you want it to be and not cycle between heating and cooling the primary mirror. Normally, temperatures are falling, and so the primary mirror follows the actual ambient air temperatures. However, if the ambient air temperature is falling and the later rising, then the

threshold setting for the fans should be set high enough so there is a difference between the two that cycling does not occur.

If you notice constant cycling between the primary heater and fan, simply change the settings so there is a larger difference between the Primary Fan and Primary Heater settings until the cycling stops. You may also disable the fans and both heaters separately by clicking the *Disable* appropriate checkbox on the Configuration Settings page for each.

Duty Cycle Settings. In order to avoid tube currents, the heaters cycle ON and OFF so they do not become overly warm. The Duty Cycle settings allow you to control how long each ON and OFF duty cycle will be. The default is 30 seconds. The number is in seconds, so if you change the Off cycle to 25, for example, and the ON cycle to 30, the heaters will stay off for 25 seconds, and then cycle On for 30 seconds and will repeat until the mirrors reach the ambient settings (plus or minus the Threshold Settings as stated above). Settings less than 10 seconds are not recommended.

Ambient Sensor Adjustment. Although the sensors are quite accurate, different sensors can read slightly differently. By adding or subtracting an amount set forth in this setting, you can adjust up or down the readout of the each temperature setting. If you are satisfied each are accurate at the default setting of 0.00, then make no adjustment. If you wish to adjust these values, you may add or subtract a value as needed.

Recommended Settings. The settings depend on the ambient temperature. A setting of 30 seconds is recommended, depending on the ambient air temperatures nothing more. As the mirror begins to get close to ambient, reduce the cycle settings to a value that will maintain the setting you desire for the mirrors. Note that fans do not cycle and stay on until ambient is reached. If you notice that the mirror temperatures are too cold or too hot, reduce the duty cycle setting until you see a fairly stable setting. The ambient temperature plays the largest role in a proper setting rapidly decreasing temperatures, for instance, will require fans, but the secondary will follow along since it is only passively cooled. On the other hand, once the secondary reaches ambient (or the target temperature), it should maintain the correct temperature closely, but will rise and fall as heat is applied,

and the heater turned on, and off. If the target temperature is more than a degree or so above the target temperature, reduce the duty cycle so less heat is applied. Some trial and error is needed to determine the exact settings, but generally, the settings as set forth above seems to work well in fairly moderate conditions (25F-70F). Optimally, the best settings are those that turn on the heaters for no more than absolutely necessary to prevent dew.

Fan and Heater Controls. Clicking off the checkbox will disable the Primary, Secondary, or Fans during Auto-Mode. This function has no effect in Manual Mode.

Simulation Mode. If the checkbox is selected, TCS will simulate an Auto mode control session using randomly generated temperatures for the Ambient, Primary, and Secondary mirrors temperature readings. It connects to a simulated Com 10 port (no actual port is connected). The TCS board does not have to be powered, or connected to the USB cable to your computer. To disable Simulation Mode, uncheck the box. A window will pop up advising you to select a Com Port to continue from the Serial Port Configuration page. If you do not wish to do so, simply click OK, but you will not be able to use Manual or Auto Mode features until you either re-select a Com Port from the Serial Port Configuration window or re-select Simulation Mode from the Configuration Window. If you exit TCS while in Simulation Mode, and Auto-Start is selected, and the TCS hardware is not connected or powered, TCS will again start up in Simulation mode using whatever settings were last selected from the Configuration window. To connect to the actual Com Port, uncheck the Simulation Mode checkbox, and re-select the actual Com Port used by your computer to connect to the TCS Hardware.

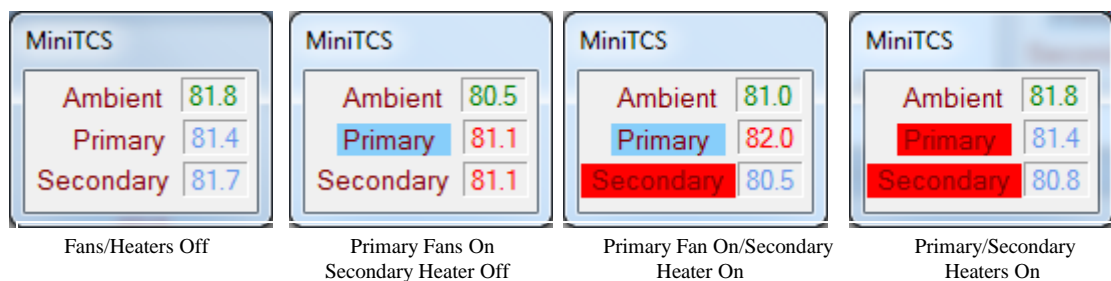
Sound. If checked, when the relays are turned off and on, a relay-click can be heard, and when the fans are on, a fan sound can be heard. The feature is enabled by default. Un-checking the checkbox disables all sounds in both Manual and Auto modes.

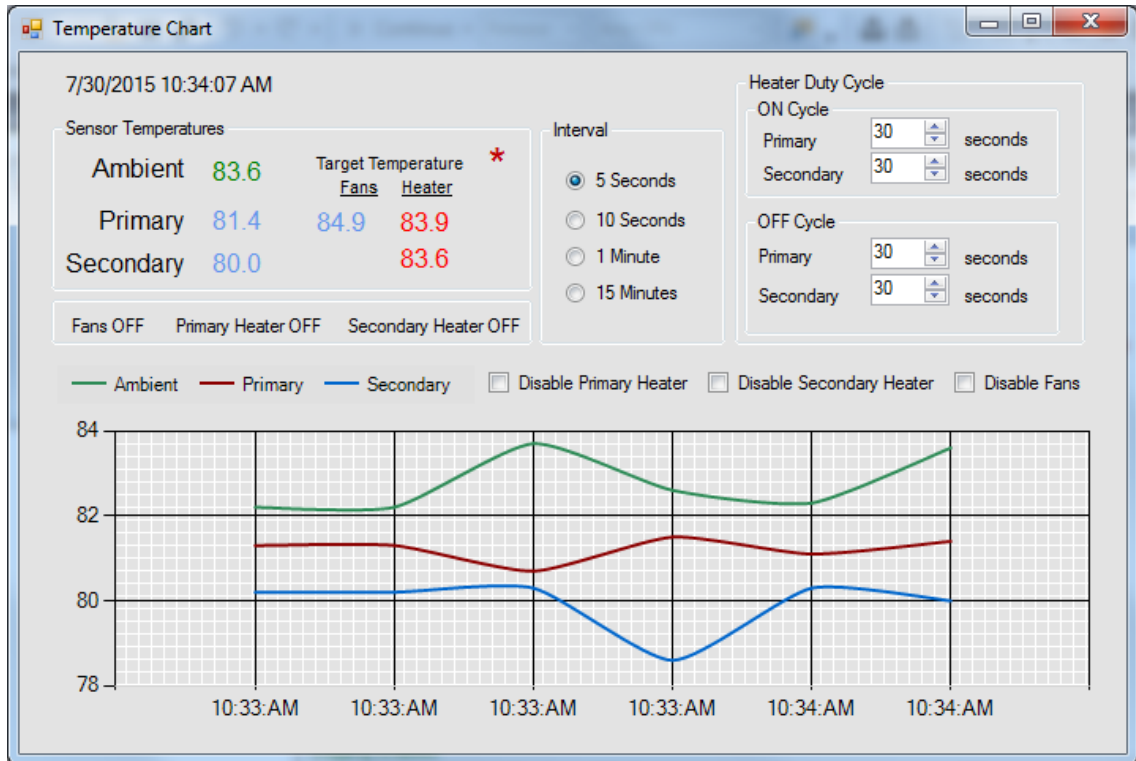
Enable Logging. Under the Configuration menu, you will find an optional “Enable Logging” feature. Clicking on this will either create a new log text file if one does not exist or append a log to an existing file every 15 seconds. The log will report

the date and time and which relays are engaged and what the temperatures were that as read by the sensors (as adjusted by the Configuration Settings above). The file is by default located at "C:\Users\Public\AGO\Log.txt. To disable, simply click on "Disable Logging" from the same menu if logging was enabled. A green label will be displayed on the Main Menu when logging is engaged. If Logging was enabled when TCS was last exited, the log will restart automatically next time TCS is launched.

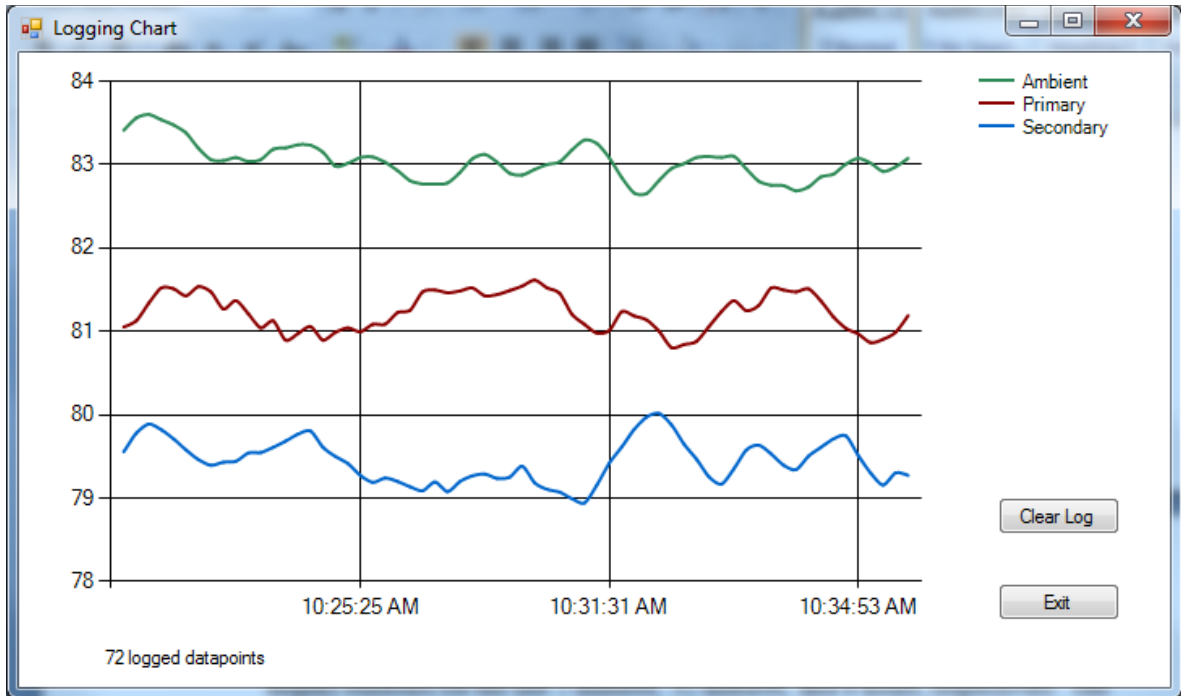
AutoStart. If Autostart is checked when the TCS application is closed, on the next start up of TCS, it will start up in AUTO mode, with all the settings that were in effect when TCS last closed. If Simulation mode was selected when TCS was last closed, it will start up in Simulation Mode and in AUTO mode, with the settings that were in effect when TCS last closed.

MiniTCS. If you only want to monitor the temperatures of the ambient, primary and secondary mirror and the operation of the fans and heaters while in Auto Mode, and don't want to see the entire TCS main window display on the Desktop, from the Settings menu, click on "MiniTCS. Note that TCS must be running in Auto mode for the MiniTCS to be displayed and cannot be displayed in Manual Mode. Clicking the left-mouse button anywhere inside the MiniTCS window will make the Main AGO-TCS window visible again and the MiniTCS window will be hidden. You can view the ambient air primary, and secondary mirror temperatures, as well as whether the primary and secondary heaters or primary fans are on or off as shown below.





Temperature Chart. Click on “Settings”, “Temperature Chart” and a chart as displayed above will open showing in real time the actual temperature readings. Temperature readings are taken every five seconds, no matter how often the chart updates. You may set the graph interval in 10 second, 1 minute, and 15 minute intervals. This will display readouts for the last 5 minutes, 32 minutes, and 8 hours, respectively. The temperatures can be followed to verify that the mirror temperatures are always above ambient to avoid dew. You may also directly change the Primary duty cycle settings without having to open the Configuration page. Note that the chart is only available in Auto mode.



Logging Chart. The Logging Chart displays all the data that has been logged in the log file. The file itself is located at C:\Users\Public\Public Documents\AGO\Log.txt. Typical log entries are shown below:

```
7/30/2015 9:21:34 AM,Fans OFF,Primary Heater ON,Secondary Heater ON,82.7F,81.5F,78.5F
7/30/2015 9:21:34 AM,Fans OFF,Primary Heater ON,Secondary Heater ON,82.7F,81.5F,78.5F
7/30/2015 9:21:39 AM,Fans OFF,Primary Heater ON,Secondary Heater OFF,83.9F,80.6F,79.3F
7/30/2015 9:21:44 AM,Fans OFF,Primary Heater ON,Secondary Heater OFF,83.2F,80.6F,80.1F
```

The last three values are the Ambient, Primary, and Secondary values. Since the chart is nothing more than the data in the log.txt file that is displayed, it could get a bit confusing if you change from Celsius and back to Fahrenheit during a run or a sensor fails to read correctly. If the chart does not appear correct, clear the log, and start a new one by clicking on the "Clear Log" button. This deletes the old log and creates a new one with fresh data. Note it takes about 60 seconds to record enough data points to display the chart.

When changing from OFF mode to AUTO mode, if there is an existing log.txt file, it is renamed using the following format: Log-MonthDayYear Hours-Minutes-Seconds.txt (example: Log-08082015145401.txt for a log saved on August 8, 2015 at 14:54:01 hours). A new log.txt file is then created and used to create the graph. If there is no existing log.txt file, one will be created. This process will occur also if you click on the "Clear log" on the log graph itself. To display an older graph, rename it as "Log.txt", disable logging

by clicking the log off on the configuration page, and then display the logged date from the file by clicking on the "Logging Chart" from the Settings Menu.

If you click on OFF or Manual mode, or disable logging on the configuration menu even in AUTO mode, no file is saved, and no data points are collected. If there are sufficient data points in an existing log file, it will display whatever data the file contains. If there is not an existing log file, however, if a log file does not exist, one will not be created until you enable logging, and change the mode to AUTO mode.

Closing TCS and saving settings. Simply click on the Top Menu "File/Close" or click on the "X" icon in the upper right window. All settings in the configuration window will be saved upon closing, and the mode setting will be placed in the "Off" position before the program exits.

Summary. In practice, what has been observed is that in moderate climates, the primary mirror is almost always warmer than the ambient air temperature as the air temperature falls much more rapidly than the temperature of the mirror, even with the fans on, until very early in the morning. With the fans on, however, it will stay very close-and should be within at least .5 (half a degree) of the target temperature the majority of the time. If you set the threshold value of the fans, for example, at 1 degree over ambient, it should cool the mirror to this temperature, and keep it there, all night long +/- .5F. The primary heater is rarely needed to be engaged.

On the other hand, the secondary will not only fall to ambient very quickly, observations show it will actually fall below ambient if not heated. Since dew only forms when the dew-point equals or is below the ambient temperature (if the dew-point is below freezing, the frost will form), it is important to keep the mirror warmer than the ambient temperature to prevent dew or frost. If the threshold setting is set for 1 degree over ambient, it will fall to that temperature, and remain there, during your session, preventing any chance of dew, slightly going a bit below the target and a bit above, usually +/- .2 degrees.

A recommended threshold setting for the fans at around .3 to 1 degree above ambient, the primary heater at .2 and the secondary a .2 to or above, with a duty cycle of 30 to prevent dew works well. However, with that being said, you should make yourself aware of the dew point and ambient humidity levels and adjust your threshold settings accordingly. Settings for the secondary that work well in moderate climates would be .3 above ambient with a duty cycle of 15-20. Use higher settings for high humidity environments or where very cold temperatures are observed to prevent dew from forming. If you notice that the mirror temperatures can't quite keep up with the falling ambient temperatures, increase the On cycle and reduce the OFF cycle slightly. The settings will change based on the meteorological conditions, but the optimal settings are always the minimum settings for the ON and Off cycles that will do the job and nothing more. As the

imaging session progresses, simply take note of the temperatures and make any adjustments needed to add more or less heat desired. Since the weather conditions can vary from extremely cold to hot, it is impossible to have a setting that works in all weather, so be aware of the conditions, and set the threshold settings accordingly.

Troubleshooting

1. I can't connect to the serial port. This is usually caused by (1) not having the 12vdc power supply connected, or not using the proper voltage or (2) not having the USB cable plugged into the computer or hub that is attached to the computer, or (3) selecting the wrong com port from the serial port configuration window. Once you connect, TCS should automatically find and connect after the first connection. On occasion, if you install other hardware that uses the same port when TCS is not connected, the correct port assignment could change as well for TCS. If that occurs, simply try to connect using the correct port from the Serial Port Configuration window.

2. TCS is not maintaining the set temperatures. If the mirror stays below the ambient plus threshold setting, increase the "On" time. If it is too hot, simply decrease it. You should also increase the "Off" time to avoid tube currents and while it is not required, closely follow On time settings. If the temperature of the primary is not being cooled sufficiently, check the small black knob on the back plate to be sure it is in the highest fan speed position. It has been found that the Secondary mirror heater will take longer to warm the mirror than the Primary if they are both set on the same settings. You may want to increase the ON cycle for the Secondary heater if it is not warming the mirror sufficiently.

3. The temperatures shows strange readings, such as -273C or -479F, or an error message appears saying these readings are being read for the primary or secondary mirror. This is usually an indication the Red or Yellow plugs are not snug and not making good contact. Push them in and be sure they are firmly in place. If that does not resolve the issue, you will have to visibly confirm the wires are connected inside the TCS hardware box. If you receive the same error for the ambient, then the wire to the ambient thermistor has come loose from the board.

If you receive an error that the temperature is 622.6F or 328.1C, then most likely the plug from the 12vdc power connection is likely plugged into the plug for the sensor. Confirm the plugs match the diagrams on page two of this manual.

4. I can't find the serial port or the TCS cannot connect. Be sure to install the latest drivers from <http://www.ftdichip.com/FTDrivers.htm>.

*AG Optical Thermal Control System
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