Keo SkyScan4

Articulated Mirror Assembly

Hardware User Manual

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1 Introduction

Thank you for purchasing a Keo SkyScan4 system from Keo Scientific. This latest version of our SkyScan system is the culmination of several years of design iterations and is our most capable system yet.

The Keo SkyScan4 is a dual first-surface mirror assembly that can be pointed towards any point in the sky by rotating the two mutually perpendicular axes, one of which is vertical and the other horizontal, to the desired positions. Rotation about the vertical axis varies the azimuth (compass bearing) of the pointing direction while rotation about the horizontal axis varies the zenith angle of the pointing direction.

Both axes are capable of full 360-degree continuous rotation through the use of electrical brushes and slip rings for transferring power and communication through to the rotating axis. This improvement over our legacy systems, which were limited to approximately 200 degrees of azimuth travel and required complicated calculations for achieving full 360 degree pointing, allows for simplified control of the device and smooth tracking of trajectories.

The SkyScan system is suitable for use with space weather, aeronomical, and surveillance instrumentation such as photometers, narrow-field imagers and Fabry-Pérot Interferometers (FPIs). It can also be used as a heliostat or trajectory tracker.

High-reflectance, first-surface quality mirrors and a high-transmittance entrance window are used to minimize light loss through the system. Modern servo-motor technology is used drive the axes to provide fast, repeatable, and high-precision pointing or scanning.

All that is needed to communicate with and control the SkyScan system is a suitable computer with an available USB2 port.

Figure 1: The SkyScan4

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2 System Components

2.1 System Components Overview

A standard SkyScan4 system consists of the SkyScan unit, a power supply unit with AC cord, a power tether cable, a data tether cable, a USB cable, a user manual, and software USB stick.

Figure 1: Typical System Components

2.2 SkyScan Unit

This is the main component of the SkyScan system. It is a self-contained unit comprising two mutually perpendicular axes (azimuth and zenith) each of which has an Animatics SmartMotor™ for precise motion control.

2.2.1 Drive System

This new and improved SkyScan4 uses PowerGrip® GT®2 synchronous belts for transmitting power from the gearboxes to the axes. The unique curvilinear tooth profile delivers smooth, quiet operation and precise registration with virtually no backlash. These belts are combined with precision gearboxes and Animatics Class 5 SmartMotor integrated servo motors to provide a high accuracy, long lasting, and zero maintenance drive system.

The Class 5 SmartMotors used on the SkyScan communicate with each other using the Combitronic™ protocol over the CAN bus which allows for one of the motors to act as a master and execute commands on the other, all at a blazing fast 1MBaud data rate. This greatly simplifies the programming of the system and improves the coordination of the two axes.

The floating point capabilities of these motors allow for the user to specify all positions and velocities in their native units (degrees and degrees per second) rather than having to calculate them in device units (encoder counts). The modulo encoder count capabilities completely eradicate any position overflow issues found in previous SkyScan devices.

2.2.2 Electrical Brush System

The original Keo SkyScan was limited to 200° of travel in the azimuth axis due to limitations put in place by having wired power and communications. The new SkyScan uses electrical brushes and brass slip rings to transfer power and communications into the rotating device. This allows for full 360° continuous rotation about both axes. No longer is it necessary to flip the zenith axis to the inverted position to point in some directions.

2.2.3 Coordinate System

Important Information

All references to cardinal directions (north, south, east, and west) in this manual are with respect to the earth's geographic coordinate system, ***not*** the magnetic coordinate system. Aligning the device with magnetic north may cause significant errors in the pointing accuracy of the system.

The SkyScan system uses a spherical coordinate system defined by an azimuth angle and a zenith angle where the azimuth angle is measured clockwise from north and the zenith angle is measured from the zenith in the direction of the azimuth angle (see Figure 2). Since all possible points can be described with a 0 to 360° azimuth range and a 0 to 180° zenith range, negative zenith values are not strictly necessary. The SkyScan will however accept negative zenith angles which are simply interpreted as a positive zenith angle in the *azimuth angle + 180°* azimuth direction.

Note

The SkyScan mounting plate is designed so that the power connector is oriented in the south direction.

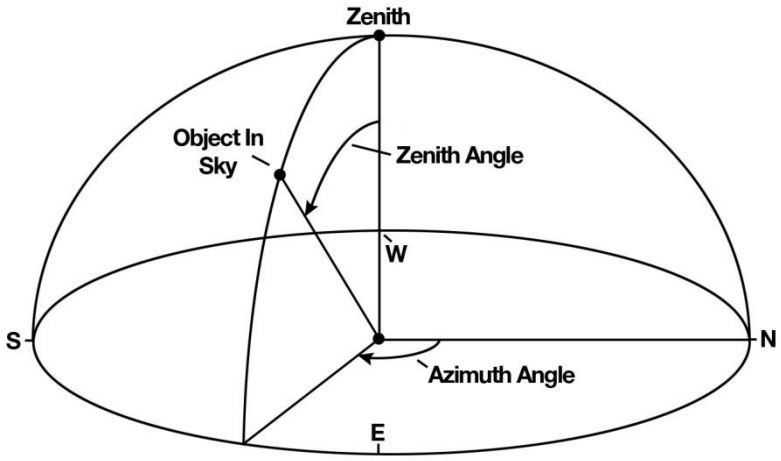

Figure 2: SkyScan Coordinate System

The coordinates of the SkyScan are always given by the position of the two axes, i.e. the azimuth and zenith angles of the point the SkyScan is pointing at. In this manual they are represented as a position pair, (Az,Ze). For example, an azimuth angle of 110° and a zenith angle of 45° would be represented as (110°,45°).

Due to the optical geometry of the SkyScan unit, the azimuth head will always appear to be lagging the actual azimuth position by 90 degrees. As shown by the top-down view of Figure 3, despite the physical azimuth axis being aligned with north, the actual azimuth angle is 90 degrees. In this same figure, the zenith axis is also positioned at 90 degrees making the current position of the SkyScan (90°,90°).

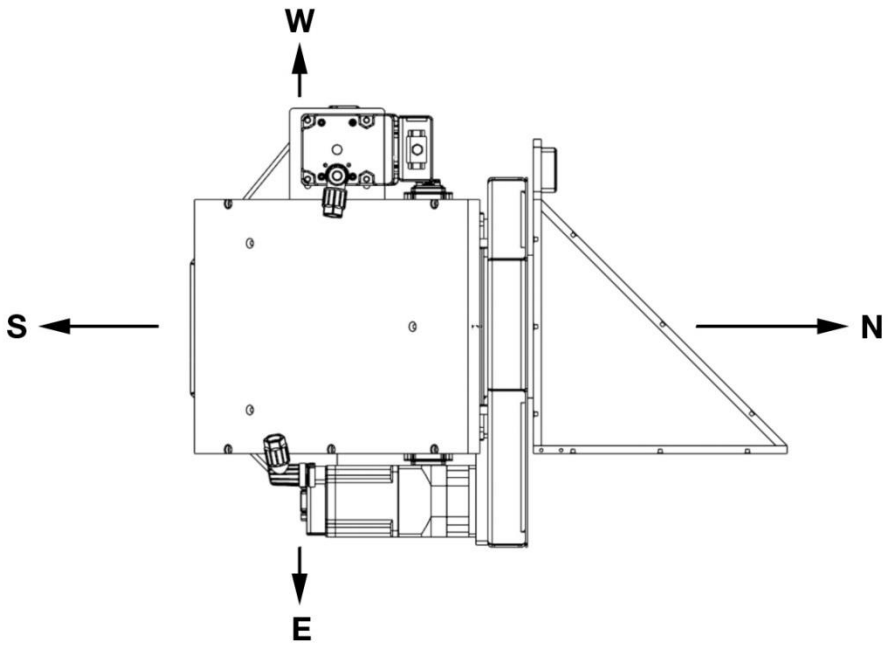

Figure 3: Top-Down Coordinate System View

After the SkyScan performs a homing cycle it positions itself in the parked position. This position was chosen to be (90°,180°) which corresponds to the physical azimuth axis being aligned with north and the zenith axis pointing straight down. This serves to protect the window, mirrors, and any instrumentation

you may have attached to the SkyScan by preventing any direct light from entering the system. The parked position is shown in Figure 4.

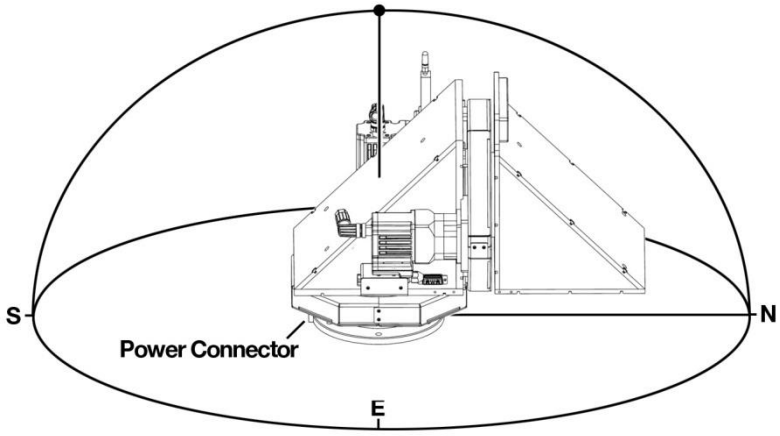

Figure 4: SkyScan in Parked Position

2.3 Power Supply Unit

The AC line-voltage line cord supplied with your system should be compatible with the region to which the system was shipped. If the line cord is incompatible, please contact Keo Scientific for a replacement.

Maximum Power Output: 240 W
Input: 100 – 240 VAC, 50 – 60 Hz, 6.3A
Output: 24 VDC @ 10A maximum

2.4 Cables

Power Tether Cable: The standard 7m (23') tether cable has 3-pin LEMO FGG.2B connectors that interconnect the power supply with the SkyScan4. This tether is used for transferring power to the SkyScan.

Data Tether Cable: The standard 7m (23') tether cable has 3-pin LEMO FGG.1B connectors that interconnect the power supply with the SkyScan. This tether is used for communications with the SkyScan.

USB Cable: The provided 2m (6') USB Mini-B to USB A cable is used to connect the power supply with the host computer.

2.5 User Manuals

SkyScan4 Hardware User Manual: This manual describes how to install and use the SkyScan4 system components. A PDF version of this manual is provided on the Documentation and Utilities USB Drive.

SkyScan Control Software User Manual: This manual describes how to install and use the application program. A PDF version of this manual is provided on the Documentation and Utilities USB Drive.

2.6 Software

SkyScan Control Software: The SkyScan4 system can be operated by using the SkyScan Control Software, Keo Scientific's Windows® software designed specifically for controlling the SkyScan4. This software can be used to manually control the device or automatically control it using a pre-determined trajectory. It also has the capability of running in 'Heliostat' mode which will make the SkyScan4 track the sun.

SmartMotor Interface (SMI): Located in the *Utilities\SmartMotor Interface* folder of the Documentation and Utilities USB Drive, this application is required to update the firmware of the SkyScan. See Appendix C for details on using SMI to update the firmware of your SkyScan.

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3 Installation Overview

The list below briefly describes the sequence of actions required to install and operate your system. Refer to the indicated references for more detailed information.

Action	Reference
1. If the system components have not already been unpacked, unpack them and inspect them for in-transit damage.	Section 4.3: Unpacking the System4.3, page 18
2. Verify that all system components have been received.	Section 4.4: Equipment and Parts Inventory, page 18
3. If the components show no signs of damage, verify that the appropriate power cord has been supplied with the power supply.	Section 4.2.2: Power Requirements, page 17
4. Securely mount the device in a suitable location.	Section 4.5: Mounting, page 19
5. **Turn the device ON.**	
6. Turn on the computer and begin running the application software.	SkyScan Control Software Manual

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4 System Setup

Caution

To minimize the risk to users or to the system equipment, turn the system **OFF** before any cables are connected or disconnected.

4.1 Introduction

The Keo SkyScan4 system consists of three hardware components:

- SkyScan unit
- Power supply
- Cables

All of the components and cables required to use the SkyScan are included with your shipment. Keep all of the original packing materials so you can safely ship the SkyScan system to another location or return it for service if necessary. If you have any difficulty with any step of the instructions, contact Keo Scientific support. For support contact information, refer to Section 8.2.

Hardware installation will consist of:

- Mounting the SkyScan in the desired location.
- Connecting various cables.

Software installation depends on the application software you will be using to run the system. Refer to the manual supplied with the software for information about installing and setting it up.

4.2 System Requirements

4.2.1 Environmental Requirements

Storage temperature: ≤80°C
Operating environmental temperature: +5°C to +70°C
Relative humidity: ≤30%; non-condensing

4.2.2 Power Requirements

The SkyScan unit receives its power from the supplied power supply which in turn plugs into an AC power source.

Power supply input voltage range: 100 VAC to 240 VAC (50/60 Hz)
Power supply input current: 6.3A

4.2.3 Mechanical Requirements

A sturdy platform capable of supporting 31lbs (14kg). The more rigid the platform the smoother the operation of the SkyScan will be during quick acceleration and deceleration.

4.2.4 Host Computer

Note
Computers and operating systems all undergo frequent revision. The following information is only intended to give minimum computer requirements. Please contact Keo Scientific to determine your specific needs.

The SkyScan system needs a host computer to communicate with and control it. The power supply has an integrated FTDI USB to Serial adaptor which will work with virtually any operating system in both 32-bit and 64-bit environments: Windows XP or newer, Linux, or Mac OS X. Drivers for these environments can be found on the Documentation and Utilities USB Drive in the *Drivers\FTDI* folder.

The SkyScan Control Software provided with your SkyScan system is only compatible with Windows 7 or newer in both 32-bit and 64-bit environments. If you want to use the SkyScan with a non-Windows platform you will need to write your own control software. The SkyScan has an easy to use interface that is controlled with simple commands which are sent to its virtual serial port. See Section 5 for details on communicating with the SkyScan system and see Section 6 for details on the available commands.

4.3 Unpacking the System

While unpacking the SkyScan, check the system components for possible signs of shipping damage. If there are any, notify Keo Scientific immediately.

The system is shipped in a custom shipping case for maximum protection. The case can also be used to store the device while it is not in use. Please save the case so that it can be used to ship the device to a new location or to return it to Keo Scientific for repairs if necessary.

To remove the SkyScan4 from its packaging, simply lift it out of the shipping case and place it on a clean flat surface. The SkyScan4 will sit on a flat surface without falling over, however it is recommended that you always clamp it to the surface it is sitting on before powering it up.

Caution
To minimize the risk to users or to the system equipment, ensure the SkyScan4 is securely mounted before powering it on.

4.4 Equipment and Parts Inventory

Upon receiving the Keo SkyScan4, please confirm that you have all of the parts required to set up the SkyScan system. A complete system consists of:

- **SkyScan4 Unit**
- **SkyScan4 Power Supply**
- **Power Supply to Wall Cable:** 2 meter (6.5 ft.) cable is standard.
- **Power Supply to SkyScan Power Tether Cable:** 7 meter (23 ft.) cable is standard.
- **Power Supply to SkyScan Data Tether Cable:** 7 meter (23 ft.) cable is standard.

- **USB Cable:** 2 meter (6 ft.) mini-B to A cable is standard.
- **SkyScan4 Hardware User Manual**
- **SkyScan4 Control Software User Manual**
- **Documentation and Utilities USB Drive:** Includes drivers, utilities, and user manuals.

4.5 Mounting

Caution

Ensure the SkyScan4 is securely mounted to a solid surface before applying power. This can be achieved using the provided mounting flange bolt holes or, for temporary mounting, C-clamps.

If using C-clamps, please ensure that the zenith head will not collide with the clamp by manually rotating the device and checking for interference.

The SkyScan4 ships with a mounting flange containing 3 holes for 1/4-20 socket head cap screws as shown in the schematic in Appendix B. It is important to note that the power connector is located at the 180° (south) position as shown in Figure 4 on page 12.

Feel free to mount the device using this flange as you see fit. As long as the device is securely mounted there shouldn't be any problems.

Important Information

The pointing accuracy of the SkyScan is largely dependent on how accurately it can be mounted. If it were mounted perfectly level (in both directions) and perfectly aligned with geographic north, then the accuracies stated in Appendix A hold true.

However, unless the control software takes potential misalignment into account, any errors in mounting alignment will result in decreased pointing accuracy. For example, if the SkyScan is mounted pointing 2° east of geographic north, there will be a +2° error in the azimuth angle of all positions sent to the device. Inaccuracies in leveling the device will result in complex non-constant errors in both the azimuth and zenith axes.

The Keo SkyScan Control Software has a built in alignment calibration routine that uses 3 data points of the sun's position over the course of a day to calculate a transformation from the local SkyScan coordinate system to the global geographic coordinate system. After the alignment calibration is complete, points of interest can be specified by their true global coordinates and the software will translate that into an equivalent position for the SkyScan to point to. After performing an alignment calibration, no matter the error in mounting the device, the accuracies stated in Appendix A will hold true.

An alternative to doing software alignment calibration is to mount the SkyScan in such a way as to allow for easy alignment adjustment. The ideal mounting solution would provide adjustment in both directions (north-south and east-west) as well as rotationally about the azimuth axis.

After successfully mounting the SkyScan4, it is important to ensure that the pointing heads can move freely without bumping into surrounding objects/personnel. Gently rotate each axis through the full 360-degree range. It should feel smooth. There will be some noise generated by the reducing gearboxes which is completely normal and should not be cause for concern. The azimuth axis will feel considerably stiffer because it uses a much higher gear reduction ratio than the zenith axis.

Your SkyScan4 is now ready for operation.

4.6 Driver Installation

The only driver that needs to be installed before you can start communicating with your SkyScan is the one for the FTDI USB to Serial adaptor integrated in the power supply unit. Once this is done, the SkyScan device will appear as an additional COM port available to your PC. Application software can access the device the same way it would access a standard COM port.

Important Information

On most operating systems, this FTDI driver will automatically install upon connecting the USB cable. If it does not install properly, then use the instructions below to manually install it.

1. Locate the device driver for the FTDI adaptor.
    a. Navigate to *Drivers\FTDI* on the software USB drive, or
    b. Go to http://www.ftdichip.com/Drivers/VCP.htm to download the latest driver available for your operating environment.

2. Install the device driver. There are installation guides available from FTDI for the various different operating environments. http://www.ftdichip.com/Support/Documents/InstallGuides.htm

3. Connect the USB cable between the power supply and the host computer. It will be detected and installed as a COM port.

You can determine the COM port number of the SkyScan by navigating to the Windows Device Manager (*Start* > *Control Panel* > *Device Manager*) and then expanding the *Ports (COM & LPT)* section. The SkyScan is installed as a USB Serial Port. Depending on the other devices installed in your system there may be multiple USB Serial Ports. In that case you may need to use trial and error to find the correct port.

4.7 Software Installation

The SkyScan4 ships with Keo SkyScan Control Software which can be used to control the SkyScan from a Windows based PC running Windows 7 or newer. Please refer to the SkyScan Control Software User Manual for instructions on installing and running this software.

5 Operation

Once the SkyScan4 has been installed as explained in the preceding chapters, operation of the system is straightforward.

5.1 The First Power-Up

Before powering up the SkyScan4 for the first time, please ensure that all items in the below checklist have been completed.

☑	Item
	SkyScan4 is securely mounted?
	360 degree rotational test for clearance complete for both the azimuth and zenith axes?
	FTDI USB adaptor installed on host computer?

It is now time to connect the power supply and power-up the SkyScan4. First plug the power supply into the wall and ensure that the power switch is in the OFF position (the RED portion of the power switch should not be visible). Now connect the data and power tethers between the SkyScan4 and the power supply.

Caution

Make sure the power tethers are routed so as to not interfere with the motion of the SkyScan4.

Now that the SkyScan4 is mounted and connected to the power supply, it is time to turn it on. Simply flip the power switch on the front of the power supply to the ON position. The SkyScan4 will now start searching for the “home” position of each axis. The automatic homing routine used by both axes is detailed below:

1. The axis starts moving in the positive direction.
2. Motion continues until the magnetic sensor detects the homing magnet and moves past it at which point the axis is decelerated to a stop.
3. The axis moves in the negative direction at a slower speed until the magnet is detected again at which point the position is saved.
4. The axis continues until it has moved past the homing magnet at which point the axis is decelerated to a stop.
5. The axis moves back in the positive direction until the magnet is detected again at which point the axis is decelerated to a stop. This position is also saved.

6. An average of the two saved positions is taken (this serves to find the center of the homing magnet) and a home offset[1] is applied.
7. The axis now moves to the parked position.

The SkyScan4 will now sit in this parked position until commanded to do otherwise.

Note

Audible noise from the SmartMotors is normal (the motor is working hard electro-magnetically to maintain the stable PID loop) and not in any way considered harmful. However, in a correctly tuned system, the motion should be smooth with no "jerkiness". If motion is "jerky", please contact Keo Scientific as something may have been damaged internally during shipping.

5.2 Communicating with the SkyScan4

Communicating with the SkyScan4 is done through the USB to Serial connection previously configured.

To open a communication channel with the SkyScan, simply choose the COM port the device was assigned and use the following settings.

Baud Rate	115200 (115.2k)
Data Bits	8
Parity	None
Stop Bits	1
Flow Control	None

5.3 Firmware Updates

From time to time, Keo Scientific may release new updated firmware for the SkyScan system. This updated firmware could include bug fixes and new or improved functionality. The procedure for updating the system firmware can be found in Appendix C.

[1] The home offset is determined at the time of assembly and is used to compensate for any minor discrepancies in assembly alignment.

6 Command Reference

The SkyScan4 can be controlled manually from any serial terminal application, such as RealTerm[2], or automatically through a client-side application written by the user. For the purposes of this manual, it will be assumed that the user is manually typing commands in a serial terminal. Moving these commands into a client application is a trivial (albeit necessary) step for routine scientific operations.

Commands are sent to the SkyScan4 as ASCII characters and all commands need to be terminated by a carriage return (0x0D). In the following sections, a carriage return will be indicated by <CR>.

The firmware loaded onto the SkyScan4 is much improved over previous versions of the product. It now features a custom command interpreter which simplifies the commands and provides a lot of flexibility in terms of what can be achieved.

Note

We are always looking at improving the functionality of the device, so if you have a request for a new feature or a way to improve an existing feature, please don't hesitate to contact Keo Scientific.

6.1 Command Overview

Below is a summary of all the commands offered by the SkyScan firmware. Each command needs to be terminated with a carriage return before it is processed by the SkyScan. More details on each command can be found in the section indicated. The "Idle?" column indicates whether the SkyScan must be idle or not for the command to be used. Using a command that is not valid when the device isn't idle will result in an error code of `-10` being returned (syntax error). You can check the current status of the SkyScan using the `S?` command (see Section 6.14 for details).

Command	Description	Idle?	Section
`?`	Prints out a help menu which summarizes the commands.	Y	6.3
`Cn?`	Reports a configuration parameter.	Y	6.4
`Cn(...)`	Sets a configuration parameter.	Y	6.5
`G!`	Starts a trajectory.	Y	6.6
`H!`	Starts a homing routine.	Y	6.7
`O?`	Reports the current axis offsets from the trajectory.	N	6.8
`P?`	Reports the current axis positions.	N	6.9
`P(a,z[,v,m])`	Moves the axes to the specified positions.	Y	6.10
`S!`	Stops all motion.	N	6.11
`S1!`	Stops the position or velocity mode motion.	N	6.12
`S2!`	Stops the trajectory mode motion.	N	6.13
`S?`	Reports the current operating status.	N	6.14
`T!`	Initializes a trajectory mode move.	Y	6.15
`T(n,t)`	Defines a new trajectory.	Y	6.16
`V?`	Reports the current axis velocities.	N	6.17

[2] RealTerm is an easy to use, free serial terminal application for Windows.
https://sourceforge.net/projects/realterm/

V(a,z)	Moves the axes at the specified velocities.	Y	6.18
X!	Exits custom command mode.	Y	6.19

6.2 Error Codes

Every command that is sent to the SkyScan will immediately return a response. This response will either be an acknowledgment of the command or the response to the command. The commands that can take a while to complete (homing routine, trajectory, etc.) will return an acknowledgment of the command immediately and then follow up with a completion response when the routine is completed. This prevents a user application from ever getting hung up waiting for a response from the SkyScan.

Error Code	Description
1	No Error, Success
-1	Parameter 1 Error, First parameter out of range
-2	Parameter 2 Error, Second parameter out of range
-3	Parameter 3 Error, Third parameter out of range
-4	Parameter 4 Error, Fourth parameter out of range
-10	Syntax Error, Command not recognized

6.3 Help Menu Command

This command instructs the SkyScan to print out a summary of all the available commands. This is only useful when commanding the SkyScan manually through a terminal application.

6.3.1 Command Format

```
?<CR>
```

6.3.2 Command Response

```
COMMAND DESCRIPTION
======= ==================================
?       Displays this help menu.
.          .
. <SNIP>   .
.          .
X!      Exit custom command mode.
```

6.3.3 Error Codes

```
None
```

6.4 Report a Configuration Parameter Command

This command reports a configuration parameter. See Section 7 for details on the available configuration parameters.

6.4.1 Command Format

```
Cn?<CR>
```

6.4.2 Parameters

```
n     The ID of the configuration parameter to report.
```

6.4.3 Command Response

```
<ID Specific>
```

6.4.4 Error Codes

```
-1    The configuration parameter hasn't been set yet.
```

6.5 Set a Configuration Parameter Command

This command sets a configuration parameter. See Section 7 for details on the available configuration parameters.

6.5.1 Command Format

```
Cn(x)<CR>
```

6.5.2 Parameters

```
n     The ID of the configuration parameter to set.
x     The value to use for setting configuration parameter n.
```

6.5.3 Command Response

```
1     Success
```

6.5.4 Error Codes

```
-1    Invalid configuration parameter ID.
-2    Invalid configuration parameter value.
```

6.6 Start a Trajectory Command

This command starts a trajectory and is only valid after the initialize trajectory command (see Section 6.15) has been used.

6.6.1 Command Format

```
G!<CR>
```

6.6.2 Parameters

```
None
```

6.6.3 Command Response

```
1     Success
```

6.6.4 Error Codes

```
None
```

6.7 Start a Homing Routine Command

This command starts a homing routine running. Returns an acknowledgment immediately followed by a completion response upon completion of the homing routine.

6.7.1 Command Format

```
H!CR>
```

6.7.2 Parameters

```
None
```

6.7.3 Command Response

```
1     Acknowledgment of command.
!H:1  Homing routine complete (sent when routine is complete).
```

6.7.4 Error Codes

```
None
```

6.8 Report Axis Offsets Command

This command reports the current offsets of the two axes from the running trajectory. This command is only valid while a trajectory is running

6.8.1 Command Format

```
O?CR>
```

6.8.2 Parameters

```
None
```

6.8.3 Command Response

```
az,ze
  az  The azimuth offset in degrees.
  ze  The zenith offset in degrees.
```

6.8.4 Error Codes

```
None
```

6.9 Report Current Axis Positions Command

This command reports the current positions of the two axes of the SkyScan.

6.9.1 Command Format

```
P?<CR>
```

6.9.2 Parameters

```
None
```

6.9.3 Command Response

```
az,ze
  az  The azimuth position in degrees.
           0° ≤ az < 360°
  ze  The zenith zenith in degrees.
        -180° ≤ ze < 180°
```

6.9.4 Error Codes

```
None
```

6.10 Move to Position Command

This command moves the SkyScan to the specified position at the specified (optional) velocity. The final parameter specifies an absolute or relative move.

The valid range for the azimuth position depends on the whether expanded range mode has been enabled or not (defined by configuration parameter 7 – see Section 7.8). By default this will be disabled so the valid range will be `0° ≤ az < 360°` but if it is enabled, then the valid range will be `-360° ≤ az < 720°`.

If no velocity is specified, then the default SkyScan velocity (defined by configuration parameter 4 – see Section 7.4) is used. If using relative mode it is required that you also specify the velocity.

6.10.1 Command Format

```
P(az,ze[,v,m])<CR>
```

6.10.2 Parameters

```
az    The azimuth position to move to in degrees.
           0° ≤ az < 360°
        -360° ≤ az < 720° (expanded range enabled)
ze    The zenith position to move to in degrees.
        -180° ≤ ze < 180°
v     Optional, the velocity to move at in degrees per second.
            0 < v ≤ 120 [deg/sec]
m     Optional, the move mode.
        0   absolute
        1   relative
```

6.10.3 Command Response

```
1     Command acknowledgment.
!P:1  Move completed (sent when the move is completed).
```

6.10.4 Error Codes

```
-1    Azimuth position out of range.
-2    Zenith position out of range.
-3    Velocity out of range.
-4    Invalid mode.
```

6.11 Stop All Motion Command

This command stops all current motion of the device. It is also used to cancel a trajectory after it has been initialized with the `T!` command but before it has been started with the `G!` command.

6.11.1 Command Format

```
S!<CR>
```

6.11.2 Parameters

```
None
```

6.11.3 Command Response

```
1     Success
```

6.11.4 Error Codes

```
None
```

6.12 Stop Position and Velocity Motion Command

This command stops any motion that is the result of a position or velocity move command (see Sections 6.10 and 6.18).

6.12.1 Command Format

```
S1!<CR>
```

6.12.2 Parameters

```
None
```

6.12.3 Command Response

```
1     Success
```

6.12.4 Error Codes

```
None
```

6.13 Stop Trajectory Command

This command stops any motion that is the result of a trajectory start command (see Section 6.6).

6.13.1 Command Format

```
S2!<CR>
```

6.13.2 Parameters

```
None
```

6.13.3 Command Response

```
1     Success
```

6.13.4 Error Codes

```
None
```

6.14 Report Operating Status Command

This command reports the current operating status of the SkyScan. The status is stored bitwise so that it is possible to have multiple statuses at the same time. For example, the SkyScan can be both running a trajectory and jogging at the same time.

Status Bit	Name	Description
0	IDLE	Currently idle. All commands are valid.
1	HOMING	Currently running a homing routine.
2	MOVING	Currently running an absolute or relative position move.
3	JOGGING	Currently running a velocity move.
4	TRAJECTORY WAITING	Trajectory has been initialized and is waiting to start.
5	TRAJECTORY RUNNING	Currently running a trajectory.
6	UPLOADING TRAJECTORY	Currently uploading a trajectory to the SkyScan.

Example: Assume that the SkyScan is currently running a trajectory and jogging at the same time. Sending the `S?` command to the SkyScan would return `40`. 40 can be represented in binary as shown below. You will notice that bits 3 and 5 are set while the rest are not set. Bits 3 and 5 correspond to the statuses JOGGING and TRAJECTORY RUNNING so it can be seen that the SkyScan is currently both running a trajectory and jogging.

Bit	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Value	0	1	0	1	0	0	0

6.14.1 Command Format

```
S?<CR>
```

6.14.2 Parameters

```
None
```

6.14.3 Command Response

```
n     The current status variable.
```

6.14.4 Error Codes

```
None
```

6.15 Initialize Trajectory Command

This command initializes a trajectory by moving the SkyScan to the starting point of the trajectory. It then waits for either the stop trajectory command `S!` (see Section 6.11) or the start trajectory command `G!` (see Section 6.6).

6.15.1 Command Format

```
T!<CR>
```

6.15.2 Parameters

```
None
```

6.15.3 Command Response

```
1     Success
```

6.15.4 Error Codes

```
None
```

6.16 Define a New Trajectory Command

This command starts the upload of a new trajectory into the SkyScan. This command needs to be immediately followed by the trajectory data. The SkyScan will return a 1 after each trajectory pair is successfully saved in the device. Do not send another trajectory pair until you have received the acknowledgment that the previous pair has been successfully saved.

Example: You have a trajectory with 3 data points that are separated by 5 seconds. You would send the following to the SkyScan.

Sent to SkyScan	Received from SkyScan
T(3,5)<CR> 1.23,4.56<CR> 7.89,1.23<CR> 4.56,7.89<CR>	1 1 1 1

6.16.1 Command Format

```
T(n,t)<CR>
az_1,ze_1<CR>
az_2,ze_2<CR>
az_3,ze_3<CR>
  .
```

```
  .
  .
az_n,ze_n<CR>
```

6.16.2 Parameters

```
n     The number of azimuth-zenith pairs in the trajectory.
        0 < n ≤ 750
t     The time in seconds between pairs.
        0 < t ≤ 32767
az_n  An azimuth position, in degrees.
ze_n  A zenith position, in degrees.
```

6.16.3 Command Response

```
1     Success
```

6.16.4 Error Codes

```
-1    Number of pairs out of range.
-2    Time between pairs out of range.
-10   Error parsing floating point number.
```

6.17 Report Current Velocity Command

This command reports the current velocity of the axes of the SkyScan. Note that due to the way that the SmartMotors handle trajectories, this command doesn't return a valid value when a trajectory is running.

6.17.1 Command Format

```
V?<CR>
```

6.17.2 Parameters

```
None
```

6.17.3 Command Response

```
az_v,ze_v
  az_v  The azimuth velocity in degrees per second.
  ze_V  The zenith velocity in degrees per second.
```

6.17.4 Error Codes

```
None
```

6.18 Move at Velocity Command

This command moves the axes at the specified velocities. Negative velocities result in negative direction movement.

6.18.1 Command Format

```
V(az_v,ze_v)<CR>
```

6.18.2 Parameters

```
az_v  The azimuth velocity in degrees per second.
            0 < az_v ≤ 120 [deg/sec]
ze_v  The zenith velocity in degrees per second.
            0 < ze_v ≤ 120 [deg/sec]
```

6.18.3 Command Response

```
1     Success
```

6.18.4 Error Codes

```
-1    Azimuth velocity out of range.
-2    Zenith velocity out of range.
```

6.19 Exit Custom Command Mode Command

This command kicks the SkyScan SmartMotors into their default communication states so that they can be reprogrammed. After executing this command a power cycle is required to return to normal operating conditions.

6.19.1 Command Format

```
X!<CR>
```

6.19.2 Parameters

```
None
```

6.19.3 Command Response

```
1     Success
```

6.19.4 Error Codes

```
None
```

7 Configuration Parameters

There are several different configuration parameters available on the SkyScan. These parameters affect the operation of the device and should only be modified if you know exactly what you are doing. Some are programmed during the initial assembly of the device and should not be modified unless instructed to do so by Keo Scientific.

Important Information

These parameters affect the operation of the device and should only be modified if you know exactly what you are doing.

7.1 Parameter 0: Azimuth Home Offset

This parameter is the offset, in encoder counts, between the 0° position of the mounting flange and the position the azimuth axis homes to during a homing routine. This value is adjusted so that after a homing routine the azimuth axis is properly aligned with the 0° position of the mounting flange.

7.1.1 Command Format

```
C0(n)<CR>
```

7.1.2 Parameters

```
n     The number of encoder counts to apply as an offset.
```

7.1.3 Command Response

```
1     Success
```

7.1.4 Error Codes

```
-10   Syntax Error (if n isn't a proper number)
```

7.2 Parameter 1: Zenith Home Offset

This parameter is the offset, in encoder counts, between the vertical and the position the zenith axis homes to during a homing routine. This value is adjusted so that after a homing routine the zenith axis is properly aligned in the 180° position (pointing straight down).

7.2.1 Command Format

```
C1(n)<CR>
```

7.2.2 Parameters

```
n     The number of encoder counts to apply as an offset.
```

7.2.3 Command Response

```
1     Success
```

7.2.4 Error Codes

```
-10   Syntax Error (if n isn't a proper number)
```

7.3 Parameter 2: Cam Interpolation Mode

This parameter is the mode to use for interpolating a trajectory loaded into the device using the trajectory commands. There are three different modes: linear, spline with non-periodic data, and spline with periodic data.

Linear mode
This mode performs linear interpolation between each of the data points in the trajectory. No smoothing is applied.

Spline with non-periodic data mode
This mode performs spline interpolation and assumes that the trajectory does not wrap from the end to the start. This has the effect of there being zero curvature to the trajectory at the end points. This is the default option.

Spline with periodic data mode
This mode performs spline interpolation and assumes that the trajectory wraps from the end to the start. This has the effect of the curvature of the trajectory at the end points being matched.

7.3.1 Command Format

```
C2(n)<CR>
```

7.3.2 Parameters

```
n     The interpolation mode.
            0     Linear
            1     Spline with non-periodic data
            2     Spline with periodic data
```

7.3.3 Command Response

```
1     Success
```

7.3.4 Error Codes

```
-2    Mode is not one of the valid options.
-10   Syntax Error (if n isn't a proper number).
```

7.4 Parameter 3: Serial Number

This parameter defines the serial number of the SkyScan.

7.4.1 Command Format

```
C3(n)<CR>
```

7.4.2 Parameters

```
n     The serial number of the device (0 <= n <= 99999
```

7.4.3 Command Response

```
1     Success
```

7.4.4 Error Codes

```
-1    Parameter 1 Error (n is out of range).
-10   Syntax Error (if n isn't a proper number).
```

7.5 Parameter 4: Default Velocity

This parameter defines the default velocity to use for all moves where the velocity is not otherwise specified.

7.5.1 Command Format

```
C4(n)<CR>
```

7.5.2 Parameters

```
n     The default velocity (0 to 120 rev/min)
```

7.5.3 Command Response

```
1     Success
```

7.5.4 Error Codes

```
-1    Parameter 1 Error (n is out of range).
-10   Syntax Error (if n isn't a proper number).
```

7.6 Parameter 5: Azimuth Counts per Revolution

This parameter defines the number of motor encoder counts per full revolution of the azimuth axis.

7.6.1 Command Format

```
C5(n)<CR>
```

7.6.2 Parameters

```
n     Number of encoder counts per azimuth revolution (n > 0)
```

7.6.3 Command Response

```
1     Success
```

7.6.4 Error Codes

```
-1    Parameter 1 Error (n is negative).
-10   Syntax Error (if n isn't a proper number).
```

7.7 Parameter 6: Zenith Counts per Revolution

This parameter defines the number of motor encoder counts per full revolution of the zenith axis.

7.7.1 Command Format

```
C6(n)<CR>
```

7.7.2 Parameters

```
n     Number of encoder counts per zenith revolution (n > 0)
```

7.7.3 Command Response

```
1     Success
```

7.7.4 Error Codes

```
-1    Parameter 1 Error (n is negative).
-10   Syntax Error (if n isn't a proper number).
```

7.8 Parameter 7: Enable Expanded Range Mode

This parameter with enable the expanded range mode for azimuth position values. Depending on the value of this setting, the azimuth limits are as shown below:

Disabled (0): $0° \leq az < 360°$

Enabled (1): $-360° \leq az < 720°$

7.8.1 Command Format

```
C7(n)<CR>
```

7.8.2 Parameters

```
n     Expanded range mode value:
        0   disabled (0 <= az < 360)
        1   enabled (-360 <= az < 720)
```

7.8.3 Command Response

```
1     Success
```

7.8.4 Error Codes

```
-1    Parameter 1 Error (n is not 0 or 1).
-10   Syntax Error (if n isn't a proper number).
```

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8 Warranty & Service

8.1 Limited Warranty

The Keo SkyScan4 is provided with a 3-year Keo Scientific Warranty. The product is warranted to meet published functional specifications and to be free of defects in materials and workmanship as defined in the specifications for three (3) years from the date of original shipment from Keo. During this time, Keo will arrange to have the product repaired or replaced without charge to you. You must return the entire instrument to Keo Scientific for inspection and assessment. You are only responsible for shipping costs to return the product.

Normal Wear Item Disclaimer: Keo Scientific does not warrant certain items against defect due to normal wear and tear. These items include cables and connectors, as well as anti-reflection coatings on windows. Also note that it is normal for the external anodized black color of the machined housings to fade over time (if exposed to solar UV for prolonged periods of time on the order of 3 years), but this should not affect instrument operation – it is often a cosmetic issue only.

Shipping damage: Any damage occurring to the instrument while in transit from Keo to customer must be reported to the shipping company or courier company immediately upon receipt of goods. Shipments are separately insured, and such damage is covered by said insurance. Please inspect instrument thoroughly upon arrival.

8.2 Contact Information

Keo Scientific's main office is located at the following address:

Keo Scientific Ltd.
430 – 11979 40 St. SE
Calgary, AB T2Z 4M3
Canada

Tel: +1-403-452-7222

In the event that you need technical support to troubleshoot a problem with your Keo SkyScan4, please don't hesitate to contact us at support@keoscientific.com.

An up-to-date list of addresses and telephone numbers is available on our website at www.keoscientific.com/contact.php.

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Appendix A Specifications

Basic

Dimensions	See Appendix B.
Weight	SkyScan Unit: 30.5 lb (13.8 kg) Power Supply: 4.0 lb (1.8 kg)
Power Input	100 – 240 VAC; 50/60 Hz
Power Consumption	<50W under normal operating conditions <250W peak power
Mounting	3x mounting holes on flange for 1/4-20 socket head cap screws. See Appendix B.
Storage Temperature	≤80°C
Operating Environmental Temperature	+5°C to +70°C
Relative Humidity	≤85%; non-condensing

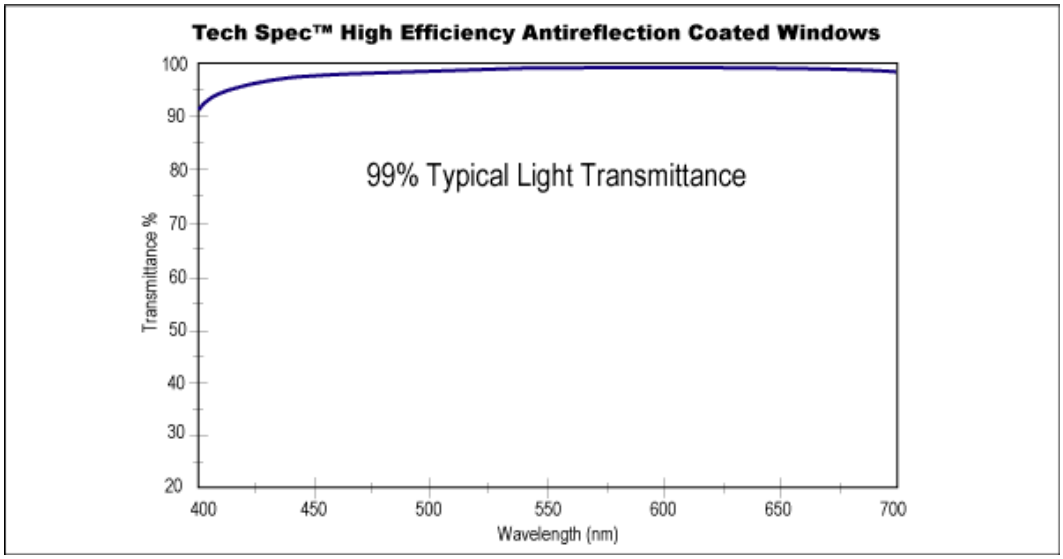
Performance

	Azimuth	Zenith
Pointing Resolution	0.0005° [1.8 arc-sec]	0.002° [7.3 arc-sec]
Backlash (gearbox + belt)	0.042° [2.5 arc-min]	0.032° [1.9 arc-min]
Repeatability	± 0.021° [1.25 arc-min]	± 0.016° [0.95 arc-min]
Accuracy	± 0.021° [1.25 arc-min]	± 0.016° [0.95 arc-min]
Maximum Speed [deg/sec]	120°/sec*	

* Limited by Keo SmartMotor firmware

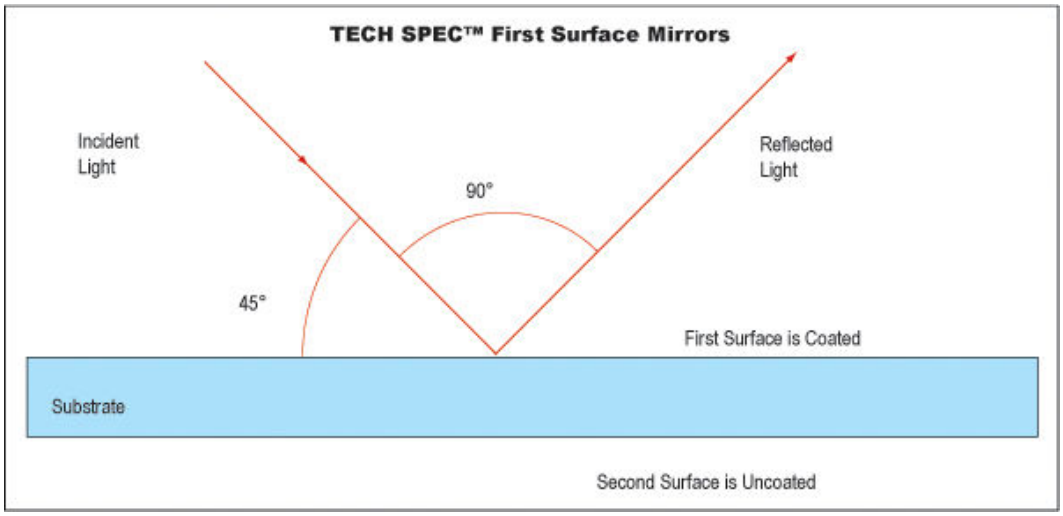
Window

Soda lime float glass with anti-reflection coating. (6.5” x 6.5” x 3mm thick)



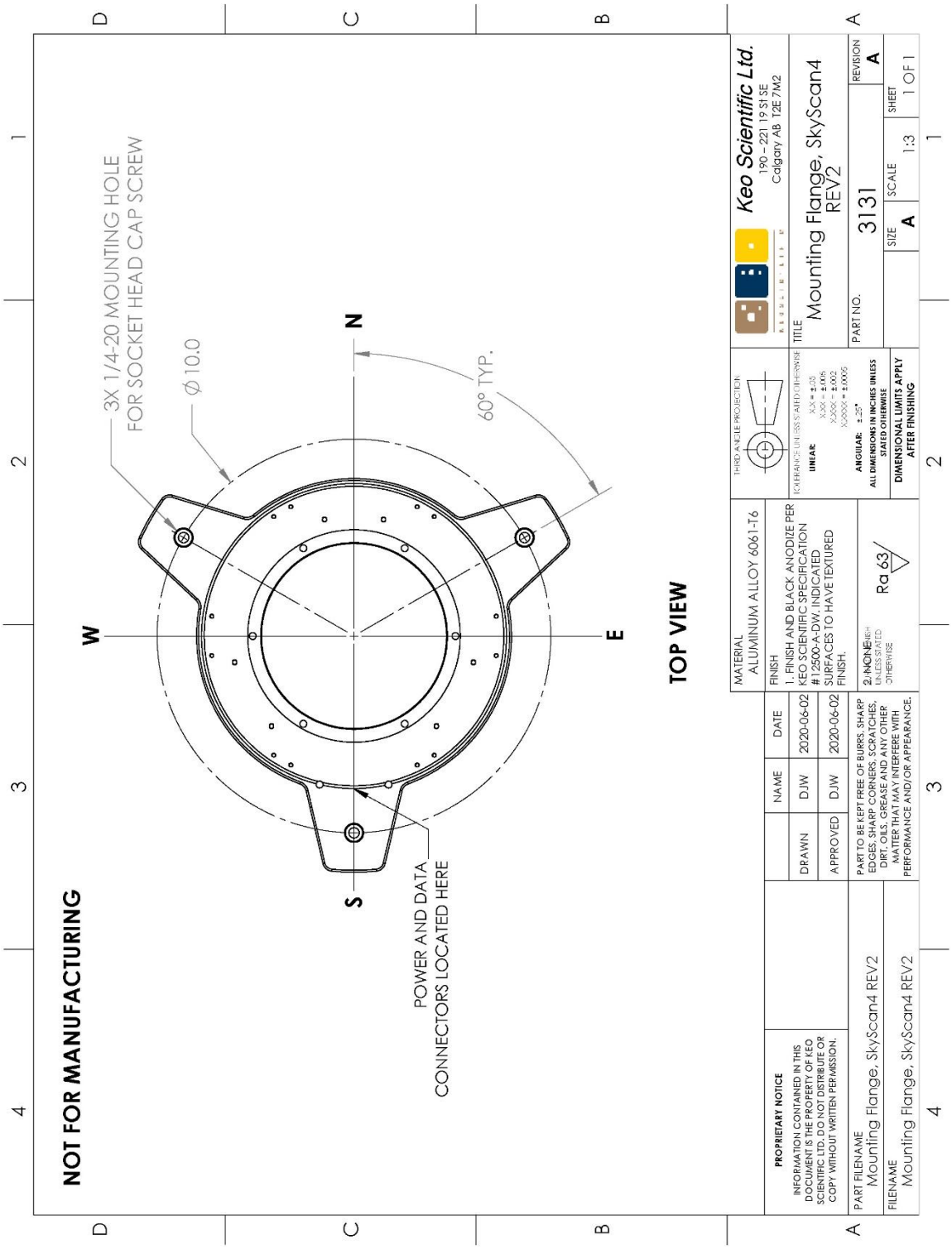
Mirrors

	Azimuth	Zenith
Dimensions (mm)	127 x 178	169 x 194
Thickness (mm)	6.0	
Surface Accuracy (λ)	4 – 6 per inch	
Substrate	Soda Lime Float Glass	
Coating	Enhanced Aluminum, R >90% from 400-650nm	

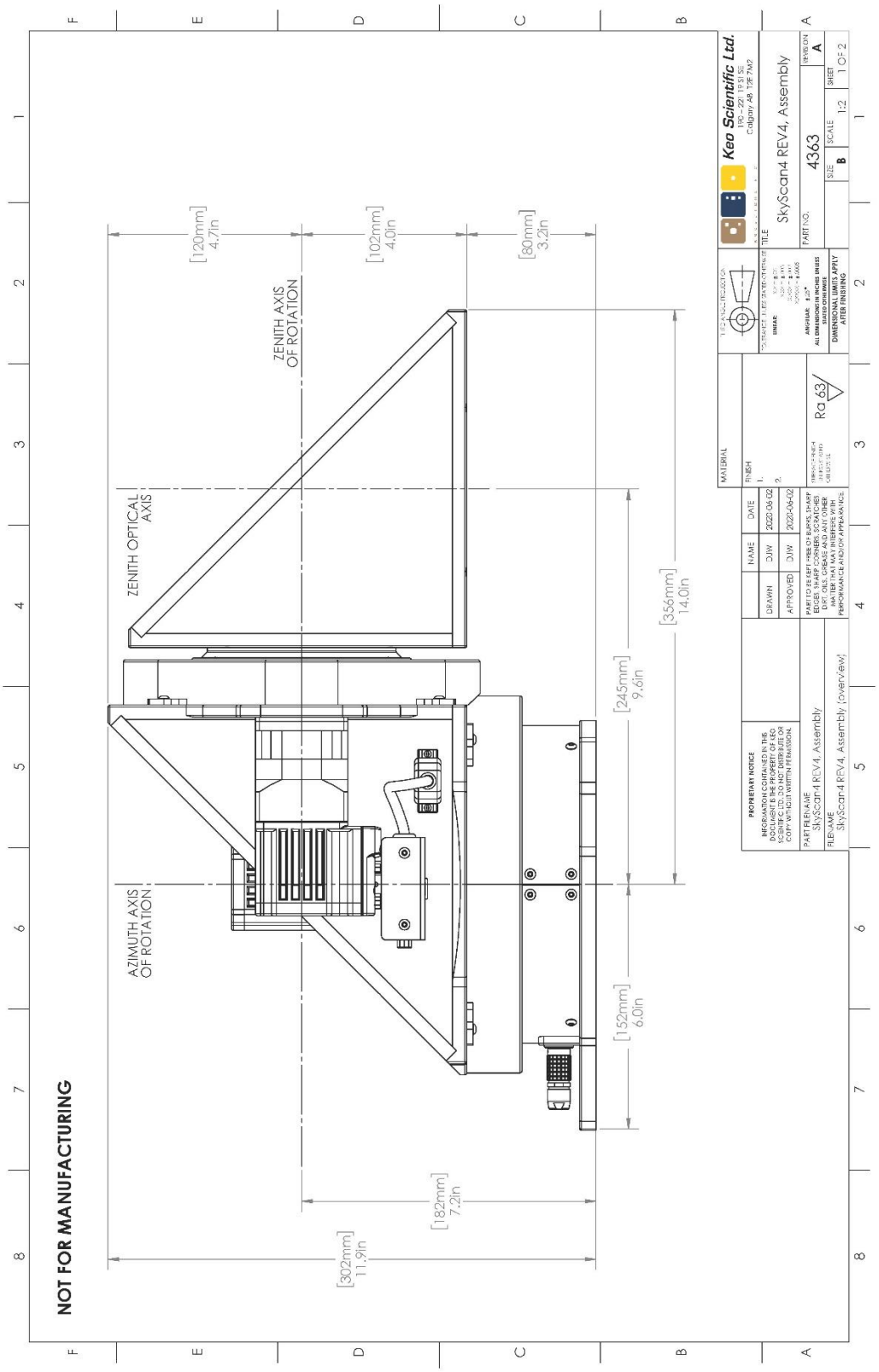


Appendix B Outline Drawings

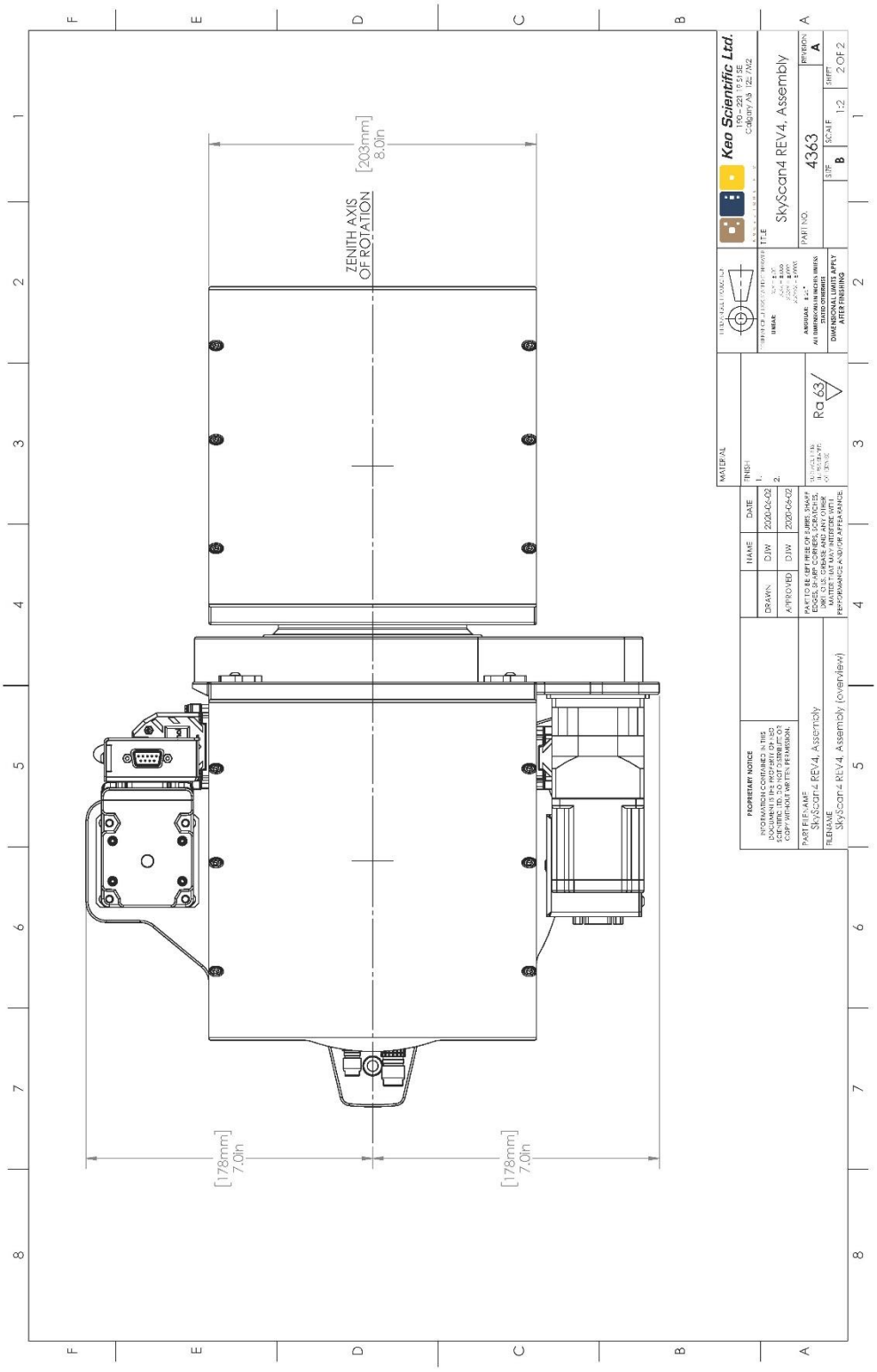
Mounting Flange Layout



Side Profile



Top Profile


ZENITH AXIS
OF ROTATION
[203mm]
8.0in
[178mm]
7.0in
[178mm]
7.0in
Keo Scientific Ltd.
SkyScan4 REV4. Assembly
4363
SkyScan4 REV4. Assembly (overview)

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Appendix C Firmware Update Procedure

Important Information

Only perform this procedure if you have been instructed to do so by Keo Scientific (by way of a firmware update advisory) and are fully comfortable with the procedure. Additional guidance can be provided by Keo Scientific.

This procedure requires the use of Animatics' SmartMotor Interface (SMI) application. This application can be installed from the Documentation and Utilities CD by navigating to *Utilities\SmartMotor Interface* and running the installer. Alternatively, the latest version of SMI can be downloaded directly from Animatics from the following website:

http://www.animatics.com/products/software/animatics/host-software/smi-smartmotor-interface.html

After SMI has been successfully installed, continue with the instructions below.

1) Programming of the SmartMotors must be done over a hardwired connection. Attach one end of a NULL modem cable to the azimuth axis of the SkyScan and the other end to the host computer.
2) Power cycle the SkyScan.
    a. Turn the power supply OFF.
    b. Wait 5 seconds.
    c. Turn the power supply ON.
3) After the SkyScan has completed its homing routine, launch the SMI application.
4) Now click on **View** and make sure that the **Terminal**, **Configuration**, and **Serial Data Analyzer** windows are checked. Your application layout should now look like the one in Figure 6.
5) In the **Configuration** window, right-click on the serial port you connected the SkyScan to (with the NULL modem serial cable) and select **Properties**. The dialog shown in Figure 5 will be displayed.

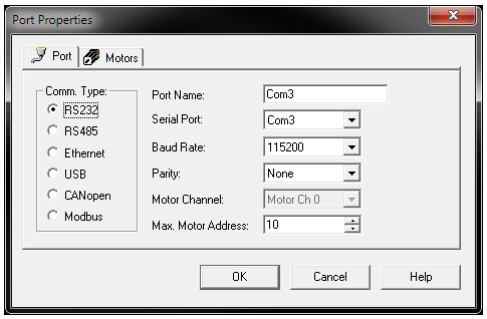

Figure 5: SMI Port Properties

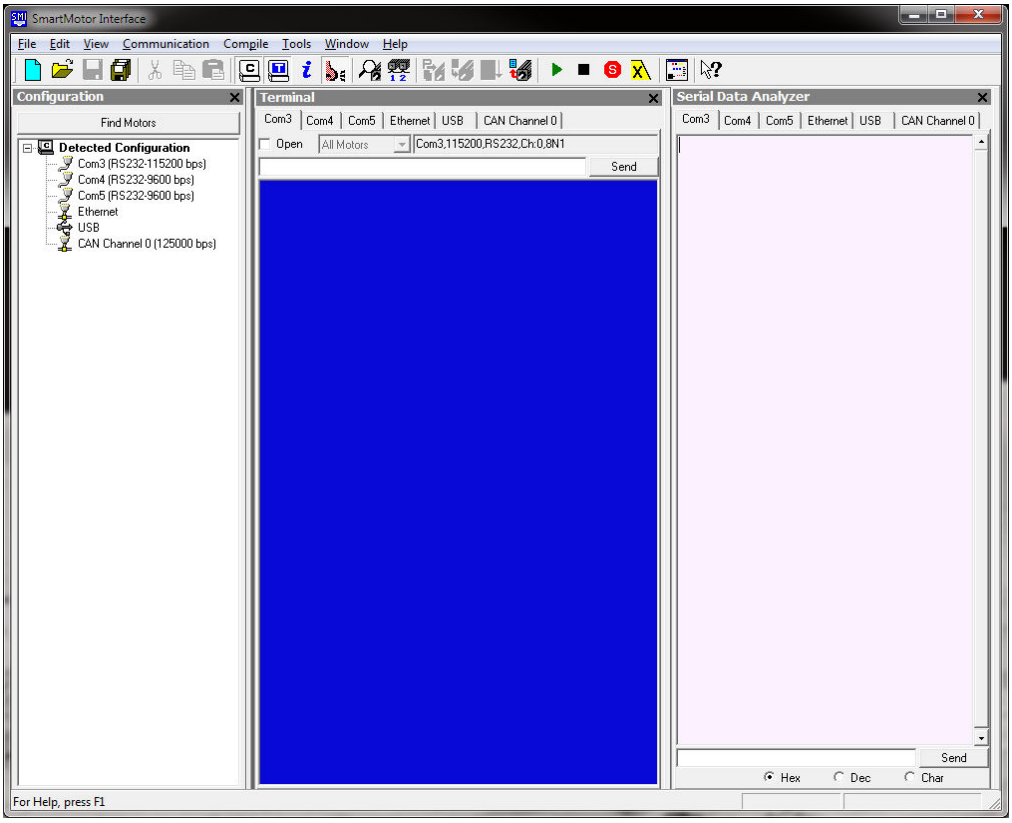

Figure 6: SMI View Layout

6) Ensure that the **Comm Type** setting is set to **RS232** and change the **Baud Rate** to **115200**. Click **OK** to save and close these settings.
7) In the **Terminal** window, select the tab corresponding to the serial port you are using. In this example we are using COM3 so we have selected the **Com3** tab.

Before we can update the firmware we need to kick the SkyScan out of custom command mode. To do this we need to send it the `X!` command. If you have a serial terminal application (like RealTerm) that you are comfortable using, then simply send X!<CR>. It will respond with a 1 indicating the command was successful. Skip to step 14 to continue the firmware update. If you don't have a serial terminal application installed you can use SMI to send this command. Continue with the instructions below.

8) Select the **Open** check box to open the serial port.
9) In the **Serial Data Analyzer** window, select the **Hex** radio button at the bottom. This will allow us to send characters specified in hexadecimal to the SkyScan. We need to do this because the SkyScan requires a carriage return at the end of the command but SMI doesn't use carriage returns. We will be adding the carriage return as a hexadecimal number.
10) In the **Serial Data Analyzer** window, find the string entry box which is just to the left of the **Send** button. Enter the following in this box.

```
58210D
```

SMI will format the entry into three 2 digit hex numbers as you type in the string as shown in Figure 7.. For those interested, these three hex numbers (`58`, `21`, and `0D`) are the ASCII character codes for the characters `X`, `!`, and `<CR>`.

Figure 7: SMI Hex String Entry

11) Click the **Send** button. This will transmit the character string to the SkyScan. The command you just sent will now appear as green text in the **Serial Data Analyzer** window. Below it you should also see some blue text. This is the response from the SkyScan. If everything went as planned it should read "`31 0D`" (which is "`1<CR>`" when converted to ASCII characters). If this is not the response you got, power cycle the SkyScan and after the homing routine has finished, try sending the command again (starting from step 11).

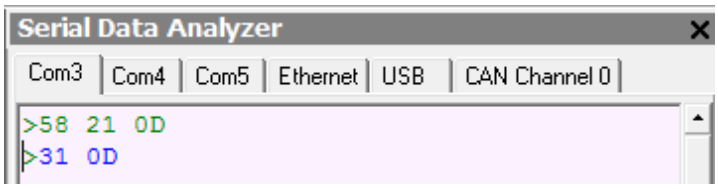

Figure 8: SMI Response to X!

12) Now close the **Serial Data Analyzer** window by either click the small 'x' in the corner or unchecking **Serial Data Analyzer** from the **View** menu.
13) You are now ready to upload the new firmware to the SkyScan. Locate the .zip file provided by Keo Scientific and extract it to a known location. You will notice that there are two files in this .zip file. One is the firmware for the azimuth axis, and the other is the firmware for the zenith axis.
14) In SMI, click **Communication** from the top menu, and then click **Transmit SMX file …**.
15) Now browse to the files you extracted in step 13, select the one with **Azimuth** at the end of the filename, and click **Open**.

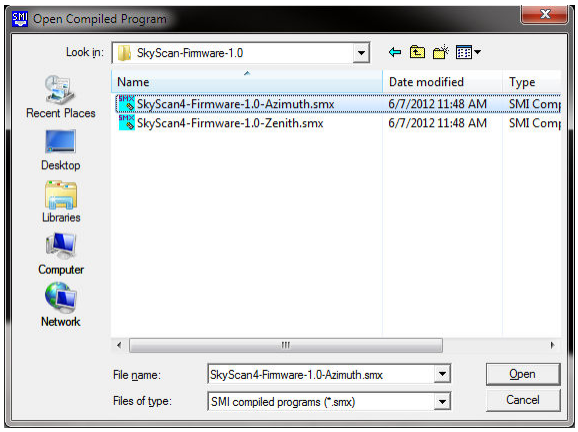

Figure 9: SMI Browse for SMX File

16) You will now be shown the **Select Motor** dialog. Select the serial port you are using in the **Ports** list and then enter the number **1** in the **Motor Address** box as shown in Figure 10.

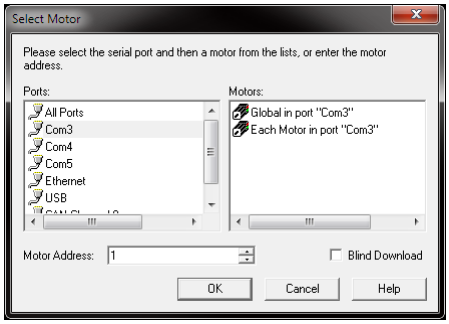

Figure 10: SMI Select Motor Dialog

17) Now click the **OK** button. This will upload the firmware file to the SmartMotor. During this process you should see a progress dialog like the one shown in Figure 11. When the upload finishes, you should see a "Finished. No Errors, No warnings." message in the **Information** window at the bottom of SMI as shown in Figure 12.

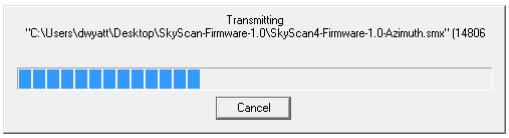

Figure 11: SMI Upload Progress

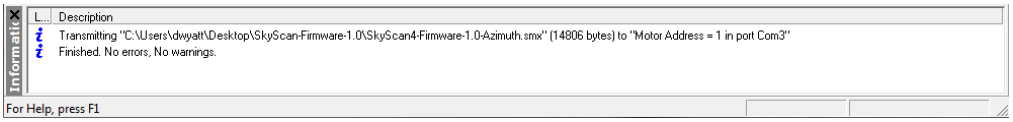

Figure 12: SMI Upload Finished

18) Now we need to repeat the firmware upload procedure for the zenith axis.
    a. First move the NULL modem serial cable from the azimuth axis to the zenith axis. The zenith axis does not have a custom command interpreter so it is not necessary to send the `X!<CR>` command.
    b. Now repeat steps 15 through 18 with the following exceptions.
        i. In step 16, select the file with **Zenith** at the end of the filename.
        ii. In step 17, enter the number **2** in the **Motor Address** box.
19) After the zenith firmware has been uploaded, close SMI and power cycle the SkyScan. It should perform its homing routine as normal and then be ready to use.