SHMSL User Guide

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Introduction

The Section Half Multisensor Core Logger succeeded the Archive-Half Multisensor Track (AMST) in the physical properties laboratory. The SHMSL simultaneously measures spectral reflectance and magnetic susceptibility on core section halves. Data generated from these sensors are used to augment the core descriptions.

Reflectance Spectrometry

–Percent reflectance plotted against depth supports lithology descriptions.
–Color parameters can provide a detailed time series of relative changes in the composition of the core material and can be used to correlate sections from core to core or hole to hole and to analyze cyclicity of lithologic changes.
–Spectral data can be used to estimate the abundances of certain compounds.

- Visible range provides semiquantitative estimates of hematite and goethite with better sensitivity than XRD.
- Near-infrared or near-ultraviolet ranges allow estimates of carbonate, opal, organic matter, chlorite, and some combinations of clay minerals.

Magnetic Susceptibility

Magnetic Susceptibility can be used to confirm whole-round core section magnetic susceptibility measurements. The SHMSL can measure magnetic susceptibility at a similar sampling point spacing to the whole-round measurements, or the user can select a completely different frequency of analysis. MS data is used for correlation with other age-depth proxy measurements.

Theory of Operation

A split and scraped core section in a half-core liner is placed on the core track, where a barcode scanner is used to scan the section ID (from the end cap) and imports sample information from the LIMS. The electronics platform moves along a track above the core section, recording the sample height in the core liner using a laser sensor. The laser establishes the location of bottom of the section. When this step is finished, the track will pull up out of the way of the user in order to facilitate the covering of the core section with GLAD® Plastic Wrap. When the user covers the core section and answers the prompt, the platform reverses the direction of movement, moving from bottom to top while recording point magnetic susceptibility and spectral reflectance data at user-specified data acquisition intervals (generally 2–10 cm).

Reflectance Spectrometry

–Measured from 380 to 900 nm at 2 nm intervals using both an LED and a halogen light source, covering a wavelength range through the visible spectrum and slightly into the infrared domain. Currently only 390nm to 732nm is being recorded. Waiting to hear back from Bill Mills.
–Scanning the entire wavelength range takes ~5 s per data acquisition offset.
–Data are generated using the CIELAB L*a*b* color system:

- L* represents lightness, where 0 yields black and 100 indicates diffuse white;
- a* represents magenta to green tinting, where negative numbers indicate red/magenta shading and positive numbers indicate green shading; and
- b* represents yellow to blue tinting, where negative numbers indicate yellow shading and positive number indicate blue shading.

–Data are also stored and returned as CIELAB Tristimulus XYZ values. The definition of X, Y, and Z is complex and the reader should refer to reference materials for an explanation. Refer to the related documentation section below.
–Finally data are stored and returned as RGB values to facilitate comparison with the imaging logger RGB values; note however that the sampling interval is quite different between the imaging logger and the integration sphere.

Magnetic Susceptibility

–Measured at the same data acquisition rate as spectral reflectance using a contact probe with a flat 15 mm diameter sensor.
–The sensor can be configured for different integration times (1 Hz or 0.1 Hz) and different numbers of replicate measurements. Our standard conditions are 3 measurements at 1 Hz measurement frequency for each offset. These three results are averaged and uploaded to the database. Thermal drift is effectively eliminated by zeroing the meter before each section.
–Data are reported in dimensionless instrument units (SI). In order to use these data as SI magnetic susceptibility units, the appropriate volume correction must be applied, which varies by sensor type. The user should not use the cgs setting so that the data set is consistent with previous measurements and with the whole-round logger results.

Hardware

The SHMSL system consists of the following hardware components (**Figure 1**):

- Bartington MS2K or MS2E (Note: MS2E is not generally recommended because of its very small read area) magnetic susceptibility contact probe
- Bartington MS2 meter, run in serial communications mode
- Ocean Optics QE Pro visible spectrum spectrophotometer
- Ocean Optics HL-2000 Halogen Light Source with Attenuator and TTL-Shutter
- Ocean Optics Multi-LED BluLoop Light Source
- Ocean Optics 30 mm integrating sphere, with a 10 mm aperture
- Acuity AccuRange AR700 Laser

- Barcode scanner
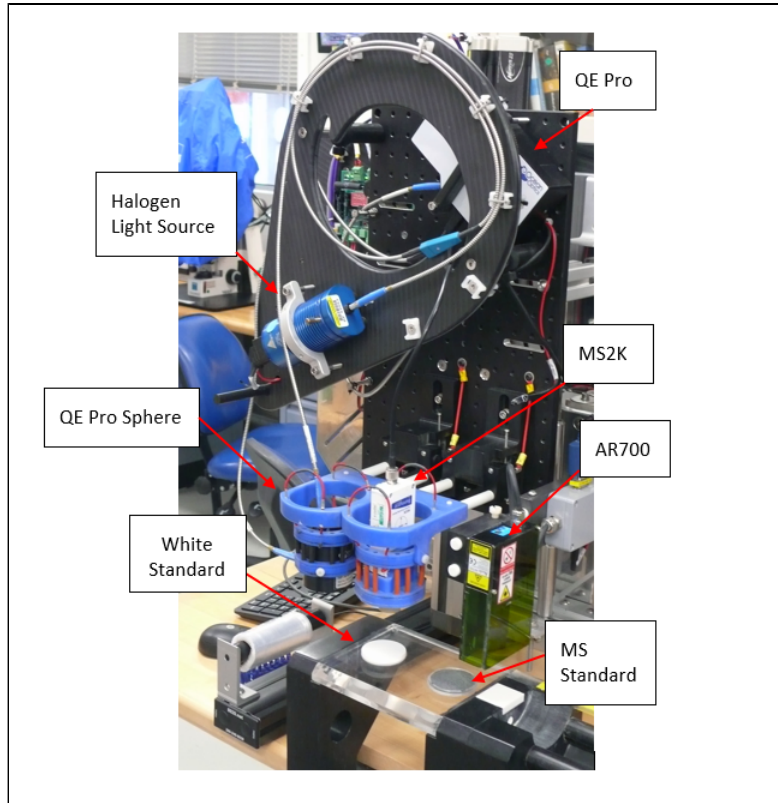- Instrument platform
- Hardware abort switch

Figure 1. SHMSL Hardware

Bartington MS2K Probe Susceptibility Contact Probe

Specification	Value
Dimensions (mm) Area of Response	165 x 145 x 50mm 15mm x 33mm diameter 25.4mm diameter
Operating frequency (kHz)	0.930
Depth of Response	50% at 3mm 10% at 8mm
Measurement period: X 1 range X 0.1 range	1.2 s SI 12s SI
Temperature induced drift	$<2 \times 10^{-5}$ SI in 5 min
Calibration (tip contact)	$K \times 10^{-5}$ SI (1cc)

Bartington MS2 Probe Susceptibility Meter

Specification	Value
Dimensions (mm)	241 × 158 × 50
Operating temperature range (°C)	−10 to +40
Linearity	1% to 9999

Ocean Optics HL-2000 Halogen Light Source with Attenuator and TTL-Shutter

Specification	Value
Dimensions (mm)	58 × 59 × 140
Wavelength range (nm)	360–1700
Stability (%)	0.5
Drift (%/h)	<0.1
Bulb life (h)	2000
Bulb color temperature (K)	3.000
Operating temperature (°C)	5°–35
Operating humidity (%)	5–95 at 40°C

Ocean Optics Multi-LED BluLoop Light Source

Specification	Value
Dimensions (mm)	62 x 66 x 150
Wavelength range (nm)	395 - 750
Stability (%)	< 0.15%
Time to Stabilize (min)	15
Drift (%/h)	<0.01%

Acuity AccuRange 700 Triangulating Laser Displacement Sensor

Specification	Value
Laser (nm)	670 nm
Resolution	±0.03% of full scale
Operating temperature (°C)	0–60
Linearity/accuracy (%)	±0.2

Bulb life (h)	>10,000
Bulb color temperature (K)	3.000
Room temperature (°C)	5°–35°
Operating humidity (%)	5–95 at 40°C
Lamp Power (W)	<12

Ocean Optics QE Pro Hamamatsu S7031-1006S Detector

Specification	Value
Dimensions (mm)	182 x 110 x 47
Detector	TE Cooled, 1044x64 element CCD array
Detector range (nm)	185 – 1100 nm
Dynamic range: Typical Single Integration Period 100 Averages 10,000 Averages Readout Noise	~85000:1 85,000:1(min) 850,000:1(min) 8,500,000:1(min) 2.5 counts RMS (typical)
Corrected linearity (%)	0.5% nonlinearity (max)
Pixel size (µm)	1024 active
Integration Time	8 ms – 60 minutes
Signal to noise ratio	1,000:1 (typical)
Operating Temperature	0 – 50° C
Temperature stability	<0.1° C

Ocean Optics ISP-30-6-R-GT Integrating Sphere

Specification	Value
Body diameter (mm)	59
Body height (mm)	58 (plus trap)
Specular Trap	Yes (SCE measurements)
Aperture (mm)	10
Internal Surface	PFTE
Spectral Range (nm)	200-2500
PFTE reflectivity	>98% (400-1500 nm) >95% (200-2500 nm)
Fibre-optic connector	SMA 905

Standards

Color Reflectance

- Labsphere, Inc. Spectralon® white standard, certified at 99% reflectivity (**Figure 2**).
- Labsphere, Inc. diffuse color reflectance targets:
  - Grayscale: 99%, 50%, 20%, 2% reflectance (Referred to as white, light grey, dark grey, and black)
  - Color: Red, Orange, Yellow, Green, Cyan, Blue, Purple, Violet (**Figure 3**).

Figure 2. WHITE Spectralon® Calibration Standard

Figure 3. Spectralon Diffuse Standards.

Magnetic Susceptibility

The MS standards are used to check for drift, not to calibrate the meter or sensor. The JRSO puck is used to check drift instead of the Bartington standard because it is less sensitive to centering the sensor.

- Bartington-issued MS puck (note: user must center this standard carefully to get the correct reading)
- JRSO-created verification puck (~48 SIx10^{-6}; mounted on track). The JRSO standard is made of Magnesium Oxide powder sealed inside a Petri dish with epoxy. The powder can be found in a PVC tube in the "MS Standards" drawer under the X-Ray track.

Launching the IMS- SHMSL application

The IMS-SHMSL software can be launched from the Windows Start menu or from a desktop icon (**Figure 4**).

Figure 4. IMS Icon

At launch, the program begins the following initialization process:

- Tests all instrument communications
- Reloads configuration values

- Homes the X and Y axis

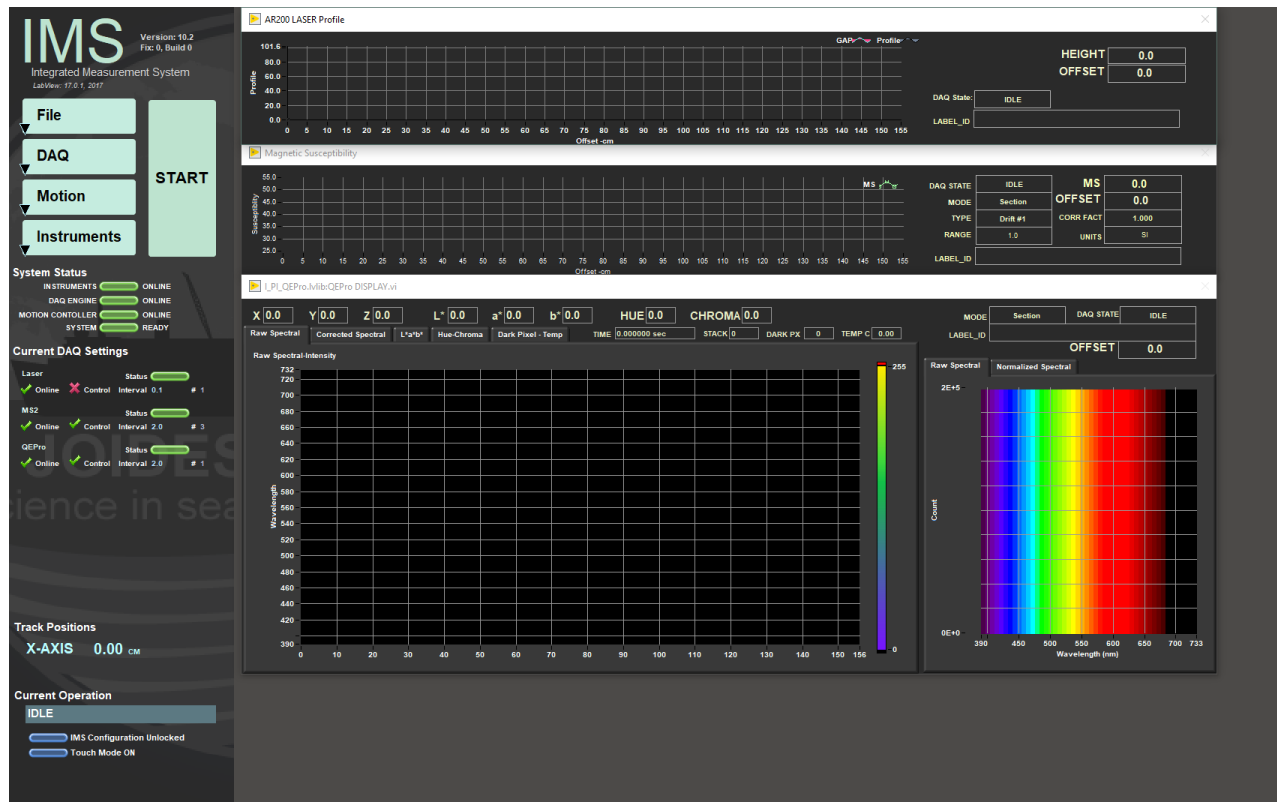After successful initialization, the main IMS- SHMSL window will appear (**Figure 5**).

Figure 5. IMS Application Main Screen.

A Quick Introduction to the IMS Program Structure

IMS is a modular program. Individual modules are as follows:

- INST plug-in: code for each of the instruments
- MOTION plug-in: code for the motion control system
- DAQ Engine: code that organizes INST and MOTION plug-ins into a track system

The SHMSL system, specifically, is built with three INST modules (MS2, QEPro, AR700), two MOTION modules (X-axis, Y-axis), and one DAQ Engine module.

The IMS Main User Interface (IMS-UI) calls these modules, instructs them to initialize, and provides a user interface to their functionality.

Each module manages a configuration file that opens the IMS program at the same state it was when previously closed and provides utilities for the user to edit or modify the configuration data and calibration routines.

The four buttons on the IMS-UI window provide access to utilities/editors via dropdown menus as shown in **Figure 6**.
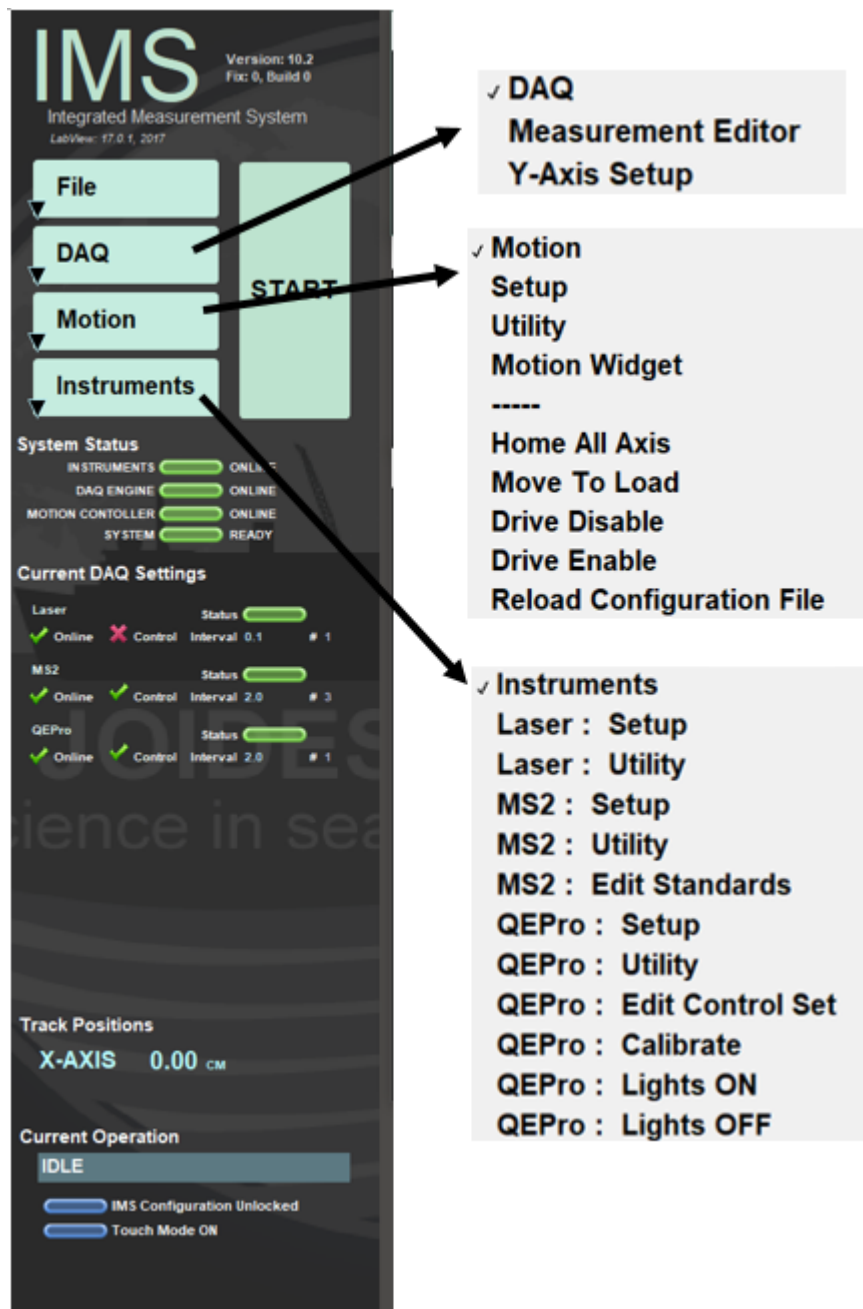
Figure 6. SHMSL IMS Menu Options

Initial Instrument Setup

Each instrument has a separate setup menu. Configuration values should be set during initial setup by the technician and scientists. The general instrument setup should not change unless there have been changes to the hardware.

QEPro Configuration

Select *Instruments> QEPro: Setup* (**Figure 6**). The QEPro Parameters window will open (**Figure 7**). This window is divided into 4 sections: General Setup, Acquistion Parameters, White and Dark Standards, and Integration Time.

General Setup

- **Instrument offset**: The x-axis distance of the laser where the center of the sensor is over the benchmarks zero edge.
- **Sensor width:** Physical size of the sensor area
- **Contact width**: Physical size of the contact surface
- **Analysis name**: LIMS analysis component (must match LIMS component exactly).
- **Instrument group**: LIMS instrument group logger name (i.e., SHMSL).

- **Model**: model name of the sensor (from manufacturer).
- **S/N**: serial number of the sensor (from manufacturer).
- **Menu name**: value that appears as the instrument's menu name.
- **Full name**: value that appears in instrument dialog boxes.

Acquisition Parameters section

- **Hi cut-off:** Used to define the upper limit of the region of interest (ROI) in the spectrum. The spectrum above this value will not be saved or used in calculations. (**Figure 8**)
- **Low cut-off**: Used to define the lower limit of the region of interest (ROI) in the spectrum. The spectrum below this value will not be saved or used in calculations. (**Figure 8**)
- **Median Filter Rank:** Number of adjacent channels used to filter noise from the signal.
- **Bin size**: The width (nm) of each bin that the spectrum is recorded in. (**Figure 8**)
- **Illuminant:** The Daylight Illuminant Standard for L*a*b calculations; International Commission on Illumination (CIE) standard illuminant used in color calculations (also called daylight illuminant)
- **Geometry:** References integration sphere measurement technique: illumination from a diffuse light source viewed 8° from normal (d/8); includes a gloss trap to exclude spectral reflections.

White and Dark calibration Section

- **White Label ID**: LIMS label_ID component value (STND-White).
- **White Text ID**: LIMS text_ID component value (WHITE).
- **Dark Label ID name**: LIMS label_ID component value (STND-Dark).
- **Dark Text ID**: LIMS text_ID component value (DARK).
- **Standard X-offset**: track position (X-axis; in cm) of laser when the center of the integration sphere sensor is over the center of the white standard.
- **Standard Y-offset**: lift position (Y-axis) when the integration sphere is in contact with the White or Dark standard (same value for both).
- **Calibration expire**: Time in hours between calibrations. The user will be given a warning when the calibration time has expired.
- **Previous Timestamp**: Time and date of last calibration (read only).
- **Remaining time**: Clock displays of the time remaining until the next calibration is needed (read only).

Integration time section

- **Integration time**: time the CCD is exposed; if too short, noise will be high; if too long, the sensor will saturate and clip data.
- **Starting integration time**: beginning time (in seconds) value for WHITE calibration; set to 0.5 for new bulbs and up to 1 for aged bulbs. This setting has no effect on data from subsequent measurements.
- **Start Time:** The integration time used to determine the white standard saturation point
- **% Saturation:** Used by WHITE calibration to determine sample integration time by calculating the integration time required to reach the specified saturation (70%–95%). Note: if cores are light colored, increase throughout by using a low saturation level; if cores are dark colored, use a high saturation level to improve signal-to-noise ratio.
- **Step Time:** The time step used to determine the White Standard's saturation point
- **White: Stack:** The number of measurements to stack for the final White calibration
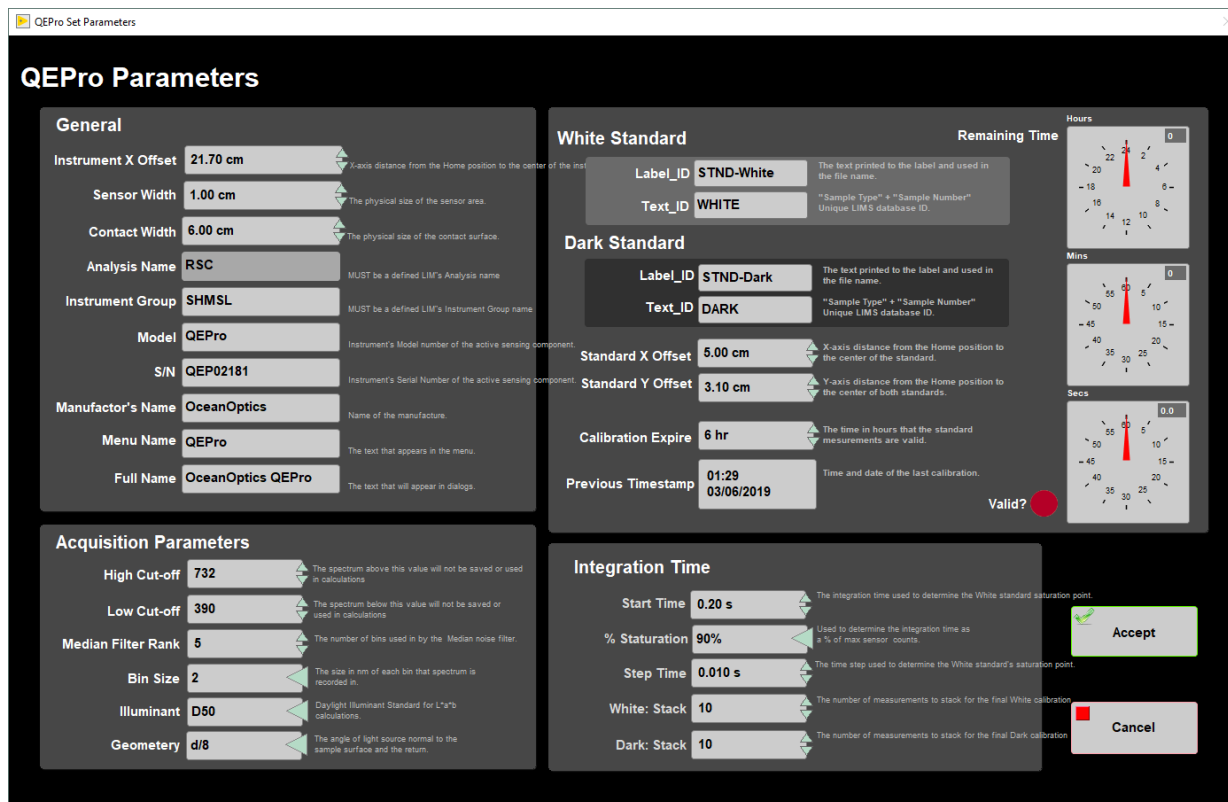- **Dark: Stack**: The number of measurements to stack for the final Dark calibration
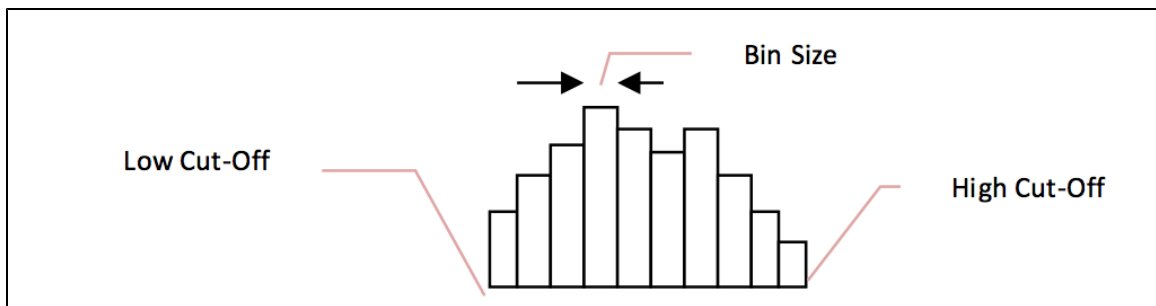
Figure 7. QEPro Setup Window

Figure 8. Illustration of high and low cut-off and bin size.

MS2 Configuration

*Select Instruments> MS2: Setup (**Figure 6**). The QEPro Parameters window will open (**Figure 9**). This window is divided into 3 sections: General Setup, MS Correction Factor, and Select MS Control*

General Setup

- **Track and Sensor Type:** Select the type of MS sensor and the track (SHMSL- Point)
- **Instrument offset**: The x-axis distance to the sensor, where the center of the sensor is over the benchmarks zero edge
- **Contact width**: Physical size of the contact surface
- **Units:** This value must match the front panel of the MS meter. Set to SI per IODP standard practice
- **Range:** This value must match the range setting on the MS meter, **1 or 10, usually 1.**
- **Analysis name**: LIMS analysis component (must match LIMS component exactly).
- **Instrument group**: LIMS instrument group logger name (i.e., SHMSL).
- **Model**: model name of the sensor (from manufacturer).
- **S/N**: serial number of the sensor (from manufacturer).
- **Manufacturer's Name:** The name of the manufacturer of the MS sensor
- **Menu name**: value that appears as the instrument's menu name.
- **Full name**: value that appears in instrument dialog boxes.

MS Correction Factor

These values are used when attempting to match data between multiple sensors. Default values are 1

- **Correction Factor:** A correction factor provided by the Bartington. Typically 1
- **Matching Constant:** Value used to correct the sensor's output to a standard value, Typically 1

Select MS Control (Point Only)

- **Standards:** Name of the standard being used
- **Label ID:** The label ID used to identify the standard
- **Text ID:** Unique identifier for the standard in the database
- **Standard's X offset:** track position (X-axis) of the laser when the center of the MS sensor probe is over the center of the standard.
- **Standard's Y offset:** lift position (Y-axis) when the MS sensor probe is in contact with the standard.
- **Standard's Value:** The standard's accepted/given value. Value established by IODP is 48 +/- 2 SI
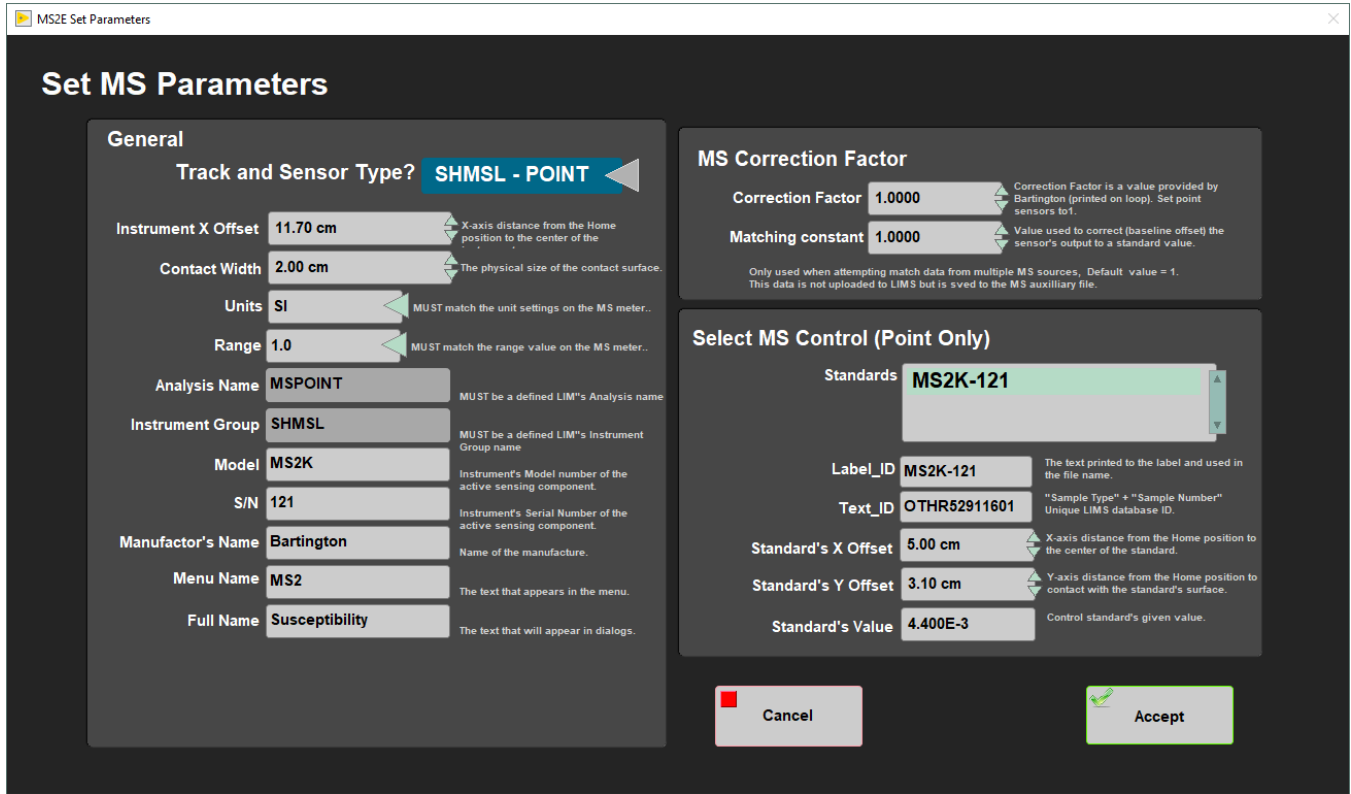

Figure 9: MS2 Setup Window

Laser Configuration

*Select Instruments> Laser: Setup (**Figure 6**). The QEPro Parameters window will open (**Figure 10**).*

General Setup

- **Analysis name**: LIMS analysis component (must match LIMS component exactly).
- **Instrument group**: LIMS instrument group logger name (i.e., SHMSL).
- **Model**: model name of the sensor (from manufacturer).
- **S/N**: serial number of the sensor (from manufacturer).
- **Manufacturer's Name:** The name of the manufacturer of the laser.
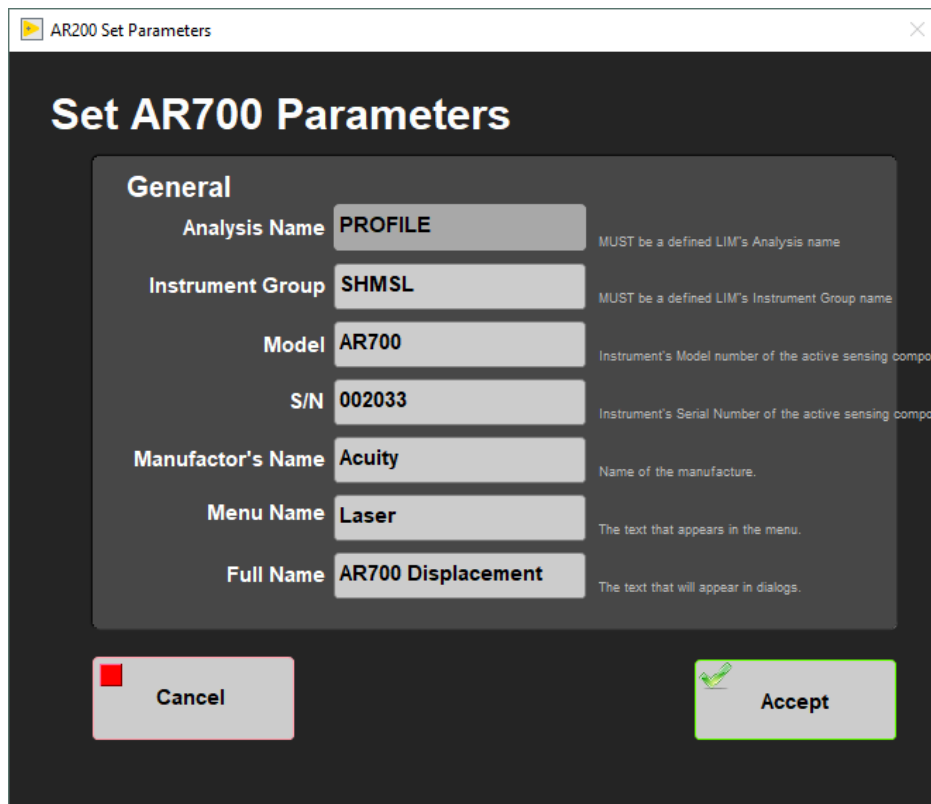- **Full name**: value that appears in instrument dialog boxes.

Figure 10: AR700 Setup Window

Setting Measurement Parameters

Prior to measuring a section half on the SHMSL, the user must:

- Set the measurement interval for each instrument
- Calibrate the QE Pro Spectrophotometer

The user may adjust the measurement parameters for each instrument on the SHMSL by selecting *DAQ> Measurement Editor* (**Figure 6**). The measurement editor window will open (**Figure 11**).

To edit the settings for a particular instrument, select the instrument from the list on the left side of the window and then click within the *Instrument Parameters* block on the right side of the screen. A window, like in **Figure 12,** will open.
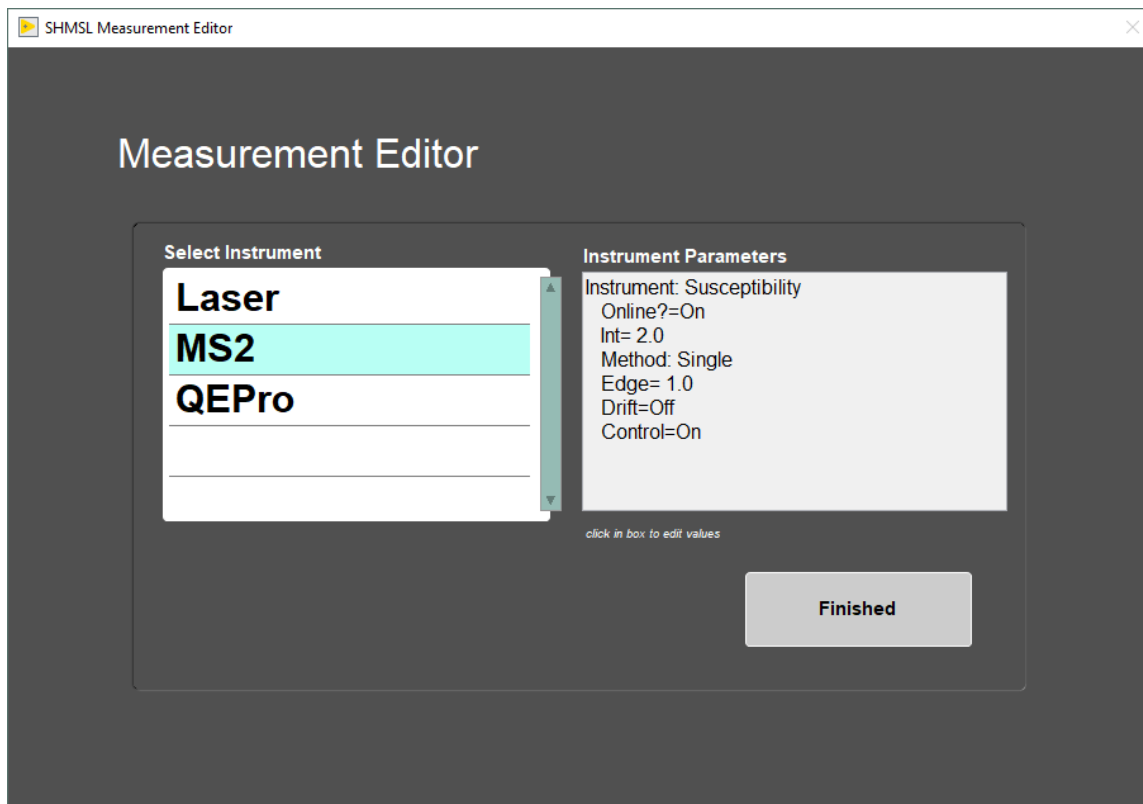
Figure 11. Main Measurement Editor Window

QE Pro Measurement Parameters

Settings available in the QE Pro Measurement editor (**Figure 12**) include:

- **Interval:** The measurement interval in centimeters
- **Edge:** The interval of core to exclude at the start and end of a section and at the edges of gaps in the core
- **Method:** Select to take a single measurement at the time set by the white calibration or to stack multiple measures and average using the measurement time set by the white calibration
- **Stack:** The number of measurements to average at a given position
- **Control:** Control ON will measure the white standard as a control each time a section is measured
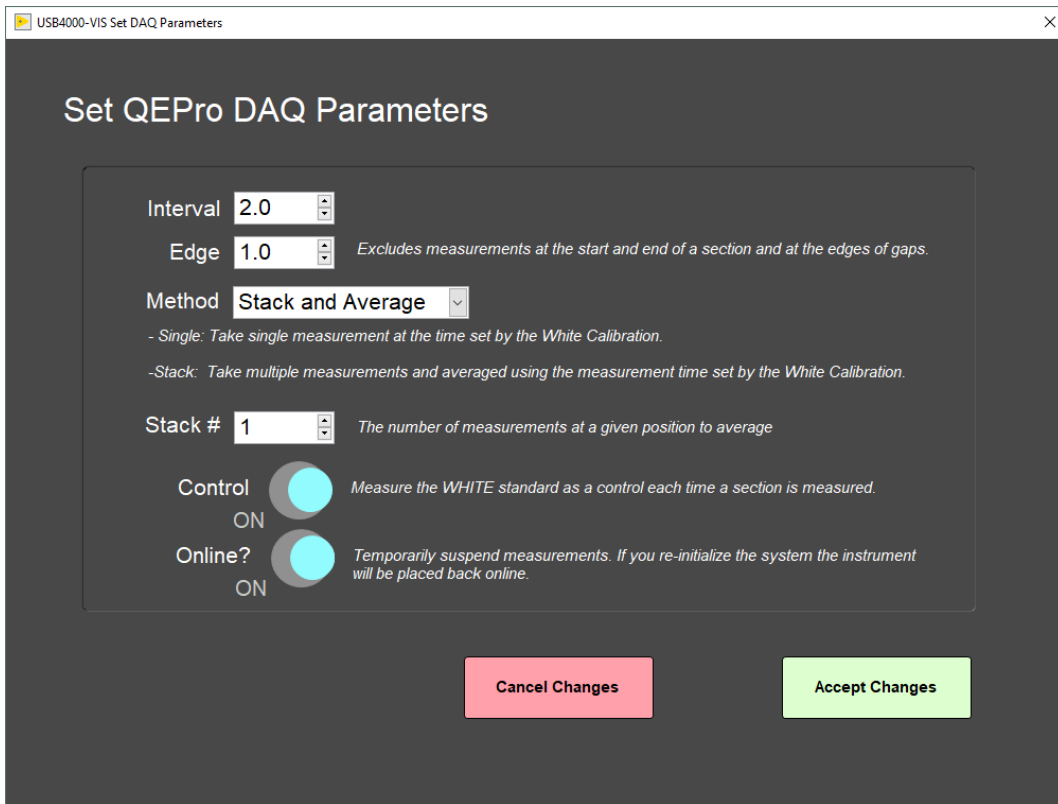- **Online?:** Suspend measurements with the QE Pro

Figure 12. QE Pro Measurement Parameters

MS Measurement Parameters

Settings available in the MS2 Measurement editor (**Figure 13**) include:

- **Interval:** The measurement interval in centimeters
- **Edge:** The interval of core to exclude at the start and end of a section and at the edges of gaps in the core
- **Average:** The number of measurements to average at a given position
- **Control:** Control ON will measure the MS standard as a control each time a section is measured
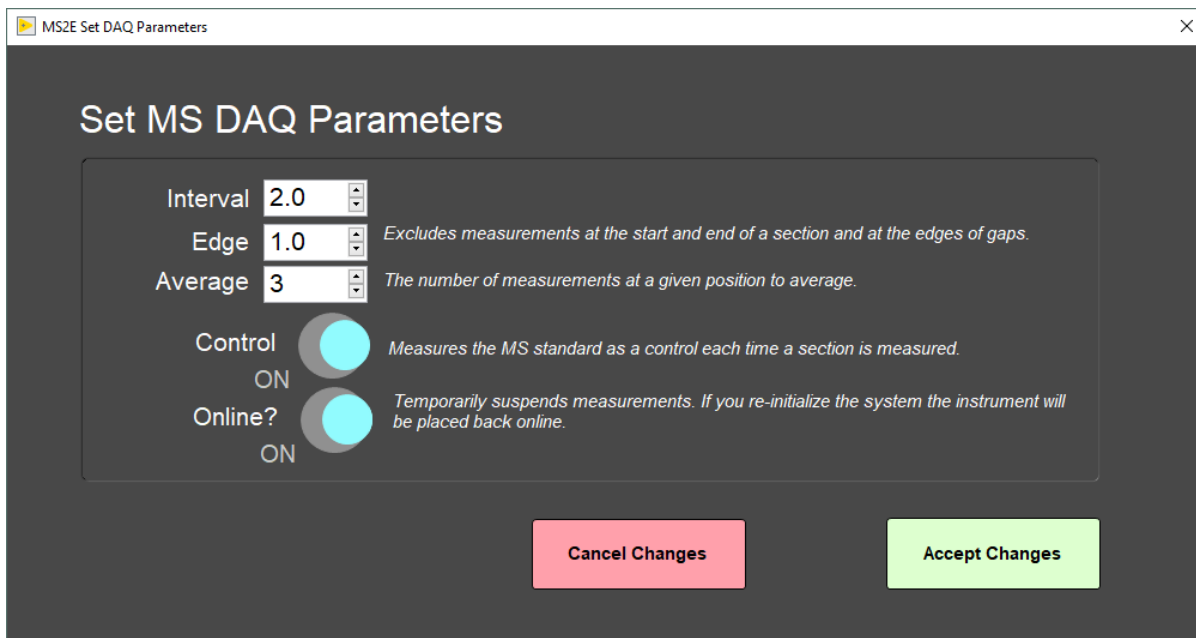- **Online?:** Suspend measurements with the MS point sensor

Figure 13. MS Measurement Parameters

Laser Measurement Parameters

The user may use the Laser Measurement editor (**Figure 14**) to set the gap offset. This is the height below the benchmark which will be tagged by the system as a gap and will therefore not be measured. For piston cores, the recommended gap offset should be set to 10 mm or less. For hard rock cores, the gap offset should be set between 20 and 30 mm.
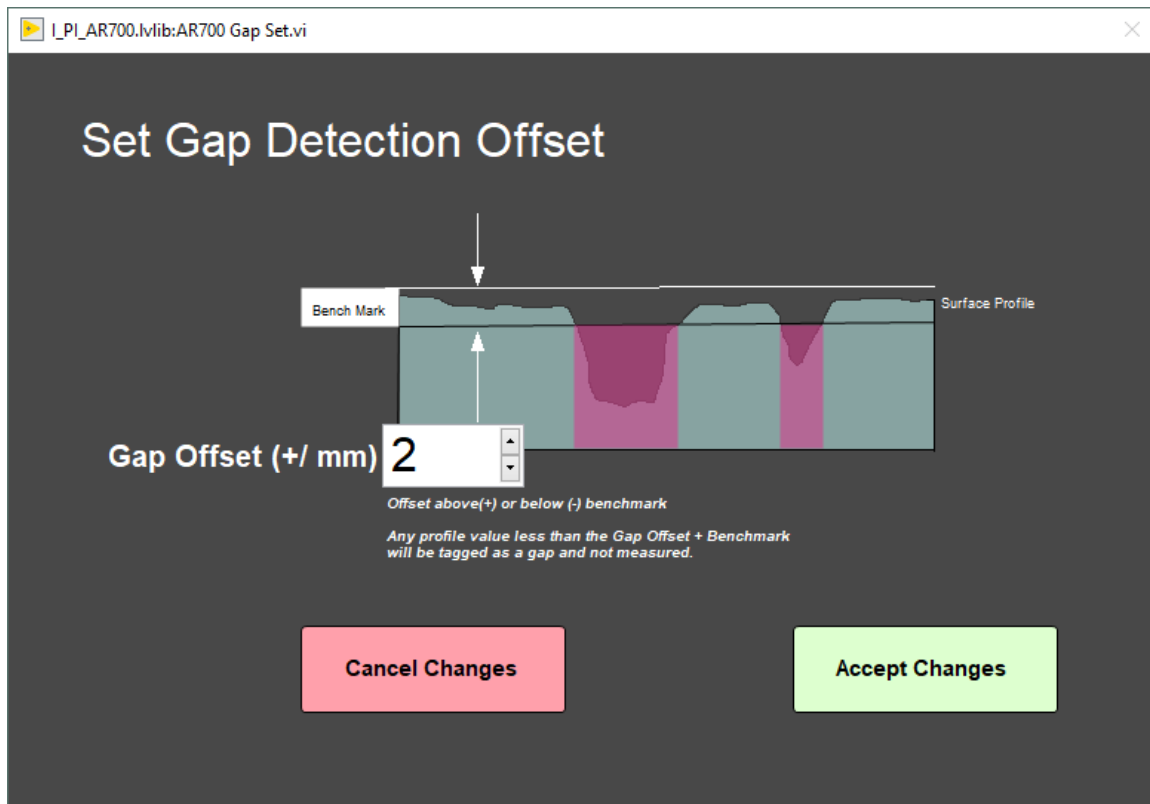

Figure 14. Laser Measurement Parameters

Starting Measurements

Section halves are measured on the SHMSL as soon as possible after splitting so that drying and oxidation do not affect ephemeral sample properties such as color reflectance. Sample preparation includes scraping to clean the core surface and covering wet core samples with plastic wrap to prevent contamination of the contact sensors.

Use GLAD® Plastic Wrap (crystal clear polyethylene) for covering the sediment.

Note: This analysis requires clear polyethylene film such as GLAD® Wrap. Other types of plastic wrap (e.g., Saran Wrap™) will not serve.

Preparing Samples

1. Use a spatula or smear slide to clean the cut surface of the core by lightly scraping away any material that was smeared across the surface during core splitting. Take the SHIL image first so SHMSL sensor marks will not be in the image.
2. Bring the endcap of the section half (usually A for archive half) to be measured to the SHMSL, you will use the endcap to scan the barcode for sample information.
3. Place the archive section in the core tray with the blue endcap up against the benchmark. The benchmark is the white square at the head of the rails that hold the section halves (**Figure 15**). If material is missing at the top of the section, be sure the section half is positioned all the way up to the top of the rail. For example, if a 150 cm section half has a missing 10 cm at the top, the yellow endcap should be placed against "0 cm" at the top of the instrument's rails. The user should enter 10.0 in the **Missing Top** (cm) field. The logger will measure the section, and all measurements will be placed at the correct offsets in the database.
4. Adjust the section so that it is as flat as possible with respect to the plane of the benchmark. There is a limit to how much the sensor heads can float when they land on a tilted section.
5. **Do not wrap the cores yet.** The Acuity AR700 laser cannot reliably see through the plastic to measure an accurate profile of the section half surface.
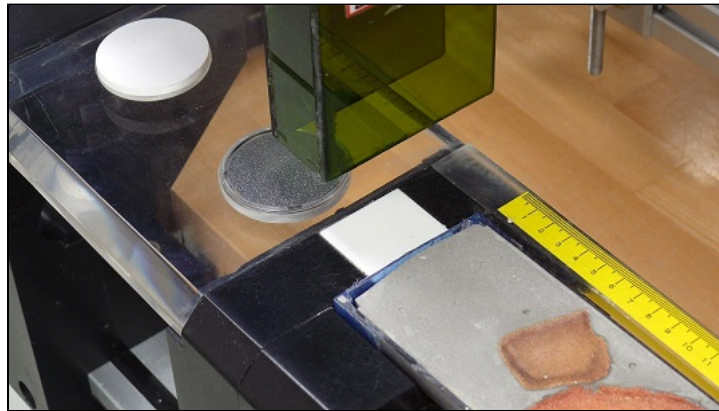
Figure 15. Benchmark location

Measuring Samples

To begin measuring, select *Start* from the main IMS SHMSL window (**Figure 3**). The SHMSL Section Information window will open (**Figure 16**).

Figure 16. Section Information Screen

1. Place the cursor in the **SCAN** text field (**Figure 16**) so that the barcode information will be parsed appropriately. Scan the section label on the section half end cap.
    a. The Sample ID, LIMS ID and LIMS length will automatically parse.
    b. User also has the option to use the LIMS entry tab or the manual entry tab for entering sample information. Be aware that samples must be named properly when using the Manual tab or the data files will not be uploaded to LIMS.
2. Select **Measure**
    a. The sensor assembly will move down the track while the laser acquires a profile of the split surface of the section (**Figure 17**).
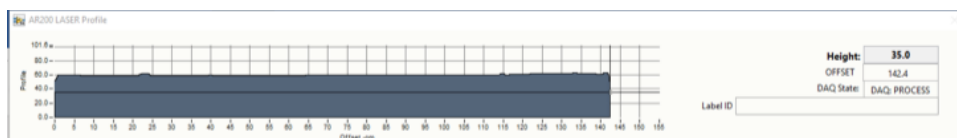
Figure 17. Laser Profile

  b. When the software has detected a gap, it will indicate regions that will not be measured by the MS and reflectance sensors on the screen in red.

    Note: (Gap detection parameters are configurable in the *DAQ> Measurement* Editor Laser window (**Figure 14**).

  c. Acquisition of this profile is why the section is not yet wrapped in plastic wrap—sometimes the laser will profile the wrap rather than the sediment beneath it and give incorrect heights to the gap detection routine.

    Add explanation of what the laser looks for to determine end of core. The laser looks for a gap deeper than the average section-half thickness. If end of section is on one of the bench blocks, the end of section may not be detected accurately.

3. When the laser reaches the end of the section, the Section Length confirmation window will appear (**Figure 18**).

  a. Verify the section length, in centimeters, is correct. If the laser length is longer than the section, manually enter the correct length in the scan length field.
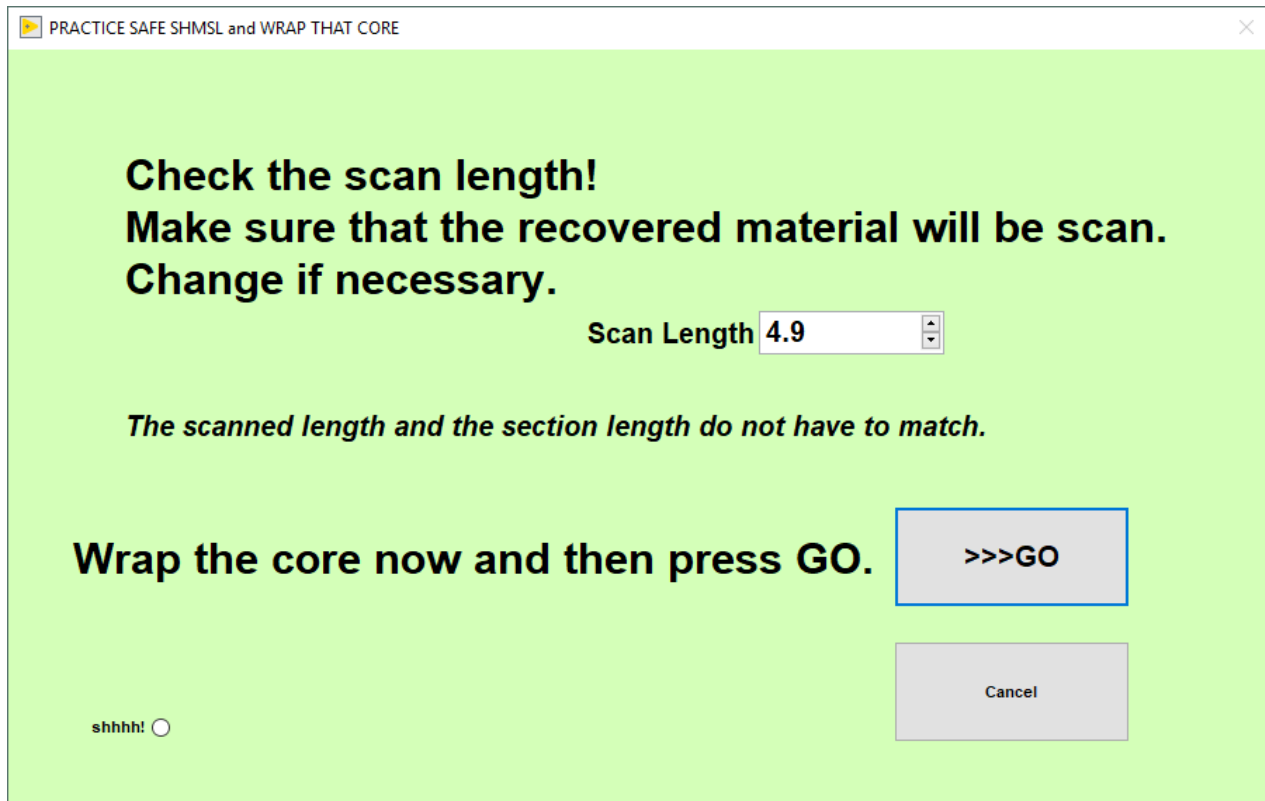

Figure 18. Section Length Confirmation Window

4. Apply GLAD® Plastic Wrap to the surface of sediment cores.

   a. **IMPORTANT!!!** It is necessary to cover the core section with GLAD® PlasticWrap in order to avoid damage to the integration sphere. Any mud that gets inside the sphere will ruin it! Care should be taken to reduce wrinkles in the wrap.

   b. **IMPORTANT!** Do not cover the standards with GLAD® Plastic Wrap; they will give erroneous results if you do.

5.Select **Go**. The measurement process will begin (**Figure 19**)

   a. For efficiency, measurements begin at the bottom of the section and move upcore.
   b. Results are displayed during acquisition on instrument graphs on screen. The QE Pro has several tabs that display different views of the color reflectance data (**Figure 20**). Tabs can be changed during the measurement sequence. The **Corrected Spectra** tab shows the corrected percent color reflectance being measured at each point.
   c. After the section has been measured, the logger takes measurements using the JRSO MS and WHITE standards as check standards, given that the control sample measurement was set up in the measurement parameters.

6. When the measurements are complete, the instruments will return to home and the sample information window will be displayed (**Figure 14**). The user may now prepare the next section and continue measurements.
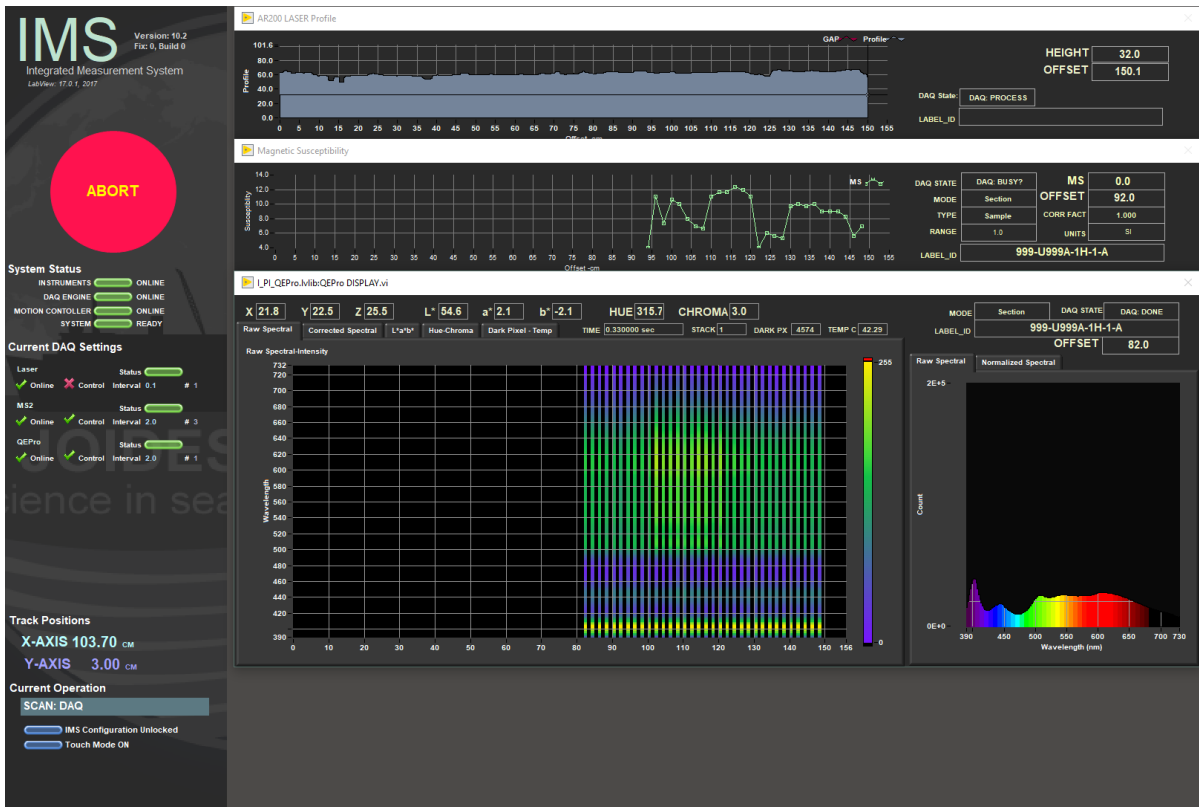
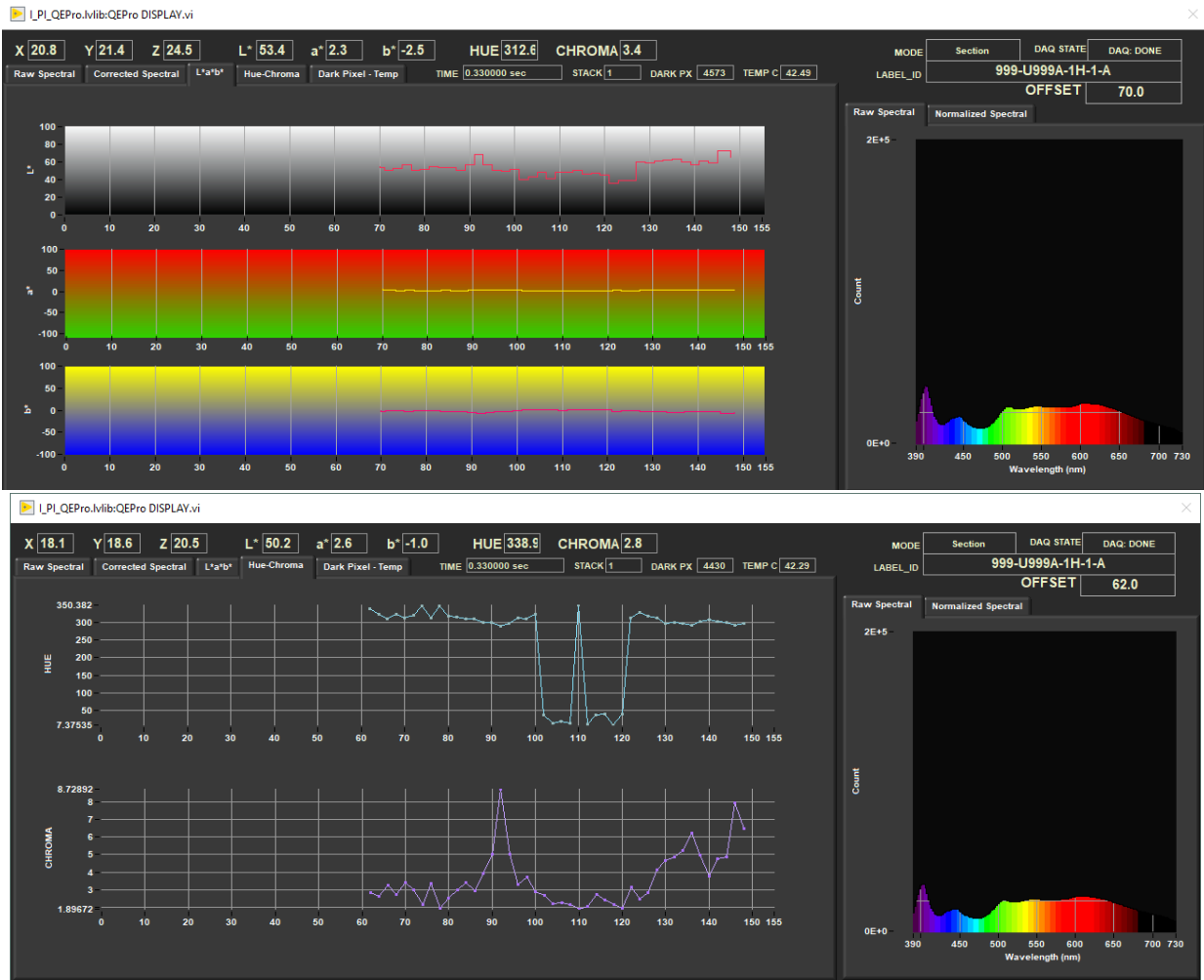Figure 19. Main IMS- SHMSL Data Acquisition Display

Figure 20. Alternative displays for the spectrometer during measurements. User may view the L*a*b* plot (left), the hue-chroma plot (right), or one of the other available tabs.

Other Features

Additional features are available in the Sample Information window. These include:

- **Exclude Intervals:** Intervals can be specified for omission (**Figure 16**). Enter the top and bottom offsets of the areas to be excluded during the measurement pass as shown in **Figure 21**. The excluded intervals apply to all enabled sensors. A green indicator on the sample information entry window (**Figure 16**) will appear when intervals are set to be excluded.

Figure 21. Exclude Intervals Window

- **Missing Top**: When the top of the section is missing, typically due to whole round sampling, the value, in centimeters, of missing material can be entered into the Missing Top field (**Figure 16**). The software will calculate the measurement offsets based off this entry.
- **Fix My Scanner**: Use this feature to reprogram the barcode scanner to properly parse section half labels for use with the SHMSL software.
- **Measure Control Set**: This feature is used to trigger the QE Pro to measure the color reflectance standards. See the Measure Control Set section under Instrument Calibration.

Instrument Calibration

Color Reflectance Spectrophotometer

The color reflectance spectrophotometer calibrates on a spectra, pure white (Spectralon® WHITE standard) (**Figure 2**), and the black is acquired with the lights off and the shutters, but closed still on the white Spectralon standard. The spectrometer calibration can be triggered automatically (typically every 6 hours) or manually by the user. The expiration time for the spectrometer calibration is set in the QEPro setup menu (**Figure 7**). Before running the first sample, the software will check the status of the spectrometer calibration. If the calibration has expired, a prompt will appear asking the user to begin an automatic calibration. It is recommended that the user calibrate every time the software prompts the user.

There is an option to ignore the calibration, but the calibration prompt will reappear with every run until the calibrations are completed and data run without a calibration update will be flagged as **calibration invalid** in LIMS.

Automatic Calibration

1. If the QE Pro is out of calibration, the **Instrument Calibration List** screen will appear (**Figure 22)**.
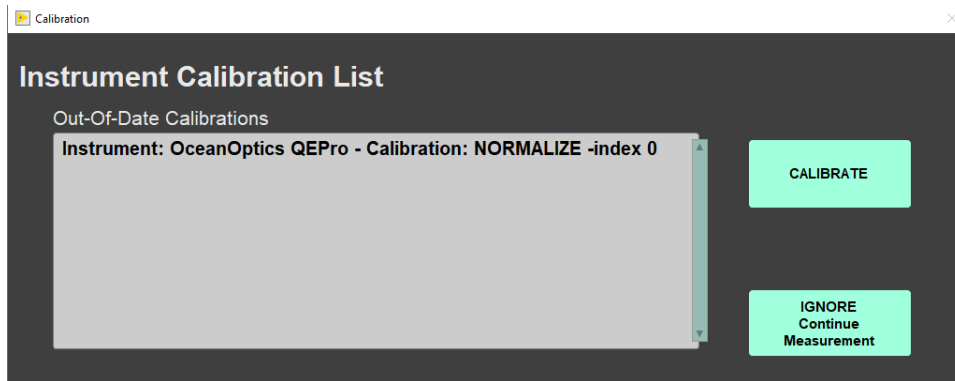
Figure 22. Instrument Calibration Prompt

2. Before beginning the calibration, ensure the WHITE standard is clean (**Figure 2**). If the Spectralon® standard appears even the least bit gray or discolored, contact the technician to clean or replace the standard! It may be useful to compare a clean, new piece of white paper to the standard—if the paper seems whiter, the standard is quite dirty.

    a. The Spectralon® standard can be cleaned according to the Spectralon® Reflectance Standards Care and Handling Guidelines. Spectralon Standards Care and Handling.pdf. Check that both lights are on and the shutters are open. If you look at the white standard while the integrating sphere is over it you should see two dots of light, one blue (LED) and one yellowish (Halogen).

3. Click the **Calibrate** button to begin the calibration process. The user may select **Ignore Continue Measurement** and skip the calibration, but the software will prompt the user for a calibration every time a measurement is started until the calibration is completed.

    a. The logger moves the QE Pro integrating sphere over the WHITE calibration standard and lowers the sensor until it touches. The sensor begins the white calibration measurements (**Figure 23**) based on the set saturation level of the total response (**Figure 7**).

    b. The display includes:

- **Max Counts**: current highest value
- **Target Counts**: percent saturation value as set in the instrument parameters (range = 32,000 counts)
- **Integration Time**: measurement period where the highest wavelength count is equal to or exceeds 80 percent of the spectrophotometer's range.

4. When the white calibration is complete, the integration time will be displayed on the screen and the user will be prompted to **Accept, Re-Start, or Abort** the calibration (**Figure 24**).

    a. The integration time should be about 0.30 to 0.55 seconds for the current dual-light source configuration, assuming the bulbs are new.

    b. If integration times increase to more than 1 second, alert the IODP technician. The halogen bulb or the LED source may need replacing.

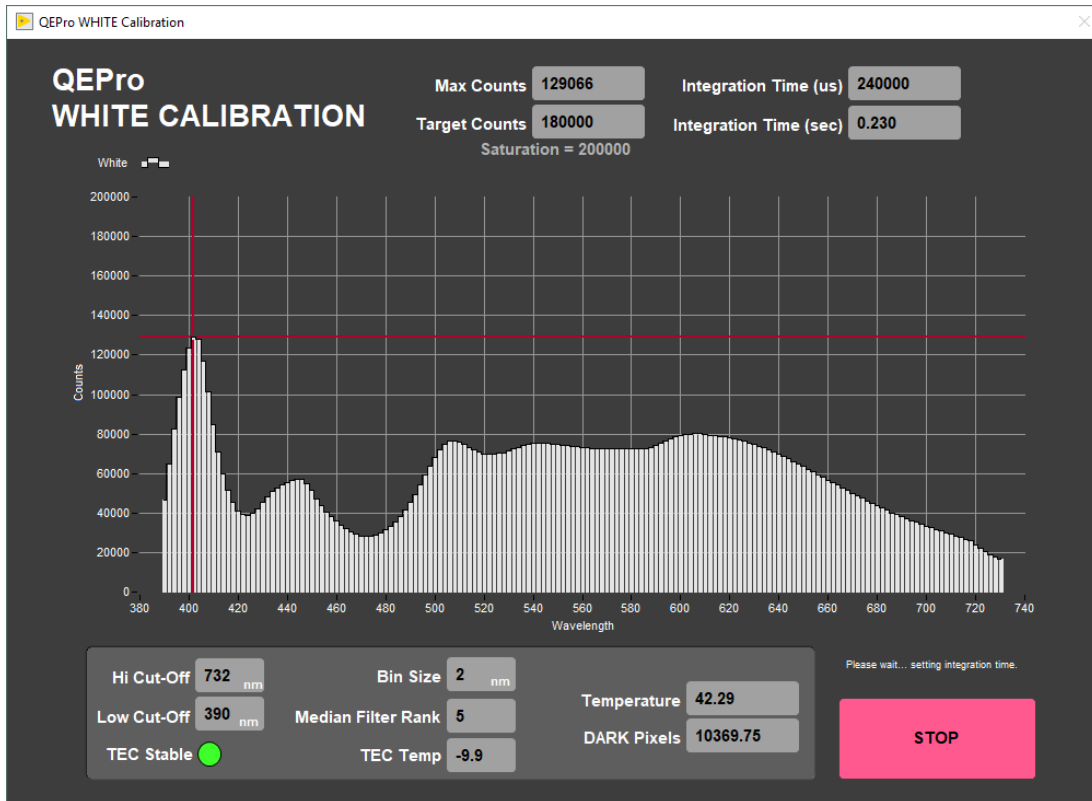5. Click **Accept** to accept the white calibration. (**Figure 24**):
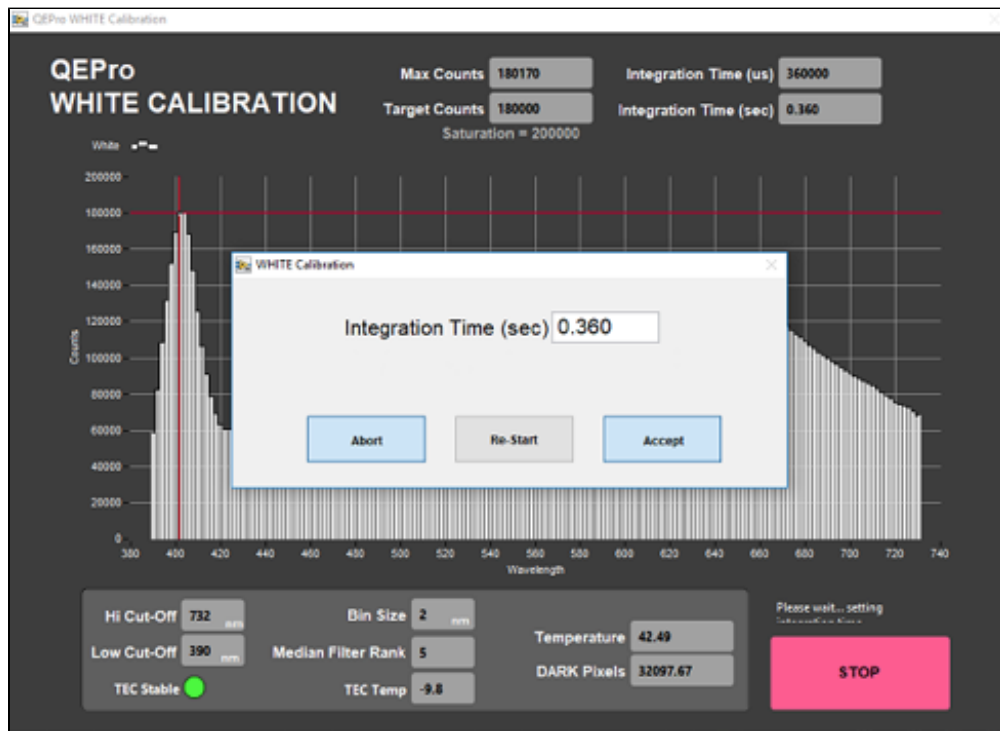
Figure 23. White Calibration Screen

Figure 24. White Calibration Integration Time Display

6. After the WHITE measurements are completed, the shutters on the light sources will close and the DARK measurement will acquire 20 measurements. The dark measurement is a baseline measurement that includes thermal noise of the system. On the screen (**Figure 25**):

- **Temperature**: should remain below 50°C; note that the TEC temperature is usually about -9 degrees C; accessed through the QE Pro Utilities screen.

- **Spectral Mean**: mean of the entire spectrum (at the line across the display plot). This should be only about 200 counts higher than the Dark Pixel count. With plastic wrap, it should not exceed 500 counts
- **Dark Pixels**: 20 pixels that have been deliberately masked to allow no light. These counts represent the thermal noise of the spectrophotometer.
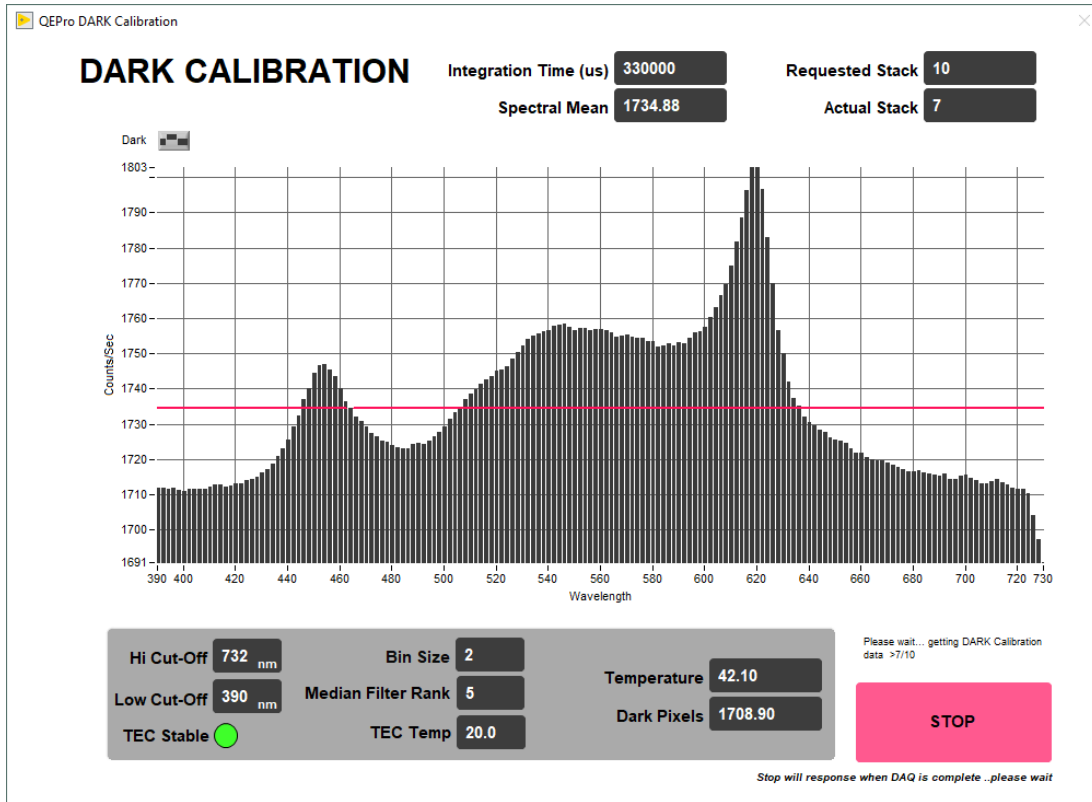

Figure 25. DARK Calibration Screen

7. When the dark calibration is complete, the user is prompted to **Abort, Re-Start, or Accept** the dark calibration (**Figure 26**).
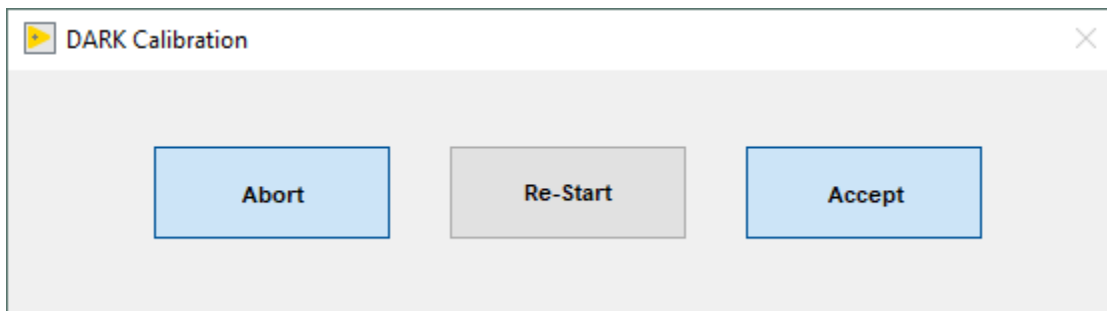

Figure 26. Dark Calibration Completed Prompt

8. The final screen shows the normalization of spectra that will occur with the just-acquired calibration (note: low values are better than high values because of signal-to-noise ratio) (**Figure 27**). Ideally, the graph would display a straight line at zero value. However, a normalization factor is required to be applied to the XYZ and L*a*b* color indexes. Normalization amplifies the noise as well as the signal. If core flow allows, the data quality can be increased by averaging multiple measurements (in **Measurement Editor** increase the **Average** parameter).
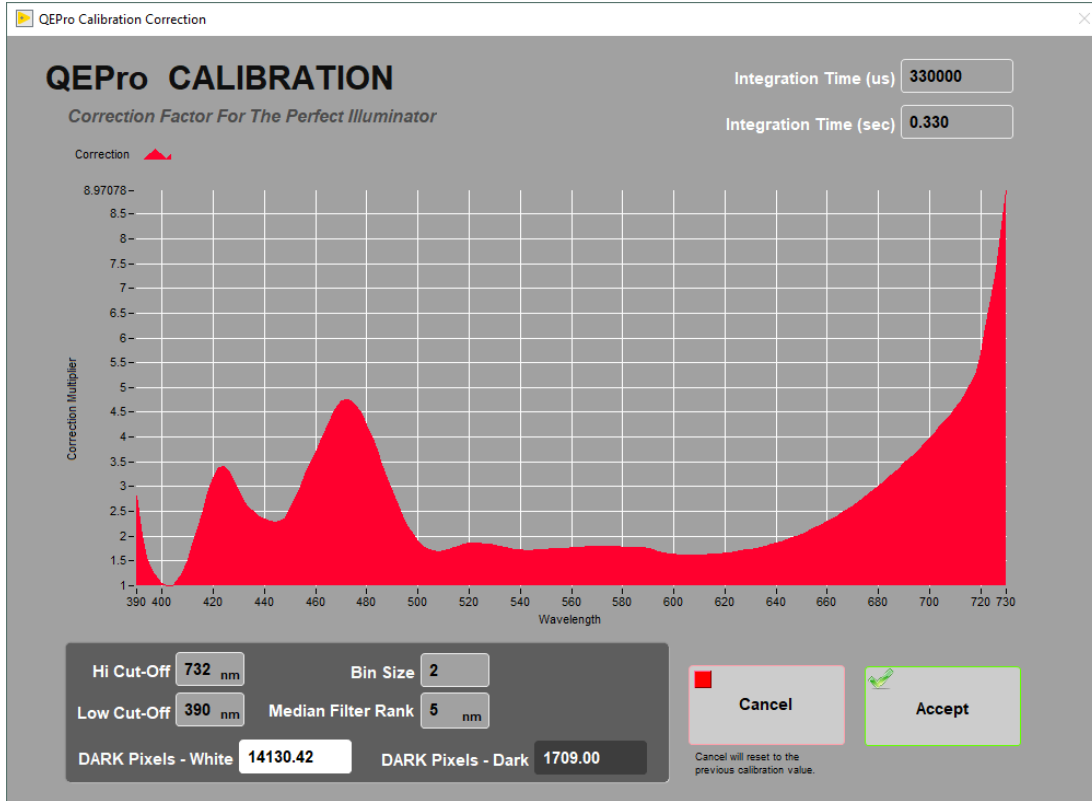
Figure 27. Calibration Normalization Factor

9. Select **Accept**. If this was an automatic calibration at the start of a measurement, the laser profile will start automatically, followed by the normal measurement sequence.

Manual Calibration

To perform calibration manually (not when specified by the software), select *Instruments > QE Pro: Calibrate* (**Figure 6**). The QEPro will move to the white standard and begin the calibration process. Follow the automatic procedure from step 4 to complete the calibration. This should be performed when a bulb is changed or other hardware configuration changes.

Recognizing a Bad Calibration

The following information is provided to assist scientists and technicians in evaluating the QE Pro calibration. Always verify the lights are on and thge shutters are open. Two dots of light should be visible exiting the integration sphere.

Figure 28 demonstrates a calibration with an old light source. When the 500nm - 740nm end of the calibration spectrum is over the amount of counts the program will process, this might be for a number of reasons, but most likely the LED light is dim or off**.** The blue end of the spectrum is within the correct amount of counts and maintains the right curve with the spike around 400 wavelength and a dip into the 420-430 range. The first thing to check is the age of the LED light source, if it is older than 1 month it should be replaced.
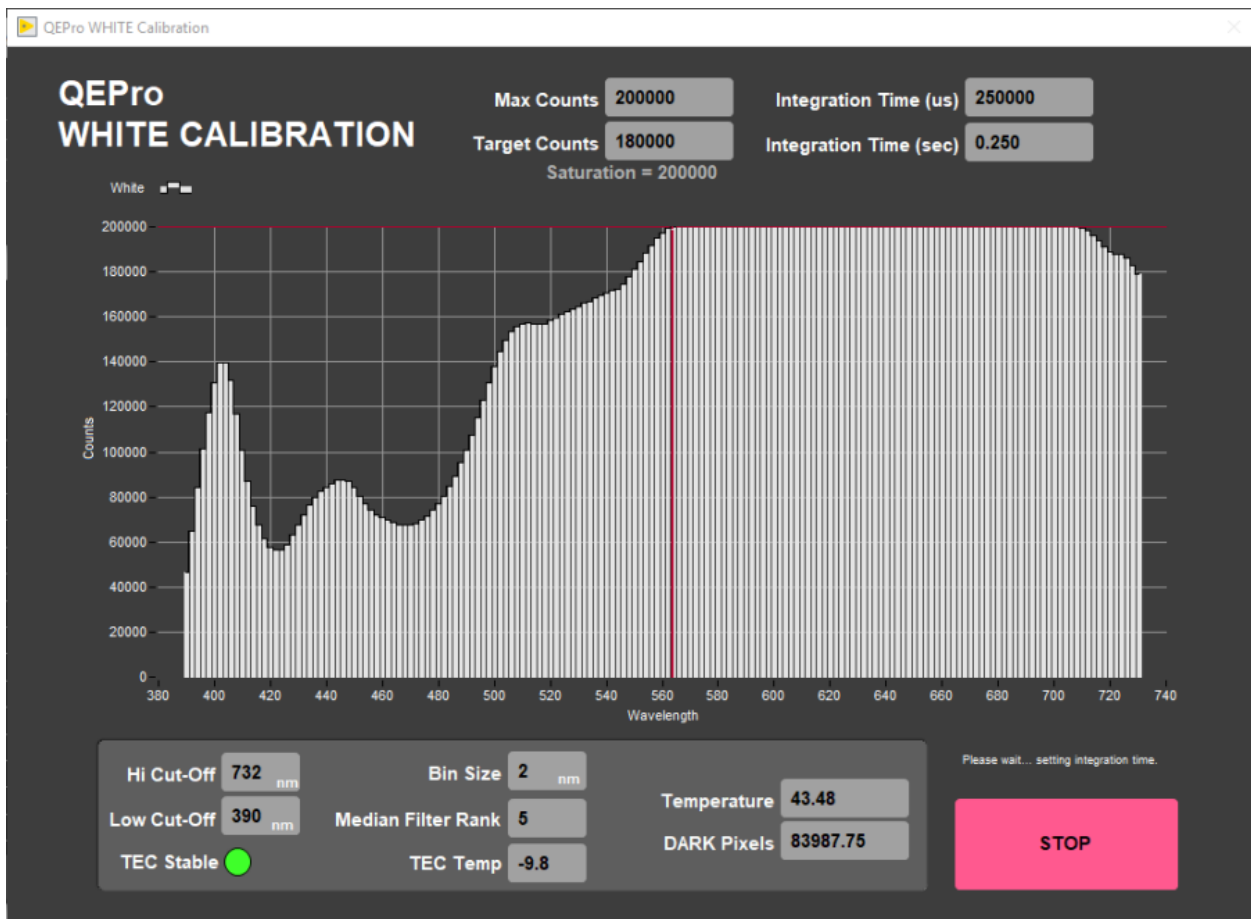
Figure 28 - White Calibration, bad lighting or bleed in.

Figure 29 demonstrates a calibration with the LED turned off (i.e., the shutter did not close properly). You'll notice the left side of the graph, the blue side, does not show the proper peaks, whereas the red side of the graph is at 180K counts. Make sure the LED light is in TTL mode and properly connected to the QE Pro, and lastly that the shutter is opening. If you look at the white standard while the integrating sphere is over it you should see two dots of light, one blue (LED) and one yellowish (Halogen).
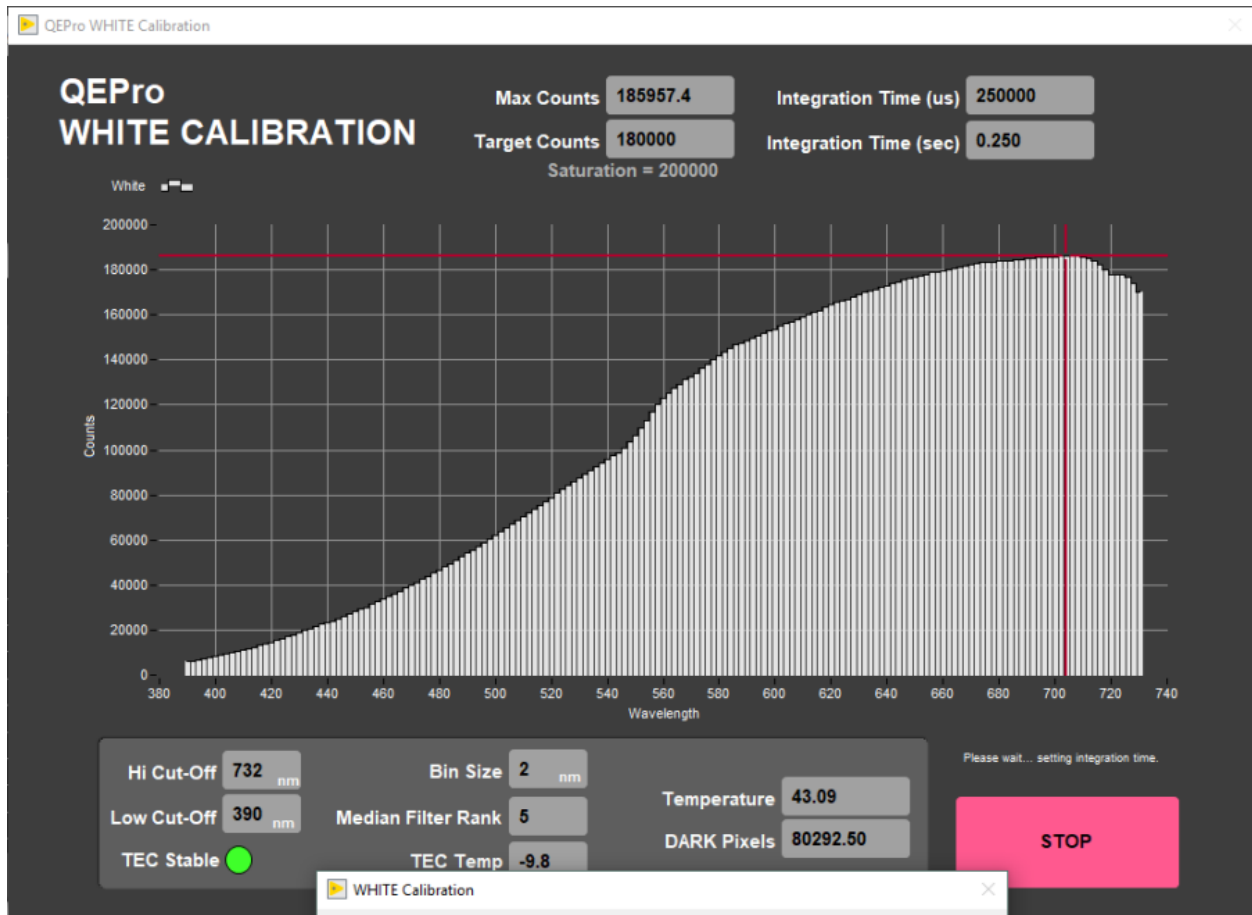

Figure 29 - White calibration, blue light (LED) turned off or other malfunction.

Measuring the Color Control Set

There are twelve color reflectance standards available in the physical properties lab in the drawers beneath the pycnometer (**Figure 3**). The black standard is not typically used in the control set.

Measuring the Control Set:

1. Set the standard holder on the track as seen in **Figure 30.**
    a. The standard holder has a white block on one end. This white block should be against the white benchmark on the track for proper positioning (**Figure 30**, red circle).
2. Place the color standards in the sample holder.
    a. The order and position of the standards are set under the *Instruments > QE Pro: Edit Standards* menu. See the *Utilities: QEPro Edit Control Set* section for more information about setting up the control set.
3. Select *Start* from the main IMS-SHMSL window (**Figure 5**).
4. Select **Measure Control Set**.
    a. The QE Pro will begin moving down the track and collecting measurements on each standard. The data for each standard will be displayed on the screen (**Figure 31**).
    b. . If the QE Pro does not properly touch down on the standards, the positions may need to be edited in the *Instruments > QE Pro: Edit Standards*. Also verify that the standard holder is against the benchmark.
5. After each standard has been measured, the data will automatically be saved to the C:/AUX_DATA/RSC/CNTRL folder as a .csv

Figure 30 - Color Reflectance Control Set on SHMSL track. The white square on the end of the standard holder should be against the white benchmark (red circle).
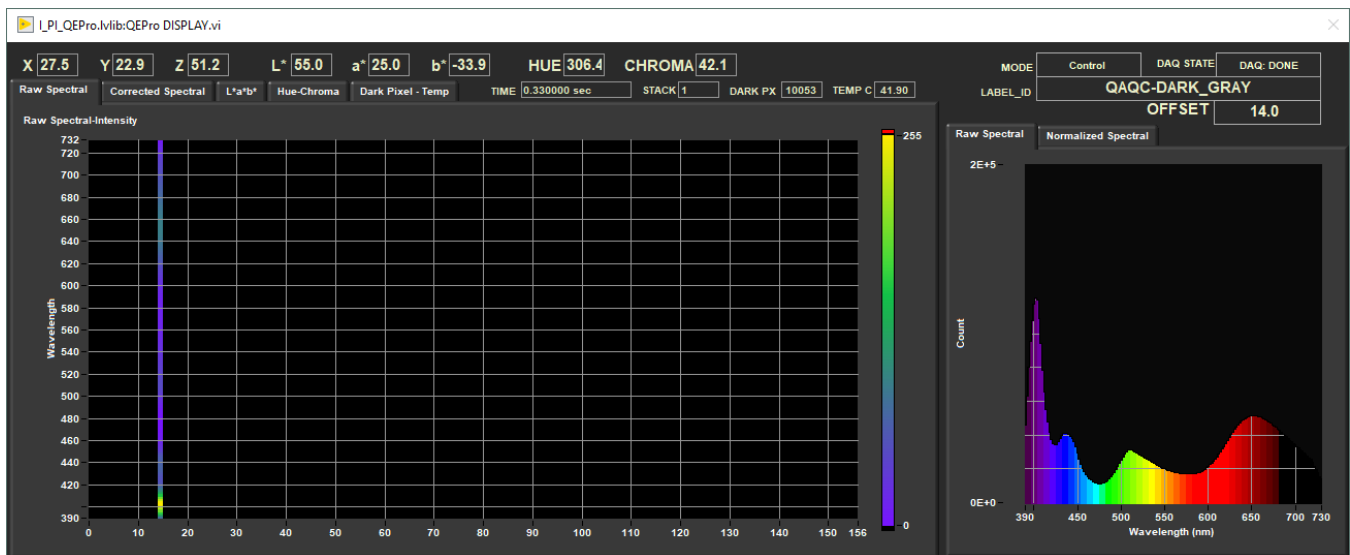
Figure 31 - IMS-SHMSL Display during control set measurements

Magnetic Susceptibility Meter

The point magnetic susceptibility meter is calibrated by the manufacturer (Bartington, Ltd.). The probe is zeroed in air before the core section is measured, so drift is not a significant factor. It is not necessary to calibrate the MS2K or MS2E probes (or the MS2C loops on the whole-round loggers), but the calibration check standard can be used to demonstrate consistent results.

Utilities

The available utilities within the SHMSL software are:

- **AR700 Laser Utility**

- **MS2 Utility**
- **MS2 Edit Standards**
- **QEPro Utility**
- **QEPro Edit Control Set**
- **QEPro Lights On**
- **QEPro Lights Off**
- **Y-Axis Setup**

AR700 Utility

Select *Instruments > Laser: Utility* (**Figure 6**). The AR700 laser utility window will open (**Figure 32**). This utility allows the user to test the performance of the AR700 in real time and allows the user to ensure that the laser is returning true distance values.
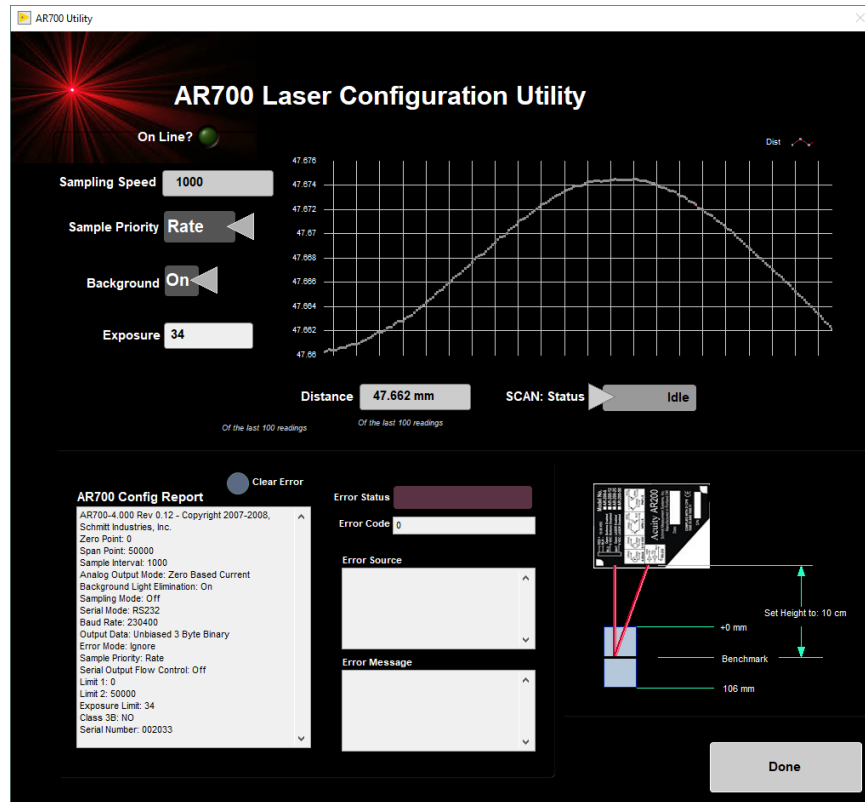

Figure 32. AR700 Laser Utility

Magnetic Susceptibility Utility

Select *Instruments > MS2: Utility* (**Figure 6**). The MS utility window will open (**Figure 33**). The utility allows the user to test the MS performance. The MS utility allows the user to zero the meter and to set it to continuous measurement.
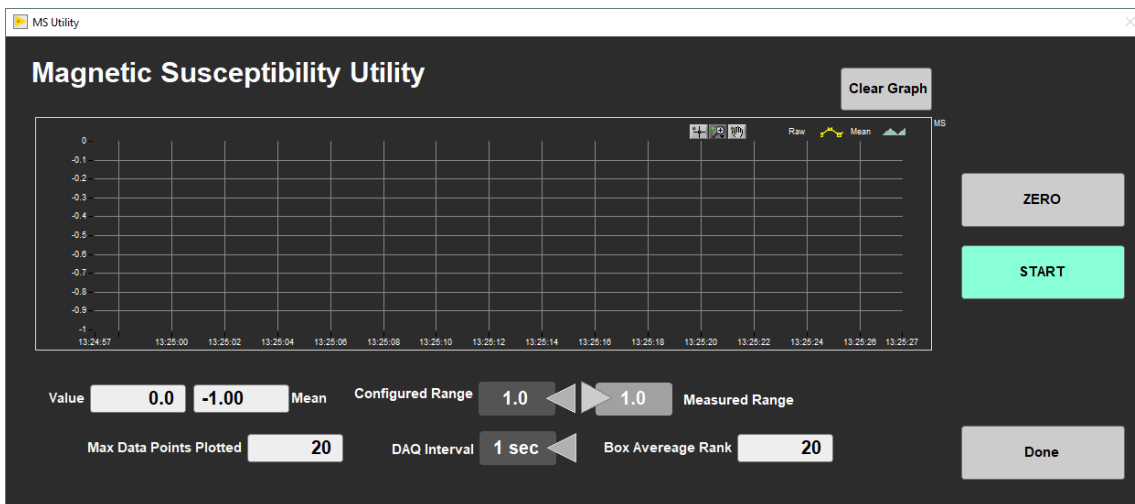
Figure 33. MS2K Utility

Magnetic Susceptibility Edit Standards

Select *Instruments > MS2: Edit Standards* (**Figure 6**).

Figure 34. MS Standard Editor Window

QEPro Utility

Select *Instruments > QEPro: Utility* (**Figure 6**). The QE Pro utility window will open (**Figure 35**). The utility allows the user to run instantaneous or continuous measurements of the spectrum being acquired by the spectrometer. Different spectra (e.g., light standard, dark standard) can be overlaid and the user has a number of other options.

Figure 35. QE Pro Utility

QEPro Edit Control Set

Select *Instruments > QEPro: Edit Control Set* (**Figure 6**). The QE Pro Standard Set Editor window will open (**Figure 36**). Th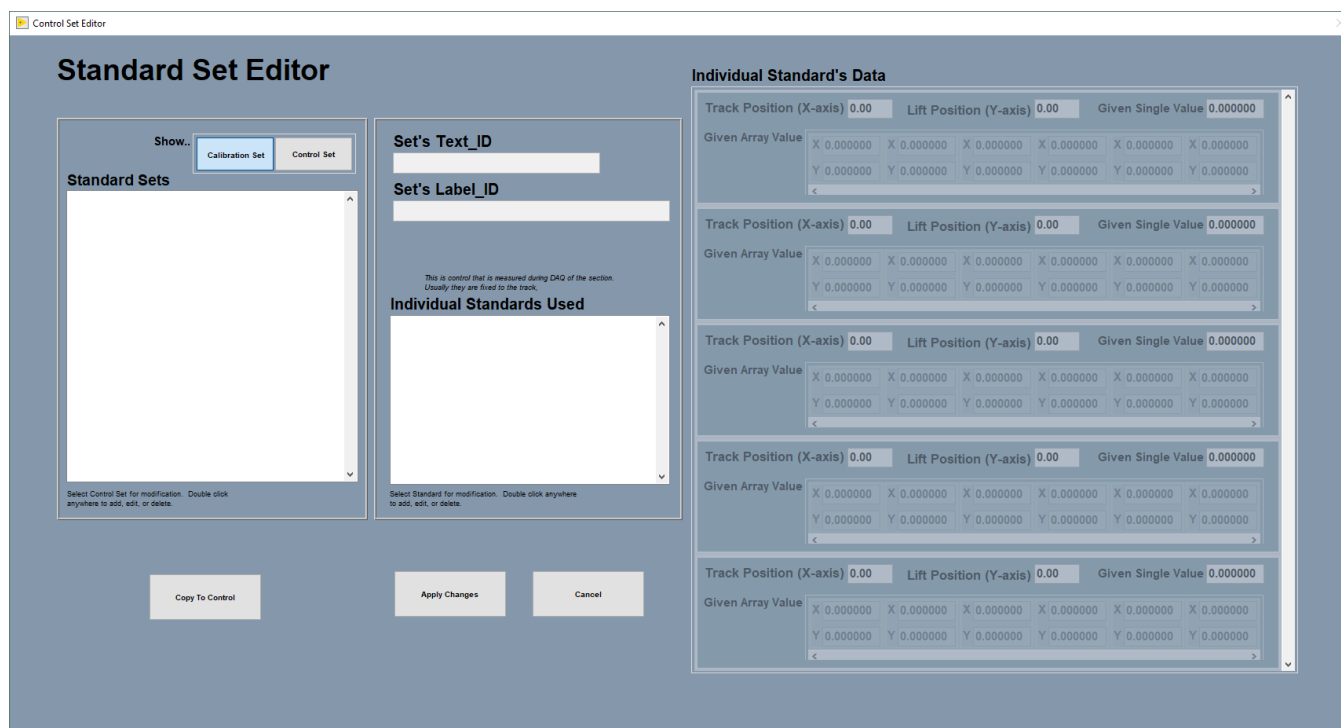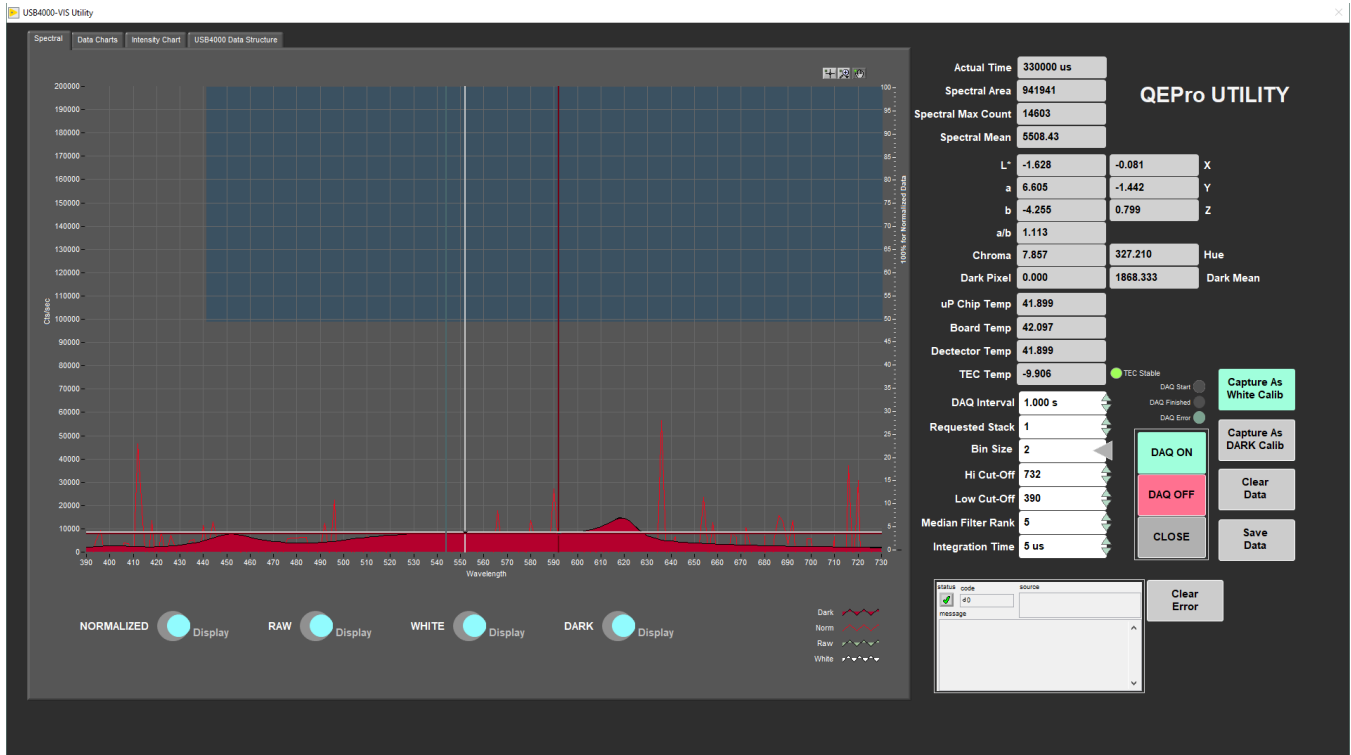is utility allows the user to define the standards and their positions on the track. These configuration values are used to determine where the QE Pro will be positioned for calibration measurements.

- To view the setup of the 99% white Spectralon® standard and the "dark" standard, select *Show* **Calibration Set.**
- To view the setup of the diffuse color standards, select *Show* **Control Set.**

To edit a standard:

1. Select the standard of interest under the *Individual Standards Used* field
   a. The current configuration will be displayed under the *Individual Standard's Data* heading.
2. Double click on the standard's name under the *Individual Standard's Used* heading. An action prompt will open (**Figure 37**).
3. Select the **Edit Standard** option to update an existing standard's identification information or position on the track (**Figure 38**). Select **New Standard** to create a new individual standard.
4. Scan the Standard Label into the Scanner field
   a. The standard labels can be found in Sample Master by selecting the Sample Table tab with the VIEW mode selected. The SHMSL standards will be listed under:
      i. Expedition:QAQC
      ii. Site: CORELAB
      iii. Hole: SHMSL

5. Select **Save**
6. Select **Accept Changes.** The new values will be written to the configuration file and will be used for all subsequent standard measurements.
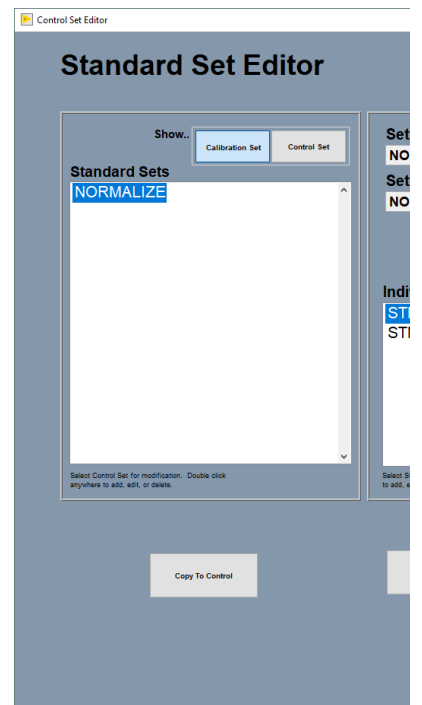
Figure 36. QEPro Control Set Window. The calibration standards can be edited (left) through the Calibration Set and the control set standards can be edited (right) through the Control Set window
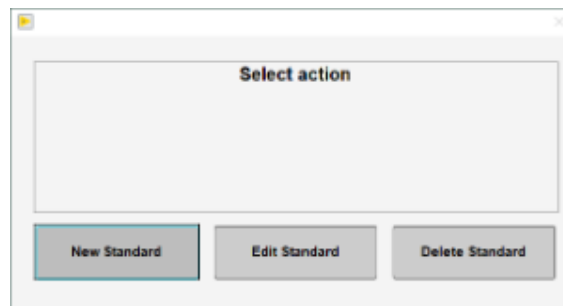
Figure 37. Action Prompt Window
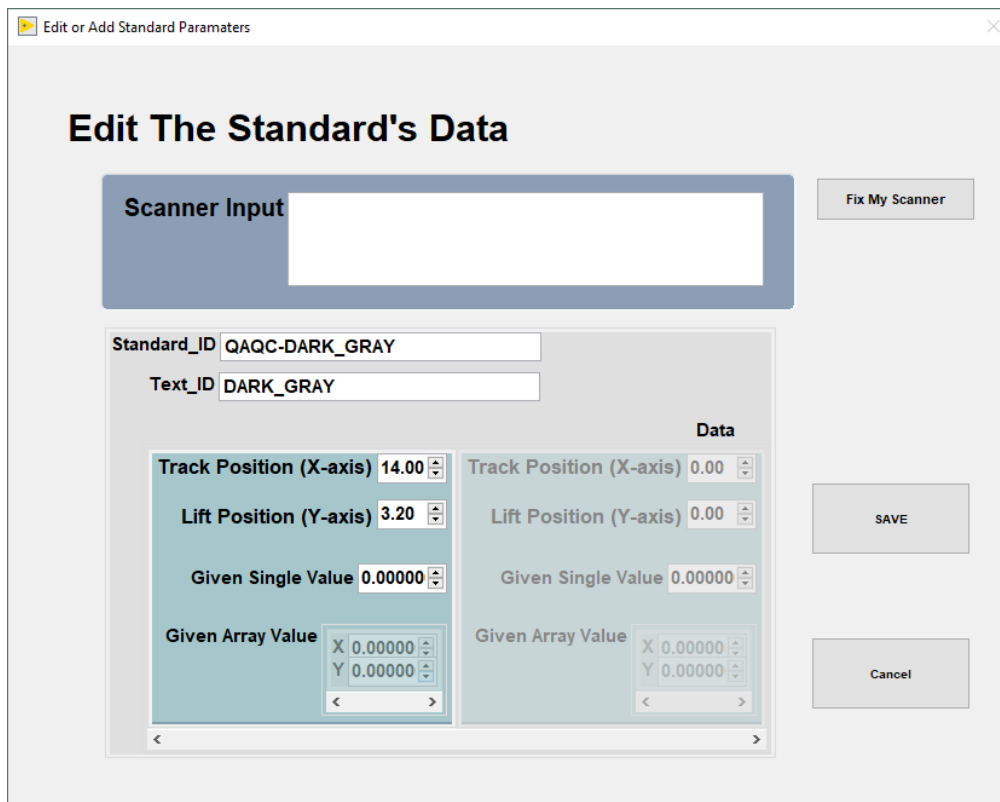
Figure 38. Edit Standard Window

Y-Axis Setup

Select *DAQ > Y-Axis Setup* (**Figure 6**). The Y-axis setup window will open (**Figure 39**). The Y-Axis setup is used to define the working distance for the AR700 laser. If anything is changed on the Y-axis mount, y-axis lift setup values should be determined experimentally.

- To determine the distance to benchmark, click the "Get Benchmark Data" button. This value is normally between 45.45 mm.
- The Touch Down Offset value is 4.00 cm.
- The Safe Clearance value (usually set to 3.0 cm) is used to prevent the sensors from running into something (e.g., a tall rock piece) that is higher than the section half liner.
- The Touch Compression value (usually set to 0.5 cm) is used to push downward gently after the landing to flatten the sensors against the core section.

Note: For very soft sediments, it may be necessary to set the Touch Compression to 0.0 cm.
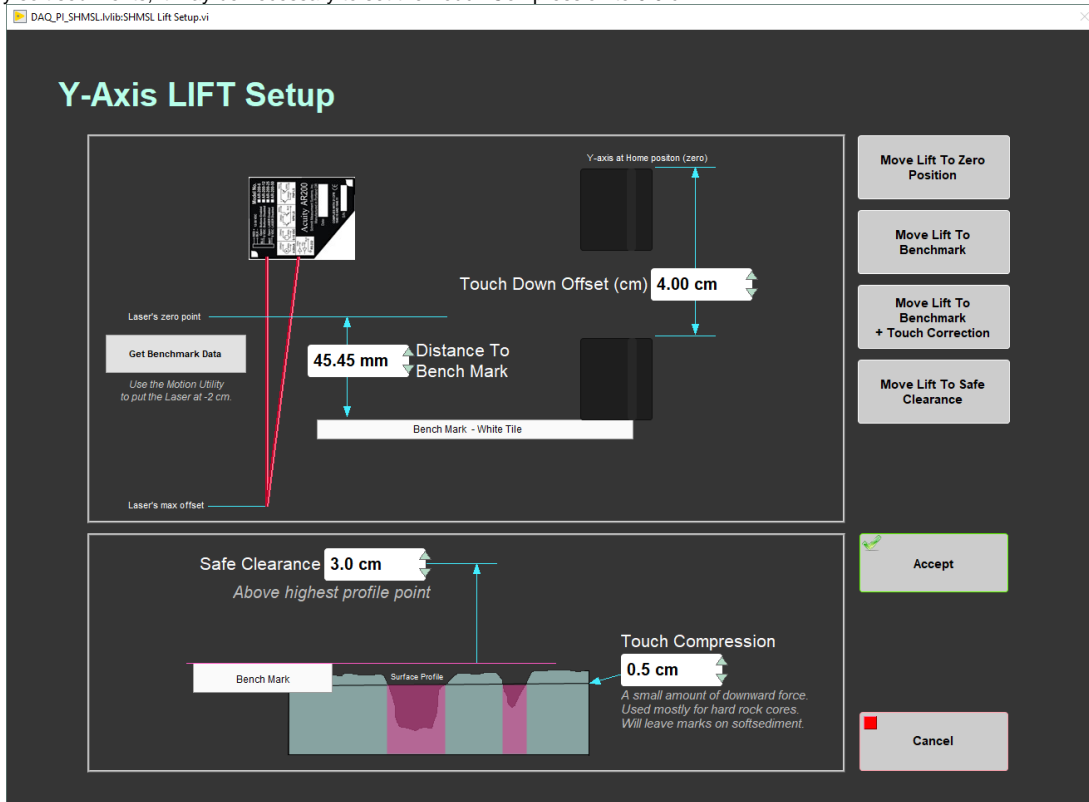
Figure 39. Y-Axis Lift Setup

Motion Control Setup

Select *Motion > Setup* from the main IMS-SHMSL window (**Figure 6**).

Motion control should be set during initial setup and further changes should not be necessary. The M-Drive Motion Setup control panel will open (**Figure 40**).

- The user may select between four setup panels from this window.
    - Motor and Track Options
    - Fixed Positions
    - Limit and Home Switches
    - Motion Profiles
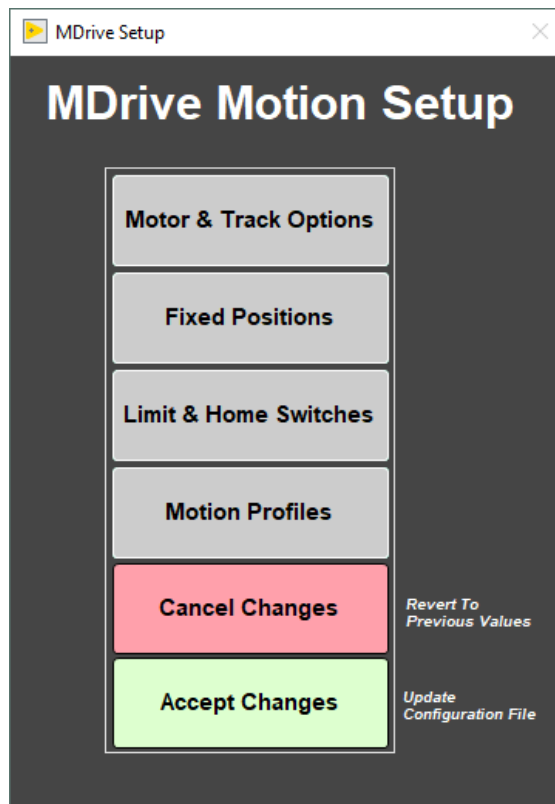
Figure 40. Motion Setup Menu

Motor and Track Options menu

Once these values have been properly set, they should not change. This panel is only for initial setup.

- Make sure to use the values shown for the SHMSL (**Figure 41**).

The relationship between motor revolutions and linear motion of the track is defined in this window and is critical to both safe and accurate operation. User should be familiar with the M-Drive motor system prior to adjusting these settings. These values are used by IMS to set motion controller parameters and convert encoder pulses into ± position values in centimeters. The correct settings for the SHMSL are as follows:

X-Axis Track Motor Setup Settings

- Encoder Pulses/rev: 2048
- Screw Pitch: 2.00000E+0
- Gear Ratio: 4.00000
- Direction of Positive Motion: CCW for positive encoder counts

Y-Axis Track Motor Setup Settings

- Encoder Pulses/rev: 2048
- Screw Pitch: 1.00000E+0
- Gear Ratio: 1.00000
- Direction of Positive Motion: CW for positive encoder counts

Click the **Motion Utlity** button to open the Motion Utility window (**Figure 42**) and test the settings. Click **Close** to exit this window.

Click **Accept** to save the values or **Cancel** to return to previous values.
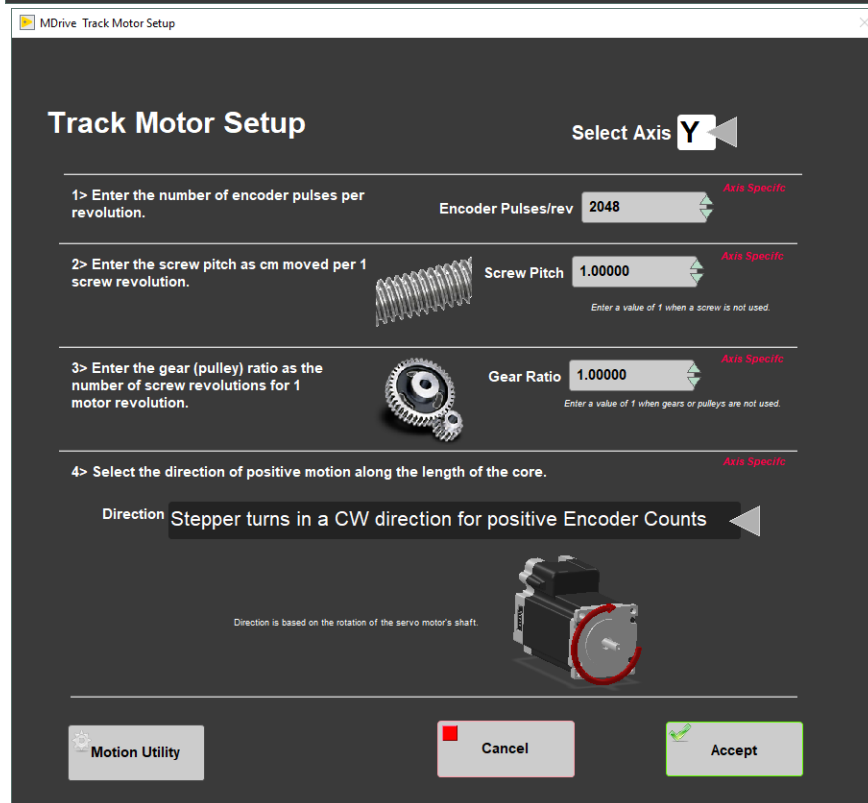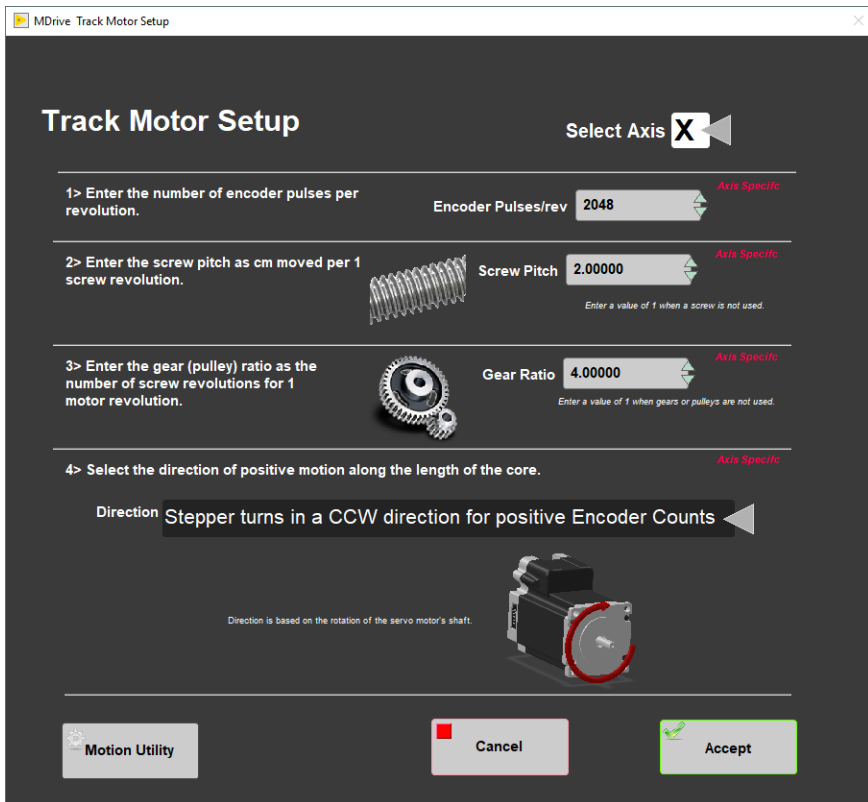
Figure 41. Track Motor Setup for the X-axis motor (left) and the Y-axis motor (right).
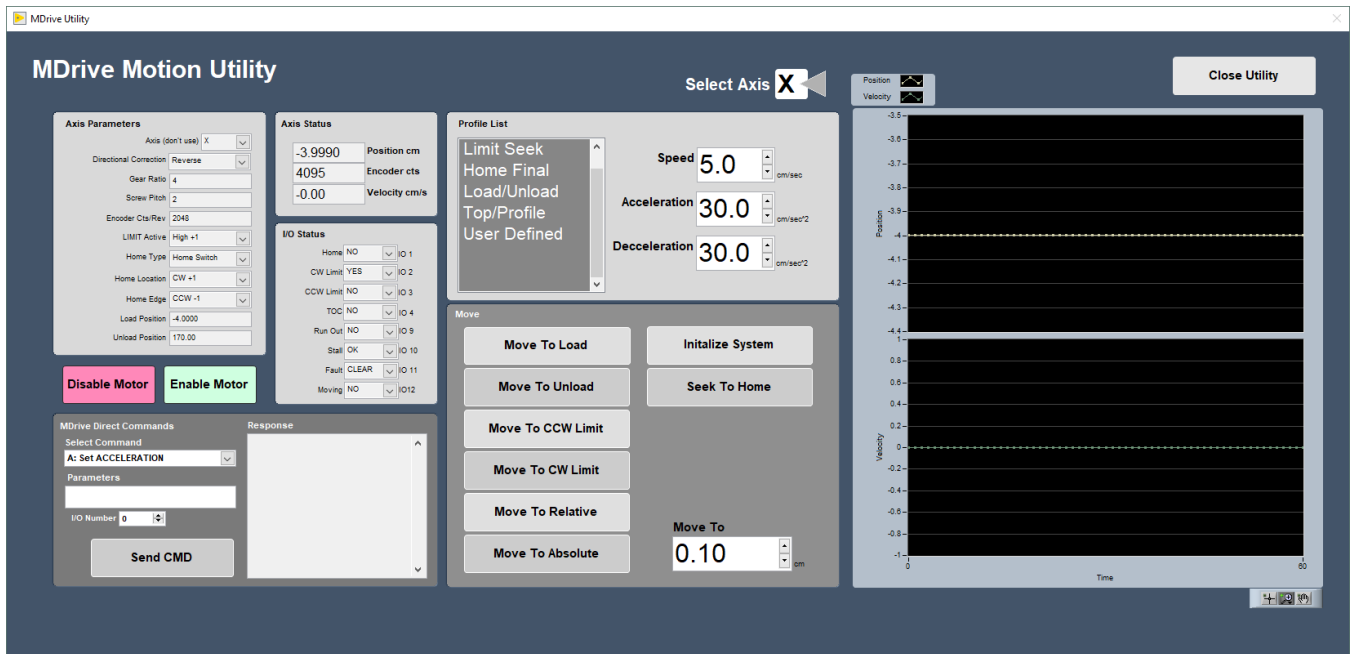
Figure 42. Motion Utility Window

Fixed Positions menu

Once these values have been properly set, they should not change. This panel is only for initial setup.

In this window the user may define fixed track locations used by IMS motion control. For the SHMSL make sure to use these value unless there has been a physical change to the system (**Figure 43**).

X-Axis Fixed Position Settings

- Max Section Length: 160.0 cm
- Track Length: 200.0 cm
- Load Position: -4.0 cm
- Unload Position: 170.0 cm
- All "PUSH Track Only" settings = OFF (or 0.0, as appropriate)

Y-Axis Fixed Position Settings

- Max Section Length: not configurable for this axis
- Track Length: not configurable for this axis
- Load Position: -3.0 cm
- Unload Position: -3.0 cm
- All "PUSH Track Only" settings = OFF.

Click the **Motion Utiilty** button to open the Motion Utility window (**Figure 42**) and test the settings. Click **Close** to exit this window.

Click **Done** to save the settings. Click **Cancel** to return to previous values.
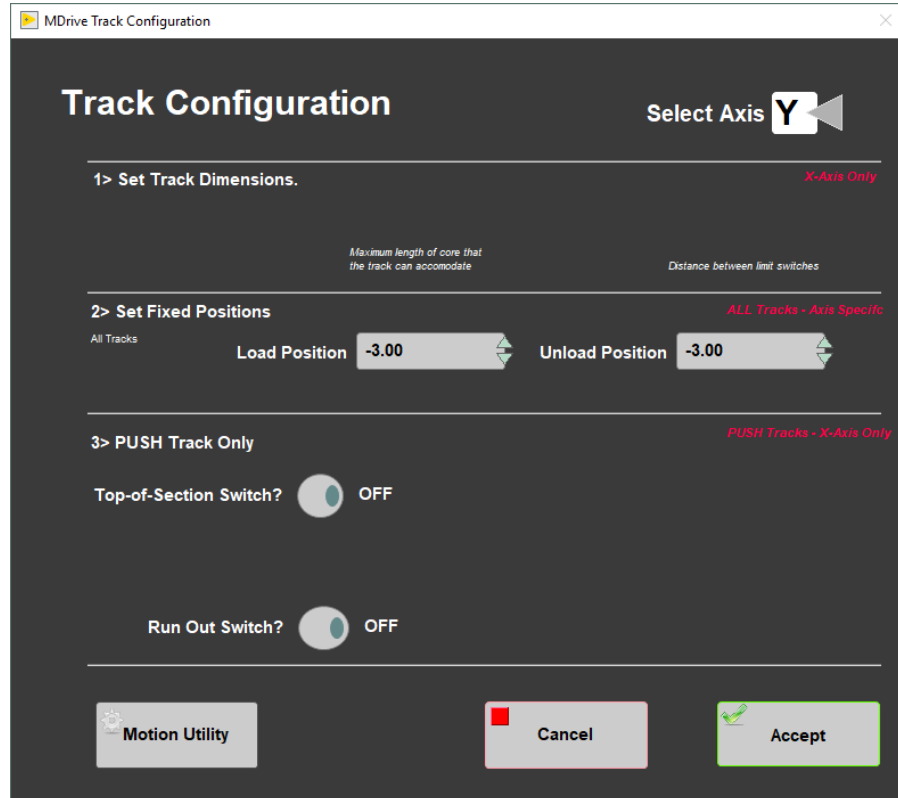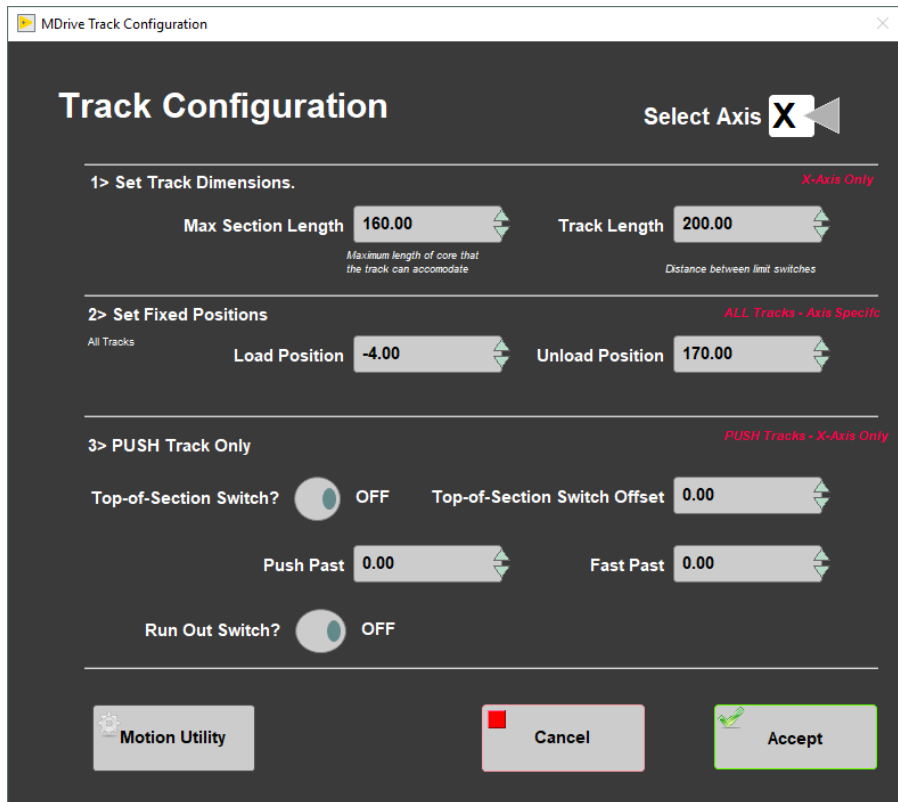
Figure 43. Track Configuration values for the X-axis (left) and Y-axis (right).

Track Configure – Limit & Home Switches

Once these values have been properly set, they should not change. This panel is only for initial setup.

The SHMSL X-axis (down-core motion) and Y-axis (vertical sensor motion) are configured using this screen (**Figure 44**). The X-axis is "CW Look @ CCW Edge" logic. The Y-axis is "CCW Look @ CCW Edge" logic.

Figure 44. X-Axis (left) and Y-Axis (right) Limit and Home Switch Configuration

Track Configure – Motion Profile

The motion profiles window can be used to adjust the speed and acceleration profiles used by the track for various types of movements (**Figure 45**).
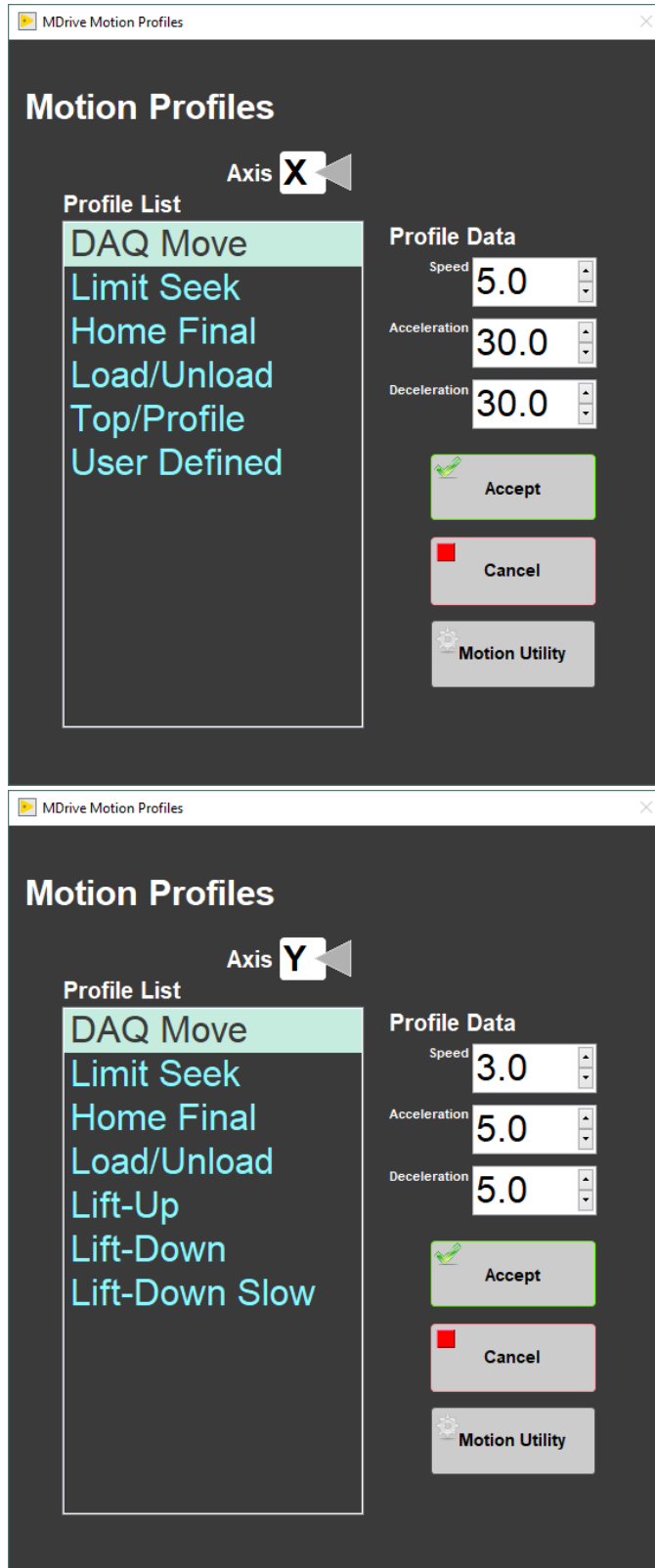
Figure 45. X-Axis (left) and Y-Axis (right) Motion Profiles

The following table shows the motion profile settings for the SHMSL X and Y axes controlled by the interface.

Axis	X-Axis	Y-Axis

Profile	Speed	Accel.	Decel.	Speed	Accel.	Decel.
DAQ Move	5.0	30.0	30.0	3.0	5.0	5.0
Limit Seek	3.0	10.0	80.0	3.0	10.0	80.0
Home Final	0.5	2.0	80.0	1.0	10.0	80.0
Load/Unload	15.0	10.0	10.0	10.0	5.0	5.0
Top/Profile	5.0	30.0	30.0	N/A	N/A	N/A
User Defined	5.0	5.0	5.0	N/A	N/A	N/A
Lift-Up	N/A	N/A	N/A	5.0	5.0	5.0
Lift-Down	N/A	N/A	N/A	3.0	5.0	5.0
Lift-Down Slow	N/A	N/A	N/A	1.0	5.0	5.0

Table: Motion Profile by Axis for SHMSL

LIMS Integration

Uploading SHMSL data to the LIMS database is executed via the MegaUploadaTron (MUT) application. MUT accesses files in the *C:\DATA\IN* directory. Once an upload is complete the data is transferred to the *C:/DATA/ARCHIVE* directory. Any file that fails to upload is transferrred to the C:/DATA/*ERROR* directory.

Data Upload Files

Data upload files are text files used by the MUT application to load acquired data into LIMS. Files with the RSC extension contain the reflectance spectroscopy and colorimetry data and files with the MSPOINT extension contain the MS point data for a section. The files with a name containing PROFILE.csv are laser profiles for a given section.

The data upload files generated by the SHMSL are:

- **.RSC:** A data file containing all of the RSC measurements for a section of core. Data include: offset, L*, a*, b*, hue, chroma, x, y and z tristimulus, and sample time
- **.MSPOINT:** A data file containing all of the magnetic susceptibility point measurements for a section of core. Data include offset, magnetic susceptibility, and a time stamp. The file also includes the range and units and serial number of the magnetic susceptibility meter used.
- **.PROFILE:** a .file containing the section half ID and the observed core length measurement (cm).

Auxiliary Files

Auxilary files are csv formatted text files written for the AR700 laser, the QE Pro, and the MS point sensor. Each of these files is referenced in their respective upload file between the <File> tags and are archived in the ASMAN database.

The auxiliary files generated by the SHMSL are:

- **rsc.csv:** a summary file containing offset (cm), sensor temperature, dark pixel count, bin interval, the wavelength range measured, the integration time in microseconds, and the raw data values in each bin.
- **mspoint.csv**: a summary .csv file containing the mean magnetic susceptibility values for each measurement along a section as well as the range and units used at the time of measurement
- **profile.csv**: a summary .csv file containing the raw AR700 laser data for a section of core at 0.1mm steps. Data include offset, uncorrected height (mm), x-sect area (square mm), and benchmark (square cm).

Reflectance Spectroscopy and Colorimetry Files

- **i_pi_gra.ini:** A file containing the configuration information related to the GRA setup at the time of the measurement
- **.RSC:** A data file containing all of the RSC measurements for a section of core. Data include: offset, L*, a*, b*, hue, chroma, x, y and z tristimulus, and sample time
- **rsc.csv:** a summary file containing offset (cm), sensor temperature, dark pixel count, bin interval, the wavelength range measured, the integration time in microseconds, and the raw data values in each bin.

Magnetic Susceptibility Files

- **i_pi_ms.ini**: A file containing the configuration information related to the MS point sensor at the time of the measurement.
- **.MSPOINT**: A data file containing all of the magnetic susceptibility point measurements for a section of core. Data include offset, magnetic susceptibility, and a time stamp. The file also includes the range and units and serial number of the magnetic susceptibility meter used.
- **mspoint.csv**: a summary .csv file containing the mean magnetic susceptibility values for each measurement along a section as well as the range and units used at the time of measurement

AR700 Laser Profile Files

- **i_pi_ar700.ini:** A file containing the configuration information related to the AR700 displacement laser at the time of the given measurement
- **.PROFILE:** a .file containing the section half ID and the observed core length measurement (cm).
- **profile.csv**: a summary .csv file containing the raw AR700 laser data for a section of core at 0.1mm steps. Data include offset, uncorrected height (mm), x-sect area (square mm), and benchmark (square cm).

Data Available in LORE

Each data set from the Section Half Multisensor Logger (SHMSL) is written to a file by section. The data for the RSC, MS-Point, and AR700 laser are each displayed under a different report in LORE. These reports are found under the Physical Properties heading and include Magnetic Susceptibility Point or Contact System (MSP) expanded report, Reflectance Spectroscopy and Colorimetry (RSC) expanded RSC, Reflectance Spectroscopy and Colorimetry (RSC) expanded PROFILE. The expanded reports include the linked original data files and more detailed information regarding the measurement.

Reflectance Spectroscopy and Colorimetry Standard Report

- **Exp:** expedition number
- **Site:** site number
- **Hole:** hole number
- **Core:** core number
- **Type:** type indicates the coring tool used to recover the core (typical types are F, H, R, X).
- **Sect:** section number
- **A/W:** archive (A) or working (W) section half.
- **Offset (cm):** position of the observation made, measured relative to the top of a section or section half.
- **Depth CSF-A (m):** location of the observation expressed relative to the top of a hole.
- **Depth [other] (m):** location of the observation expressed relative to the top of a hole. The location is presented in a scale selected by the science party or the report user.
- **Reflectance L*:** lightness of the sample expressed in the CIELAB color space.
- **Reflectance a*:** position of the color on the axis between red/magenta and green (negative = greater green character) in the CIELAB color space.
- **Reflectance b*:** Position of the color on the axis between yellow and blue (negative = greater blue character) in the CIELAB color space.
- **Tristimulus X:** x-component of the tristimulus value.
- **Tristimulus Y:** y-component of the tristimulus value.
- **Tristimulus Z:** z-component of the tristimulus value.
- **Normalized spectral data:** ASCII file with normalized spectral data.
- **Unnormalized spectral data:** ASCII file with unnormalized spectral data.
- **Timestamp (UTC):** point in time at which the observation or set of observations was made.
- **Instrument:** an abbreviation or mnemonic for the spectrophotometric sensing device used to make this observation (OOUSB4000V).
- **Instrument group:** abbreviation or mnemonic for the data collection device (logger) used to acquire this observation (SHMSL).
- **Text ID:** automatically generated unique database identifier for a sample, visible on printed labels.
- **Test No:** Unique number associated with the instrument measurement steps that produced these data.
- **Comments:** observer's notes about a measurement, the sample, or the measurement process.

Magnetic Susceptibility Point Standard Report

- **Exp:** expedition number
- **Site:** site number
- **Hole:** hole number
- **Core:** core number
- **Type:** type indicates the coring tool used to recover the core (typical types are F, H, R, X).
- **Sect:** section number
- **A/W:** archive (A) or working (W) section half.
- **Offset (cm):** position of the observation made, measured relative to the top of a section or section half.
- **Depth CSF-A (m):** location of the observation expressed relative to the top of a hole.
- **Depth [other] (m):** location of the observation expressed relative to the top of a hole. The location is presented in a scale selected by the science party or the report user.
- **Magnetic susceptibility (SI):** magnetic susceptibility of the sample, volume-corrected as follows:
    - MS2E sensor: magnetic susceptibility is reported in calibrated SI values, assuming the sample is a flat surface and has a depth greater than 10 mm
    - MS2F sensor: magnetic susceptibility is reported in instrument units, converted to SI values by a geometric factor of 2 with the sensor placed against a flat surface
    - MS2K sensor: magnetic susceptibility is reported in calibrated SI values, assuming the sample is a flat surface and has a depth greater than 10 mm

- **Timestamp (UTC):** point in time at which an observation or set of observations was made on the logger.
- **Instrument:** an abbreviation or mnemonic for the sensing device used to make this observation.
- **Instrument group:** abbreviation or mnemonic for the data collection device (logger) used to acquire this observation (SHMSL).
- **Text ID:** automatically generated unique database identifier for a sample, visible on printed labels.
- **Test No:** Unique number associated with the instrument measurement steps that produced these data.
- **Comments:** observer's notes about a measurement, the sample, or the measurement process.

Data Handling–WORK IN PROGRESS

C:\data\IN

- Section half L* a* b* and XYZ data
- MS2K check standard result
- MS2K (MSPOINT) data file
- QE Pro white check standard result
- Laser profile file

C:\AUX_DATA\PROFILE
Laser profile data in 0.1 mm steps
C:\AUX_DATA\RSC\CALIB
White and Dark calibration spectral data per wavelength (380–900 in 2 nm steps)
C:\AUX_DATA\RSC\CNTRL
Raw spectra and normalized (% color reflectance) spectral data per wavelength (380–900 in 2 nm steps) for the white check standard at the end of a run
C:\AUX_DATA\RSC\RUN
Raw spectra and normalized (% color reflectance) spectral data per wavelength (380–900 in 2 nm steps) for the measured section

Health, Safety, & Environment

Safety

- Keep extraneous items and body parts away from the moving platform, belt, and motor.
- The track system has a well-marked emergency stop button to halt the system if needed.
- Do not look directly into the spectrometer light source.
- Do not look directly into the laser light source.
- Do not attempt to work on the system while a measurement is in progress.
- Do not lean over or onto the track.
- Do not stack anything on the track.
- This analytical system does not require personal protective equipment.

Pollution Prevention

This procedure does not generate heat or gases and requires no containment equipment.

Waste Management

Dispose of soiled GLAD® Plastic Wrap in an approved waste container.

Maintenance/Troubleshooting

Common Issues

Problem	Possible Causes	Solution
MS sensor: baseline drift	Temperature variations	Ensure operating temperature is constant and preferably cool
		Make sure samples have equilibrated to room temperature
MS sensor: systematic offset from MS2C data	MS2K/MS2E zeroing environment not the same as that for the samples	Check that the zeroing height is roughly equivalent to the height of a sample, and that no large metal objects have been introduced to the area

MS sensor: reading fluctuations greater than ±1 least significant digit	External electrical noise	Check the operation area for: - large ferrous objects - heavy electrical machinery - radio frequency source devices
Track is "stuck"	Gantry flag has tripped the end-of-travel limit switch	Adjust gantry flag and run sample again
	Current limit on motors was exceeded	Check the motor for LED error indicators. Call PP tech or ET to reset motor controller
	Torque limit on motors was exceeded.	Call PP tech or ET to reset motor controller
	Power supply *voltage* too low	Call PP tech or ET to check power supply input voltage
RSC values nonsensical/too bright	Ambient *light* level too high	Reduce ambient light level/ensure integration sphere makes flat contact with sample
Laser sensor: no laser light/no laser range data	Configuration data lost	Press function button to restore factory default configuration
	Calibration data lost	Contact manufacturer
Laser sensor: LED flashes continuously at 1 Hz	Laser configuration incorrect	Call PP tech or ET to reset laser sensor

Scheduled Maintenance

Daily

- Keep contact sensors and laser window clean by wiping with a Kimwipe.
- If necessary, use isopropyl alcohol to remove soil from sensors and laser window.
- Do **not** use **any other solvent!**

Annually

- Remove the end covers on the linear actuators and check if the motor belts need tightening.
- Examine the cable management system for abraded cables or other indications of wear.
- Remove the top covers of the linear actuators and check the ball screws to see if they need cleaning or additional lubrication.

When Needed

- If the reflectance standard becomes nicked or soiled, it can be smoothed, flattened, and cleaned.

Communication and Control Setup

Data communication and control is USB based and managed via National Instrument's Measurement & Automation Explorer (NI-MAX). When you open NI-MAX and expand the Device and Interface section. The correct communications setup can be found at IMS Hardware Communications Setup.

Quality Assurance/Quality Control

Analytical Batch

The analytical batch is defined by the number of samples run between each spectrometer calibration. Each sample in the batch run with the current calibration is associated with that calibration data in the LIMS. If a calibration problem is discovered, all samples in the batch can be identified and rerun.

Accuracy

Magnetic Susceptibility

Measure a well-characterized magnetic susceptibility control sample and compare results with true value and/or whole-core track results.

Reflectance

Measure a second standard, standard reference material, or characterize a material in-house to use as a control. Measuring the BCRA-calibrated tiles ensures the desired accuracy is being maintained. This should be done periodically throughout each expedition.

Precision

Run samples or standard reference materials more than once (separate measurement runs) and calculate the standard deviation. This should be done every ~20-section halves allowing for a comparison between runs and estimation of uncertainty based on precision.

Vendor Information and Part Numbers

Reflectance Spectrometer

Vendor

Ocean Optics, Inc.
www.oceanoptics.com
info@OceanOptics.com
727-733-2447

Parts:

Spectrometer: PN QE PRO
Light source: PN HL-2000-FHSA or HL-2000-FHSA-LL
Spare bulb: PN HL-2000-B or HL-2000-LL-B
Reflectance standard: PN WS-1-SL

Magnetic Susceptibility Meter

Vendor:

Bartington Instruments, Ltd.
www.bartington.com
sales@bartington.com
44-1993-706565

Parts:

Meter: PN MS2
Sensor: PN MS2K

Laser Displacement Sensor

Vendor:

Acuity Laser Measurement
www.acuitylaser.com
702-616-6070

Parts:

Sensor: PN AR200

Related Documentation and Links

- AccuRange 700 laser displacement sensor data sheet: ar700-data-sheet.pdf
- Acuity Laser Measurement User Manual: ar700-users-manual.pdf
- Ocean Optics Halogen Light Source Operation Manual: hl2000fhsa.pdf
- Ocean Optics Fiber Optic Spectrometer Operation Manual: USB4000operatinginstructions.pdf
- Microscan MS-4 Ultra-Compact Imager data sheet: ms4spec.pdf
- Bartington MS2 Magnetic Susceptibility sensors data sheet: MS2 sensors D50020.pdf
- Bartington MS2 Magnetic Susceptibility system operation manual: OM0408 MS2.pdf
- "Environmental Magnetic Susceptibility Using the Bartington MS2 System": OM0409 J_Dearing_Handbook_iss7.pdf
- Hunt, R. W. (1998). *Measuring Colour* (3rd ed.). England: Fountain Press. ISBN 0-86343-387-1.. See pgs. 39–46 for the basis in human eye physiology of three-component color models, and 54–57 for chromaticity coordinates.
- Hunter Lab application note Vol 8. No. 1 http://www.hunterlab.com/appnotes/an04_96a.pdf

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