WRMSL and STMSL User Guide

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IMS graphic user interface for WRMSL and STMSL.

Introduction

The Whole-Round Multisensor Logger (WRMSL) and Special Task Multisensor Logger (STMSL) can simultaneously measure several parameters (e.g., density by gamma ray attenuation (GRA), magnetic susceptibility (MS), and P-wave velocity [PWL]) on core sections. These loggers are nondestructive to sediment fabric and the data generated can be used as proxies for other data. The data is used to facilitate core-core, core-log, and core-log-seismic integration and to construct composite sections. Optimal measurements require a completely filled core liner with minimal drilling disturbance.

The loggers are controlled by software designed to operate multiple instruments mounted on a track system. Logger sensors currently included on these logger systems include the following:

- Gamma ray attenuation (GRA) densitometer
- Magnetic susceptibility loop (MS)
- P-Wave velocity logger (PWL)

This User Guide provides an overview on how to use the IMS application to run the Whole Round and Special Task Multi-Sensor Loggers (WRMSL and STMSL). It assumes that the calibrations are complete and logging systems are ready to measure sections.

Launch the IMS Application

Launch IMS from the Windows Start menu or the desktop icon (*Figure 1*).

At launch, the program begins an initialization process:

- Testing instrument communications
- Reloading configuration values
- Homing the pusher arm of the motion control system.

After successful initialization, the **IMS Control** and **Instruments'** windows appear (*Figure 2*). The **IMS Control** window is on the left and the **Instruments'** windows on the right.
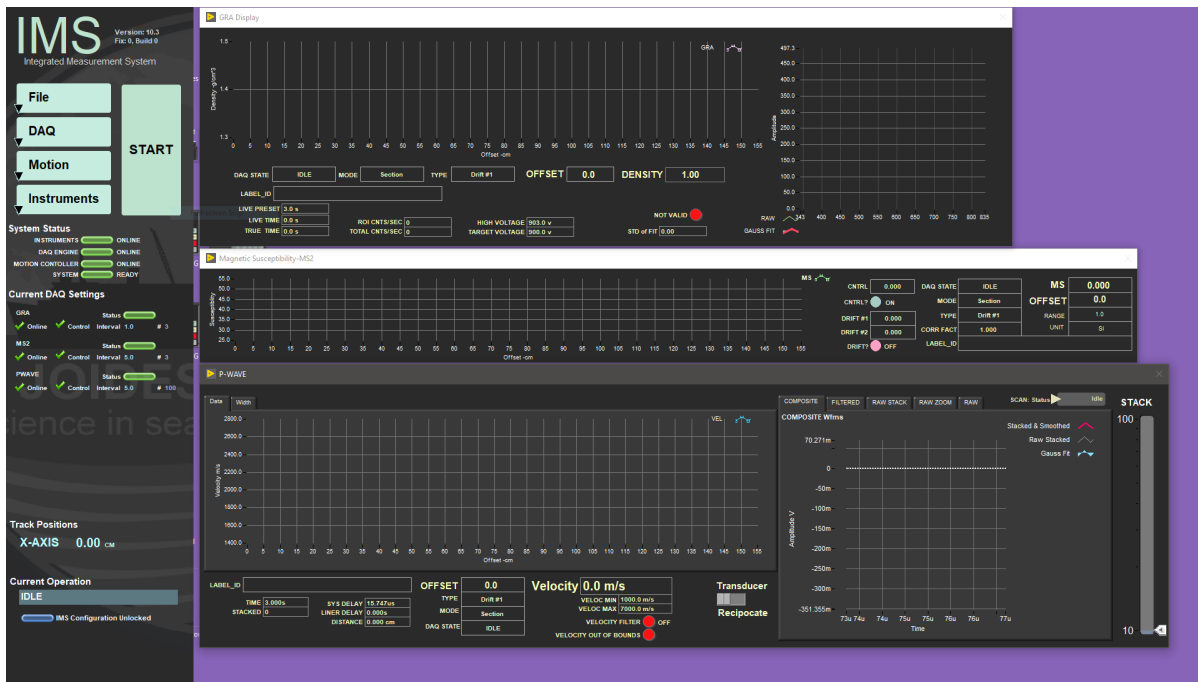

Figure 2. IMS Control and Instrument Windows.

Start a Measurement

1. Place the whole-round section on the track between the top-of-section sensor and the pusher arm (*Figure 3*).
2. Orient the section with the blue endcap towards the top-of-section sensor with working label UP.
3. Click **START** to open the **Section Information** window.
4. When the **Section Information** window opens (*Figure 4*), the cursor should be in the **SCAN** input box. If not, click in the box.
5. Hold the scanner over the label and center the dot-code with the red dot while pulling the trigger.
6. At the scanner beep, the Sample_ID and the LIMS_ID should correctly display on the screen. If not, re-scan.
7. Click **Measure**. The pusher arm moves forward and pushes the section until the blue endcap breaks the light beam of the sensor. The pusher then moves the section into the first measurement position and triggers the instruments to measure.
8. The move and measure process repeats until the pusher arm reaches its motion limits. The pusher retracts to the home position, ready to receive the next section, and the *Section Information* window opens to repeat the process.
9. Clicking **Cancel** button (and confirming) will cause loss of data for the sections which have not completed all of their measurements for a particular instrument.

Note: The label ID is used to query LIMS for the curated length. If not connected to the web servers, the length in the label bar code is used. Knowing the length is not critical, as the track will actually measure the length as part of its section handling process. If the top of the section is missing because a whole-round sample was removed, enter the length of the missing interval in the left hand area (Figure 4) so the sample position can be corrected. DO NOT place any type of spacer in front of the section to make up for the missing interval. Whole-rounds taken from the bottom of the section will not affect the measurement process.

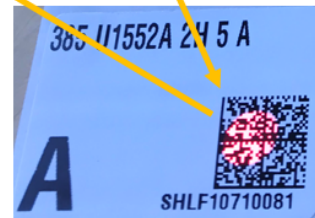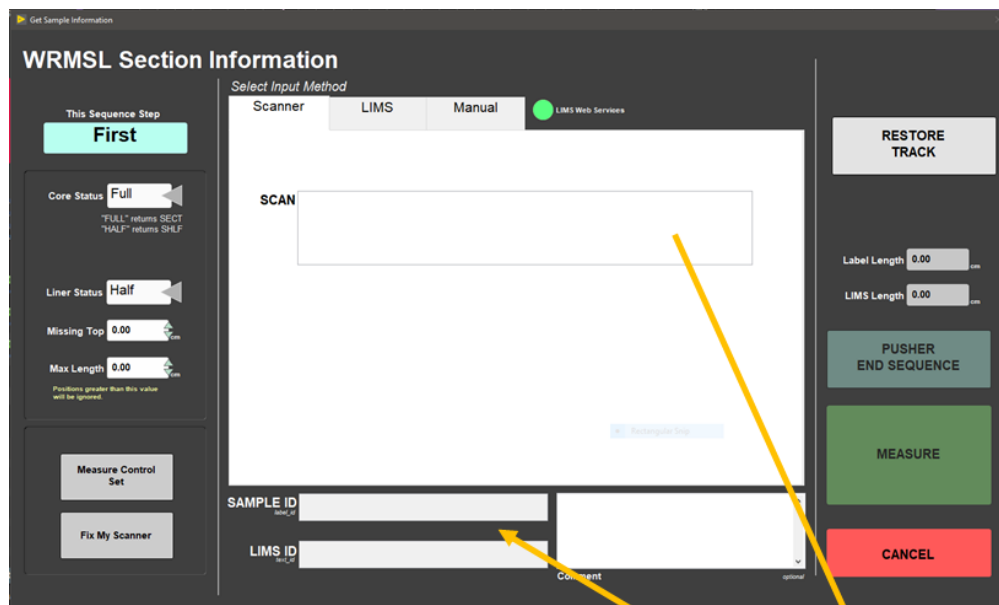*Figure 3. Blue end cap near the top-of-section sensor, clear end (bottom of section) touching the pusher.*

Figure 4. Section Information scanning window.
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Measurement Sequence

The WRMSL and STMSL are push tracks; each section pushes the previous section(s) through a set of instruments. Although it is possible to continuously process cores without a break, some of the instruments require a periodic background measurement to check and correct, if necessary, sensor drift. The track in the immediate area of the instruments must be free of cores for this background measurement.

By convention, we break the sequence of sections for background measurement between succeeding cores. To push the last section through we use a "pusher," which is a piece of core liner filled with DI water long enough to push the end of the last section through the last sensor on the track.

Therefore, the functional definition of a sequence is from the first section measured after the "pusher" (or the launch of IMS) and ends the next time the "pusher" is used. Generally, this corresponds to the first and last section of a core.

To run the "pusher", click the **PUSHER END SEQUENCE** *(Figure 5)* button located in the *Section Information* window.
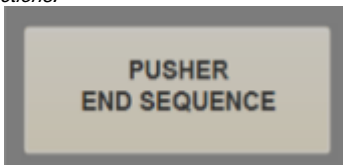*To configure or calibrate the track, read the following sections.*

Figure 5. End of Sequence Pusher button.

Preparing IMS

Perform these steps prior to starting measurements on a new site. This does not cover physical setup of the hardware or initial deployment of the software.

A Quick Introduction to the IMS Program Structure

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

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

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

The WRMSL and STMSL systems are built with three INST modules (Gamma Ray Attenuation, P-wave, and Magnetic Susceptibility), one MOTION module, and one DAQ Engine module. Each module manages a configuration file that opens the IMS program at the same state it was when previously closed and provides utilities for user edit or modification of the configuration data and calibration routines.

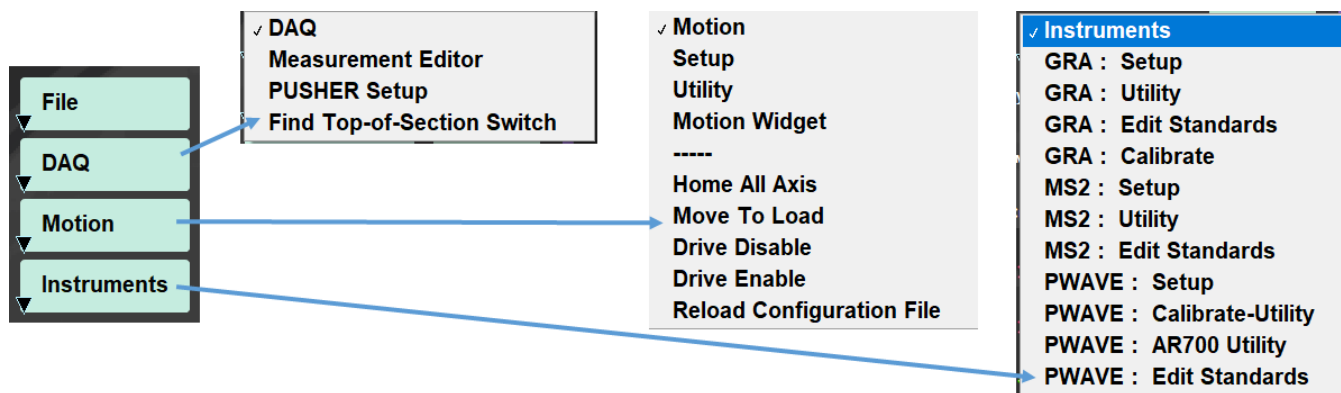The five buttons on the IMS Control window provide access to utilities/editors via drop-down menus (*Figure 6*).

Figure 6. Five buttons from IMS Control window. Menus within each button.

Initial Instrument Setup

Click on the **Instruments** menu to select each instrument's **Setup Editor** *(Figure 7, 8, 9)*. In general, the values shown in the **Setup Editor** rarely need to be changed. **Regardless, check these values at the beginning of every expedition.** Note: Do not change these values without reading the vendor's documentation.
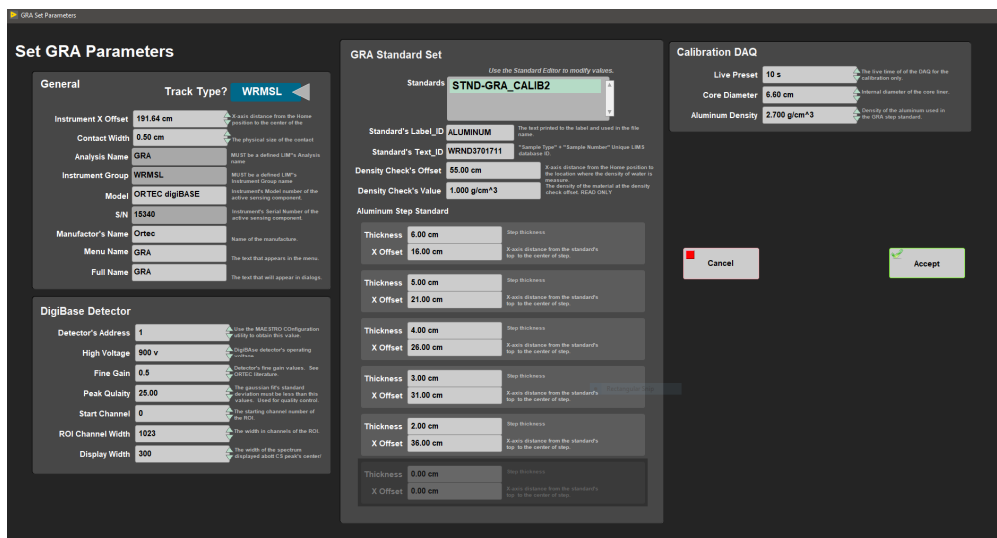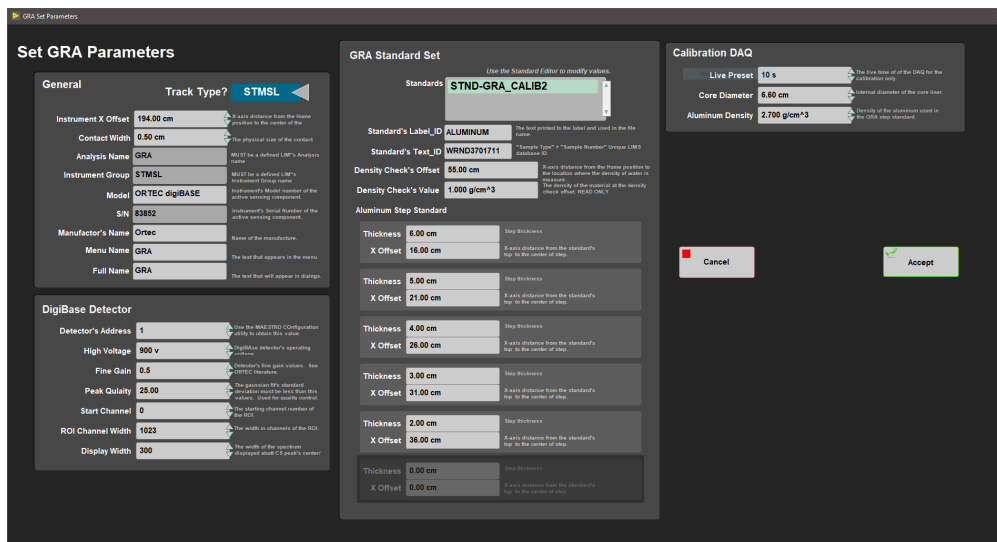
GRA: Setup

Figure 7. GRA Setup Editor.

General Information

Instrument X Offset: Offset along the X-axis (push direction) from the home switch to the center of the gamma ray source collimator. Set at 191.64 cm.

Sensor Width: Width along the core axis that influences the measured value; used in calculating edge clearance (if enabled).

Analysis Name: Defined JR_LIMS analysis.

Instrument Group: Defined JR_LIMS instrument group component.

Model: Instrument model number/name of the sensing component.

S/N: Instrument serial number of the sensing component.

Manufactor's Name: Name of the manufacturer of the sensing component of the instrument.

Menu Name: Name used in the IMS menus

Full Name: Name used in IMS Reports and displays.

Instrument-Specific Information (digiBase Detector)

Detector Address: Instrument unique addressing ID set with the MAESTRO software provided by the vendor.

High Voltage: High voltage value applied to the photomultiplier tube.

Fine Gain: Used in conjunction with coarse gain (jumper setting in the digiBase) to amplify the signal. Affects the peak's position and width in the reported channels.

Peak Quality: Used to determine the quality of the Gaussian peak fit over the Cs peak (empirically determined).

Start Channel: Start channel of the ROI (region-of-interest).

ROI Channel Width: Number of channels for the ROI.

Display Width: Width of display about the peak center during acquisition.

MS2: Setup

Figure 8. MS Parameters Setup window

General Information

Instrument X Offset: Offset along the X-axis (push direction) from the home switch to the center of the MS loop. Set at 221.64 cm.
Contact Width: Width along the core axis that influences the measured value; used when calculating edge clearance (if enabled).
Units: Set to SI; must match the physical MS meter setting.
Range: Set to 1.0; must match the physical MS meter setting.
Analysis Name: Defined JR_LIMS analysis.
Instrument Group: Defined JR_LIMS instrument group component.
Meter Model: Instrument model number/name of the sensing component.
Meter S/N: Instrument serial number of the sensing component.

Sensor Model: Sensor's model numberof the active component

Sensor S/N: Sensor's serial number of the active component
Manufactor's Name: Name of the manufacturer of the sensing component of the instrument.
Menu Name: Name used in the IMS menus.
Full Name: Name used in IMS Reports and displays.

Check Loop: If ON, check for the presence of an object within the loop before zeroing the meter.

Standard Information

Correction Factor: The vendor provides this value.

- For standard-frequency loops (80 and 90 mm, 565 Hz), this value is 1.000.
- For 10% high loops (80 mm only, 621 Hz), this value is 0.908.
- For 10% low loops (80 mm only, 513 Hz), this value is 1.099.
- For 20% low loops (90 mm only, 452 Hz), this value is 1.174.

PWAVE: Setup

Figure 9. P-Wave Logger Setup window.

General Information

Instrument X Offset: Offset along the X-axis (push direction) from the home switch to the center of the PWL transducers. Set at 251.64 cm.
Contact Width: Width along the core axis that influences the measured value used when calculating edge clearance (if enabled).
Analysis Name: Defined LIMS analysis value.
Instrument Group: Defined LIMS instrument group component.
Model: Instrument model number/name of the sensing component.
S/N: Instrument serial number of the sensing component.
Manufactor's Name: Name of the manufacturer of the sensing component of the instrument
Menu Name: Name used in the IMS menus.
Full Name: Name used in IMS Reports and displays.

Liner Correction

Liner Thickness: Thickness of the core liner (2.58 mm).
Liner Velocity: Acoustic velocity of the core liner (butyrate). Should be 2100 ± 40 m/s.
Liner Delay: Calculated value equivalent to the liner thickness divided by the liner velocity.

Velocity Filter

The filter purpose is to remove extremely low or high velocities.
Velocity Filter: Enable or disable filtering.
Min Velocity Filter: Velocities below this value are not reported.
Max Velocity Filter: Velocities above this value are not reported.

Stacking

Waveform Stack: The number of waveforms stacked and averaged. **Minimum 50**.

Instrument Calibration

To access an instrument's calibration procedure, click on the **Instruments** menu and select the instrument's calibration function. Good practice is to calibrate the instrument prior to receiving cores at each new site.

GRA: Calibration

The GRA standard is an aluminum bar inserted into a core liner, which is filled with DI water and sealed. The aluminum bar is machined into discrete steps that provide composite density values for creating a calibration curve of counts vs. density. Before calibration, use the *Standard Editor* to enter offset and thickness of each step's center. Under the **Instrument** menu, select **GRA: Edit Standards** to view the **GRA Standard Edit** window (*Figure 10*). This only has to be done once, as the values are retained in the configuration file. It is important to check the offset values against the standard because the standard can shift within the liner.

Figure 10. GRA Standard Edits window.

Define two standard sets in the *Standard Editor:* **Aluminum Steps** (density) and **Density Check** (water).

- **Aluminum Steps** : The offset (measured from liner top to center of step) and the thickness of each step are the values shown in the diagram above. Define the offsets in the order they are measured on the track.
- **Density Check**: (1) define an offset past the aluminum standard and (2) enter water density (1 g/cm^3) as the given value. The water measurement is used to validate the density calibration.

GRA Calibration Process

1. Place the standard on the track with the Aluminum in the standard toward the GRA sensor (water towards the pusher).
2. In the **Instrument** menu, select **GRA: Calibration .**
3. The pusher engages the standard and pushes it until it trips the top-of-section sensor, then moves the standard to all of the defined offsets, taking a measurement at each position. After measuring the last step, the pusher moves the standard to the offset for the water measurement.
4. After the standard is measured, the calibration data displays in the graph along with the calibration line *(Figure 11)*.
5. Using the new calibration data, a density value for water is calculated and compared to the known value of 1 gm/cm3. The curve fit provides the coefficients used in the density calculations, ln I = B(d) + C; where = Compton attenuation coefficient, d = sample diameter, I_0 = gamma ray source intensity, and I = measured intensity of gamma rays passing through the sample. Allowing bulk density to calculated by using, = 1/ (d) × ln (I_0/I).
6. Choose to apply the calibration to all future measurements by clicking **AcceptCalibratioin** or click **Cancel Calibration** to restore the previous values.
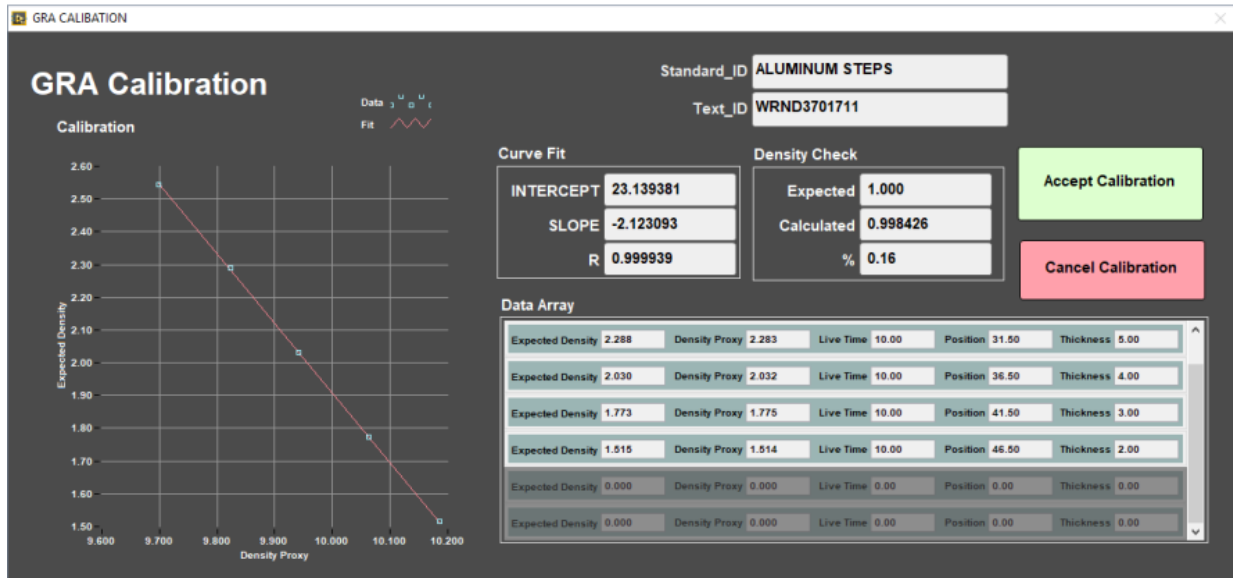
Figure 11. GRA Calibration window.

PWL Calibration

PWL Calibration process

1. In the **Instrument** menu, select **PWAVE: Calibrate-Utility** and the **PWAVE Calibration Utility** window will open (*Figure 12*).
2. Follow the steps on the right side of the **PWAVE Calibration Utility** window. Note: **Liner Delay correction** is excluded when using the Aluminum standard.
3. Place the aluminum standard between the transducers. Close the transducers. Aluminum standard width is 76.25 mm. Select **Laser Offset Correction**. Confirm that the **Distance** matches the standard's width.
4. Enter the Aluminum Standard velocity. 6295.00 m/s. Select **Determine System Delay**. Verify that the **Velocity** matches the Aluminum Standard's velocity.
5. Open transducers. Remove Aluminum Standard.
6. Position the Water Standard between transducers. Close transducers. Turn on **Liner Delay**. Enter the water's temperature (Water at room Temperature) under **Temperature**. Select Auto H2O Velocity Update. Liner Thickness is 2.58 mm. Click **Determine Liner Velocity**.
7. **Accept Changes**.
8. Open transducers and remove the water standard.

Figure 12. P-Wave Calibration Utility.

Adjusting Measurement Parameters for the Waveform

Use the Stack slider in the **PWAVE CalibrationUtility** window to adjust the measurement parameters to obtain a better waveform (*Figure 12*). These parameters may need to be adjusted if the section material has changed.

Stack: Sets the number of waveforms to average to increase the signal-to-noise ratio. Note: stack should not be any lower than 50.

Correction for acoustic velocity through water

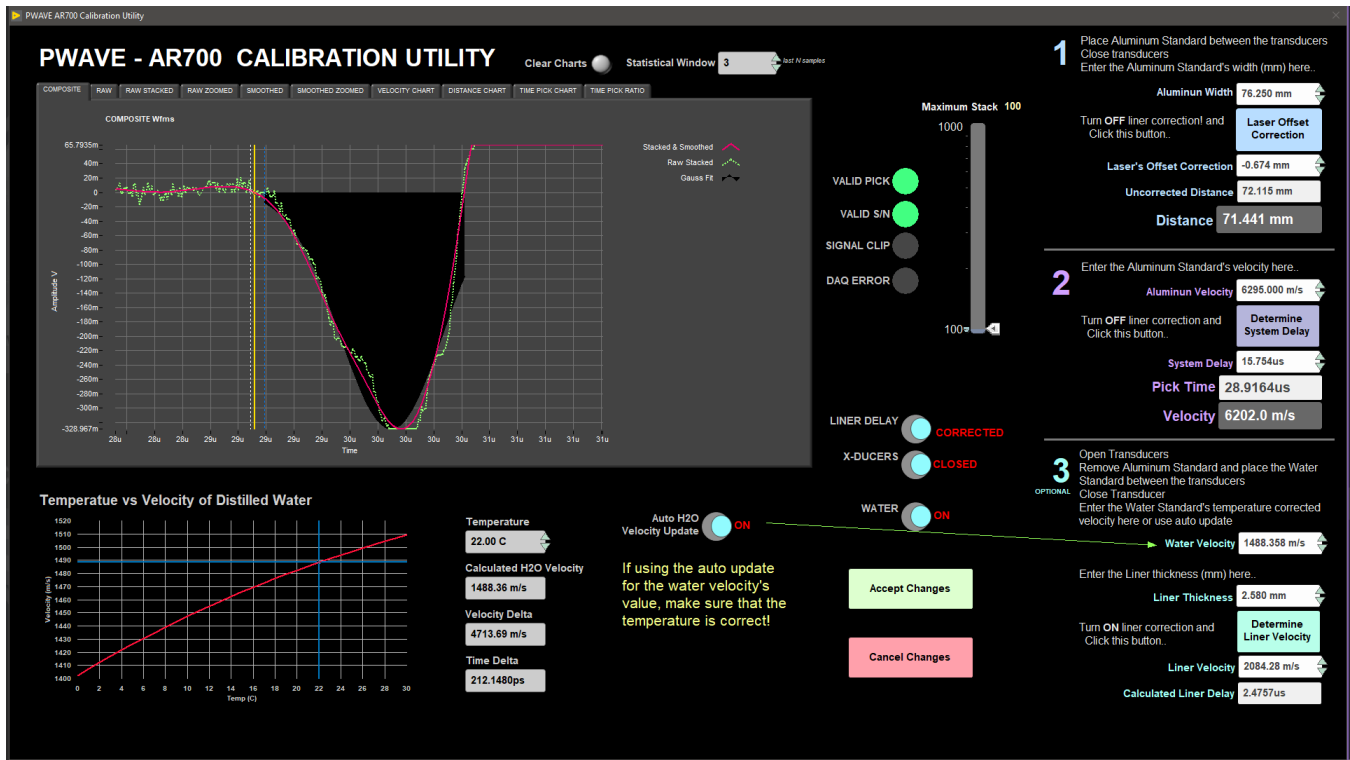In the calibration process, the PWL uses the P-wave speed through water for deriving the velocity through the CAB core liner. The acoustic velocity through distilled water is based on the equation of Marczak (1997);

$Vp\_water = 1402.385 + 5.038813T - 5.799136E\text{-}02T^2 + 3.287156E\text{-}04T^3 - 1.398845E\text{-}06T^4 + 2.787860E\text{-}09T^5$

The National Physical Laboratory (NPL) gives a brief summary of this and other equations. Marczak's equation fits a 5th order polynomial through 3 published sound-wave-speed-in-water datasets. There are other equations with many more coefficients and some that also account for variations in pressure (or depth) and salinity. Given that we operate at 1 atm and use distilled water, there is no need for more complex equations. Variations from one equation to another and to fits of the observations tend to have quoted differences and standard errors less than 0.02 m/s. Even given errors of about 0.2°C in temperature measurements, we should still be good to better than 1 m/s.

References

W. Marczak (1997), Water as a standard in the measurements of speed of sound in liquids. *J. Acoust. Soc. Am. 102*, 2776-2779.

National Physical Laboratory links with information, references, and online Vp calculators for water:
http://resource.npl.co.uk/acoustics/techguides/soundpurewater/content.html#BILANIUK
http://resource.npl.co.uk/acoustics/techguides/soundpurewater/marczak.html <- Calculator for Marczak's equation

Quality Assurance/Quality Control

Analytical Batch

The analytical batch is defined by the number of samples run between each sensor calibration. Calibrations and calibration timestamps are accessible through each sensor Instrument Interface screen.

Calibration

GRA

Calibration assumes a two-phase system model for sediments and rocks: minerals and interstitial water. Aluminum has an attenuation coefficient similar to common minerals and is used as the mineral phase standard. Pure water is used as the interstitial water phase standard. A piece of core liner containing a telescoping aluminum rod (5 varying thicknesses) and filled with distilled water is measured as a calibration standard. The largest diameter aluminum rod has a porosity of 0% and a bulk density of 2.7 g/cm^3. Water has a porosity of 100% and density of 1.00 g/cm^3. Intermediate elements verify the linearity of the log density relationship and the alignment of core and sensor. A linear least-squares fit through 3–5 calibration points yields the calibration coefficient. Total measured counts are divided by the counting time to normalize coefficients to counts per second.

MSL

Absolute susceptibility: Sample cubes are measured using the Kappabridge and results compared with corresponding readings from the Bartington instrument. Empirical correction factors have been calculated.

PWL

Pulse detection settings are checked by IODP technicians on a regular basis and do not require adjustments by the user. Pulse time is a constant which is included in the total time measured as a result of the threshold peak detection procedure used. This value changes depending on the wiring of the system. The user does not need to make adjustments to this factor. Transducer displacement and traveltime delay calibrations are performed using an Aluminum standard of known velocity and thickness and distilled water at room temperature.

Accuracy

GRA

GRA accuracy is limited by the assumption that the measured material has the same attenuation coefficient as the calibration standards used. For general sediment-water mixtures, this should be the case and error should be <5%.

MSL

Accuracy of the susceptibility meter and sensor loop is 5% (according to Bartington).

PWL

PWL accuracy can be evaluated by measuring pure water at varying and exactly known temperatures. Past experience shows that for a properly calibrated system and good acoustic coupling, the disagreement with published sonic velocity values is less than ±20 m/s.

Precision

GRA

GRA precision is proportional to the square root of the counts measured, as gamma ray emission is subject to Poisson statistics. Measurements with the system have typical count rates of 10,000 (dense rock) to 20,000 (soft mud). If measured for 4 s, statistical error is <40,000 ± 200 cps, or 0.5%.

MSL

MSL precision is 2 x 10^{-6} SI. Susceptibility values in natural marine sediment samples over an interval of only a few meters (Milankovitch or millennial scale cyclicity) can range from a few tens to several thousands of 10^{-6} SI units. Typically, variations are 2–3 orders of magnitude greater than the precision, making magnetic susceptibility one of the most precise proxies for stratigraphic changes.

PWL

Measurements on standard materials such as water and calibration standards are repeatable within ±1 km/s.

Motion Control

The track's push system consists of a NSK linear actuator driven by Schneider Electric stepping motor: MDrive23. The MDrive 23 is a high torque 1.8 º integrated motor-driver-controller that connects to the PC via USB-RS485 cable. An IODP-built interface board (*Figure 13*) provides power control, emergency, limit/home switches, specialty I/O connections, and status lights. With the exception of a built in "Home" function, the MDive's IMS motion software module provides direct control of the motor's functions. The motor can be installed directly out of the box without any special preparation.

At IMS launch, a series of commands are sent to place the motor into a known state and then to search for the home switch and zero the encoder's position out put.

It is assumed that the hardware has been installed correctly and powered up. On the very first launch, a set of default values will be loaded that should get the track safely running. BUT BE READY to kill the motion using the Emergency-Stop button. Generally, a run-off is caused by incorrect scaling factors for the gear ratio, screw pitch, and or encoder counts per revolution. Setting these up correctly usually correct the issue.

Note: If the motor fails to initialize or locate the home switch, then an error will be reported. At this point, access the motion control utilities for trouble shooting. The START button will not appear and measurements are prevented.

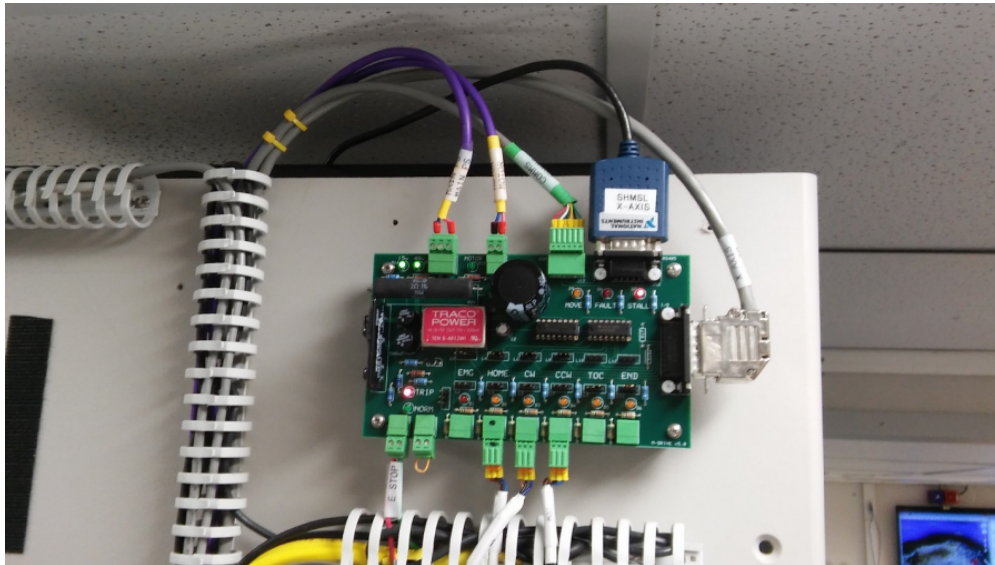*Figure 13. Interface board for motion control.*

MDrive Setup

Select **Setup** from the **Motion** menu bar for **MDrive Motion control** window (*Figure 14*).
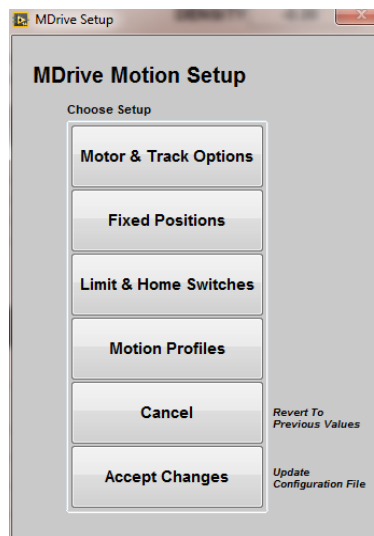

Figure 14. MDrive Motion Control window.

Track Options

Click **Motor and Track Options** to open the **Track Motor Setup** (*Figure 15*). Here is where the relationship between motor revolutions and linear motion of the track is defined.

Select Axis: In the case of the WRMSL and STMSL, it is always X.

Encoder Pulses/rev: Defined by the manufacturer of the MDrive as 2048.

Screw Pitch: Defined by the NSK actuator manufacturer as 2 cm/screw revolution.

Gear Ratio: In the current configuration, this is 4 to 1 but it can be changed.

Direction: The WRMSL is a right-hand track and a CCW rotation moves the pusher in a positive (from home to end of track) direction. The STMSL is a left-hand track so this value is set to CW. Now both are set as CCW.

Click **Motion Utility** to test these settings.
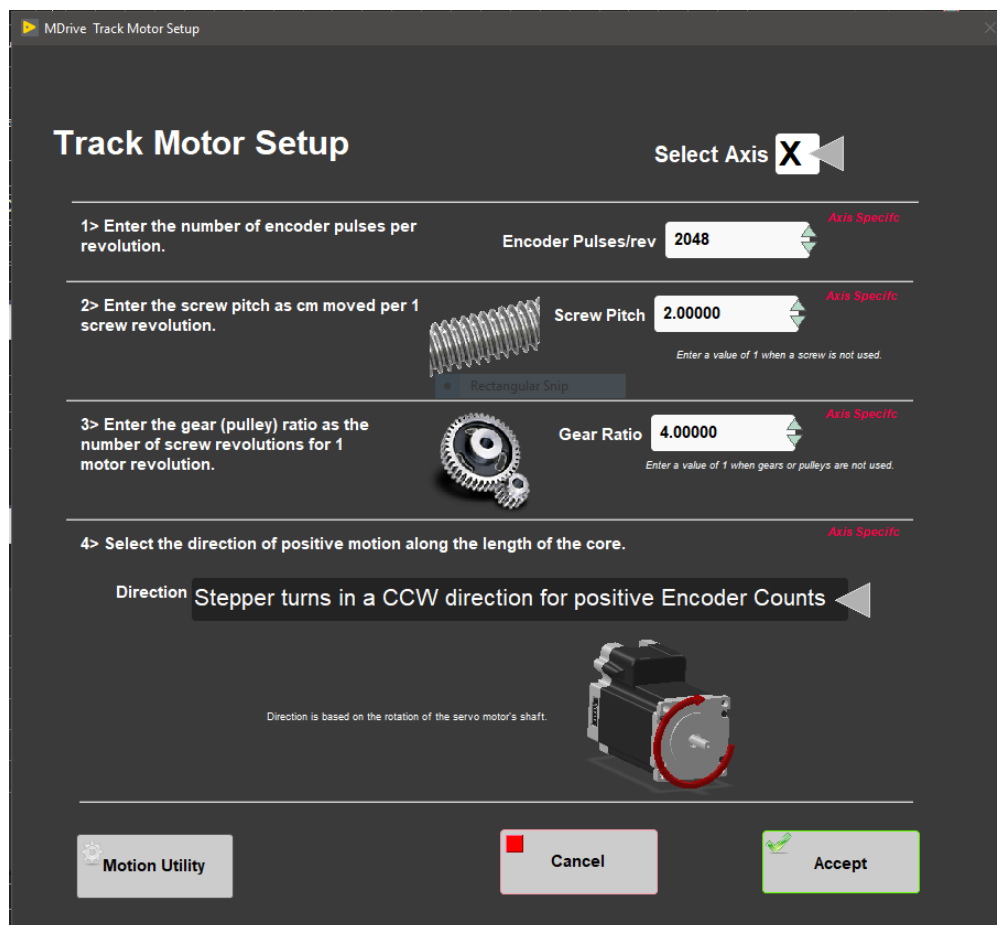Click **Accept** to save the values or **Cancel** to return to the previous values.

Figure 15. Track Motor Setup window.

Fixed Positions

Click **Fixed Positions** to open the Track Configuration window (*Figure 16*). In this window, define fixed track locations (*Figure 17*) used by IMS and enable the top of section (TOS) switch and the runout switch (ROS).
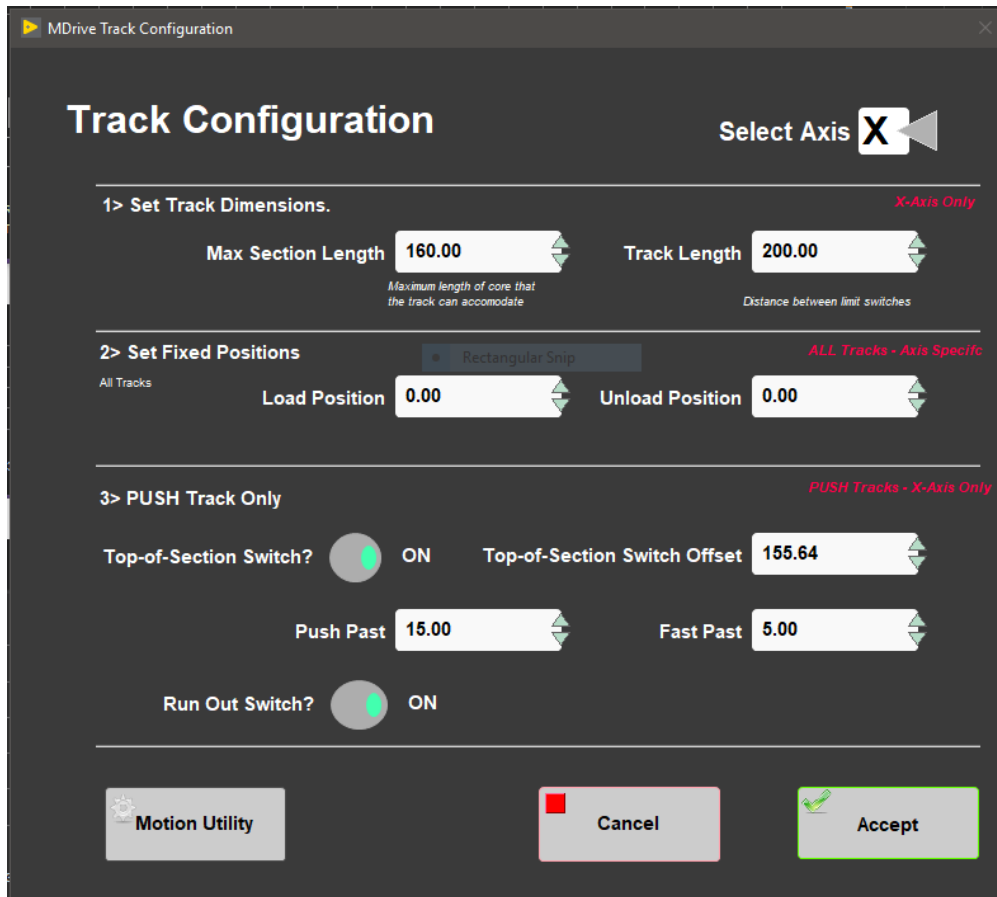
Figure 16. Track Configuration window.

Select Axis: In the case of the WRMSL and STMSL it is always X.

Max Section Length: Maximum length of section that can be placed in the track and still expect the track to handle and measure correctly. This value is set to 160 cm.

Track length: Distance in cm between the limit switches. Use the motion Utility to determine this value. This value is set to 200 cm.

Load and Unload: Offset in cm where the track will stop when ready to load a new section of core. In the case of both the WRMSL and STMSL, this the same as the home switch.

Top-of-Section Switch: THIS MUST ALWAYS BE enabled! The IMS software uses this switch to determine the physical length of the section, which is critical to the calculations that move the cores through the sensor. Without a TOS switch, the track is not functional.

Top-of-Section Switch Offset: Distance in cm from the home switch to the TOS switch. There is a utility under the **DAQ** > **Find Top-of-Section Switch** menu that will determine this value based on the current **DAQ Move** motion parameters (discussed in this section). ANY change in the motion profile requires that this utility be run because the final position (where the pusher bar stops) changes.

Push Past: The offset from the TOS where the pusher-should stop. This value set the maximum measurement interval but MUST be several centimeters less than the distance from the TOS to the limit switch.

Fast Past: Distance the pusher will move at a higher speed before slowing down to find the TOS switch. This value MUST be several centimeters less than the distance from the TOS to the maximum section length with the pusher arm in the home position.

Run Out Switch: Switch at the end of the track that when enabled pauses the motion, preventing the section from being pushed onto the floor.

Click **Motion Utility** to test these settings. Click **Accept** to save the values or **Cancel** to return to the previous values.
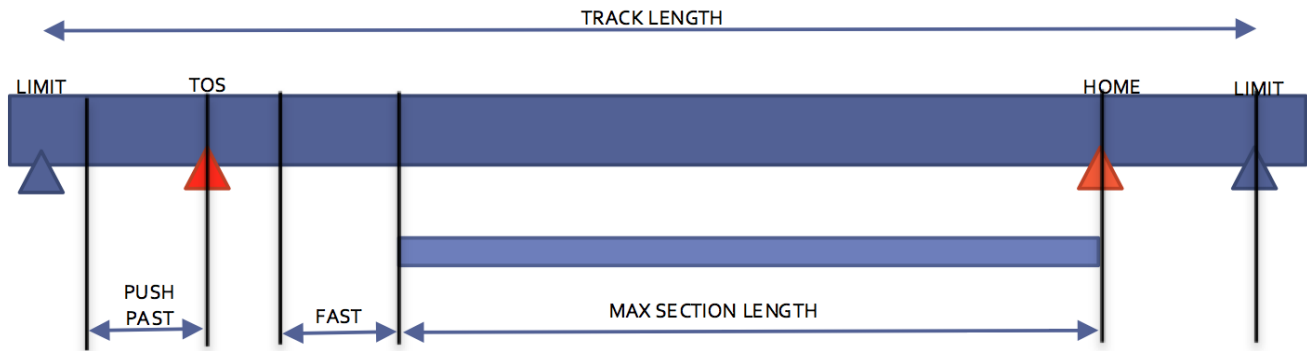
Figure 17. Schematic of fixed positions.

Limit and Home Switches

Click **Limit and Home Switches** to open Limit & Home Switches window *(Figure 18)*.
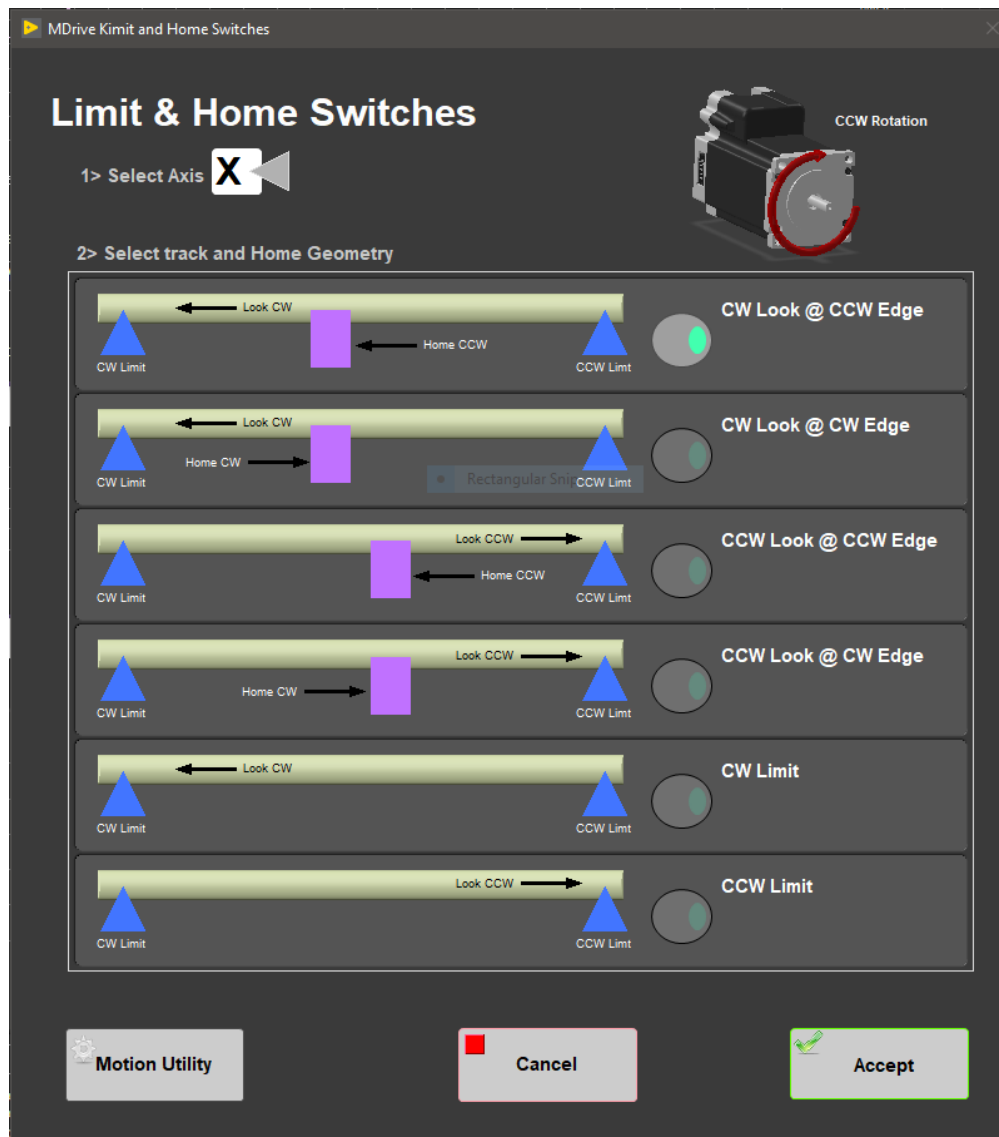
Figure 18. Limit & Home Switches window.

Select Axis: In the case of the WRMSL and STMSL it is always X.

The MDrive can be used with either a dedicated Home switch or a limit switch as a home switch. These tracks use the dedicated Home switch. Select the appropriate setup for the track in use. Use the Utilities to execute the Home command and verify the correct setting. If the home switch position of detection edge changes, verify the instrument offsets and relocate the TOS switch are still correct. Setting the edge from CW to CCW will change the offset by a least 1 cm.

Click **Motion Utility** to test these settings.
Click **Accept** to save the values or **Cancel** to return to the previous values.

Motion Profiles

Click **Motion Profiles** to open **Motion Profiles** window (*Figure 19*). The profiles are used to set the speed and acceleration profiles used by the track.

Setting the correct values for the motion profile takes a little experimentation to make the track run efficiently and safely.

Figure 19. Motion Profile window.

DAQ Move: This profile controls moves between measurement positions. Set this to a reasonable speed with gradual acceleration so the pusher does not bump the sections.

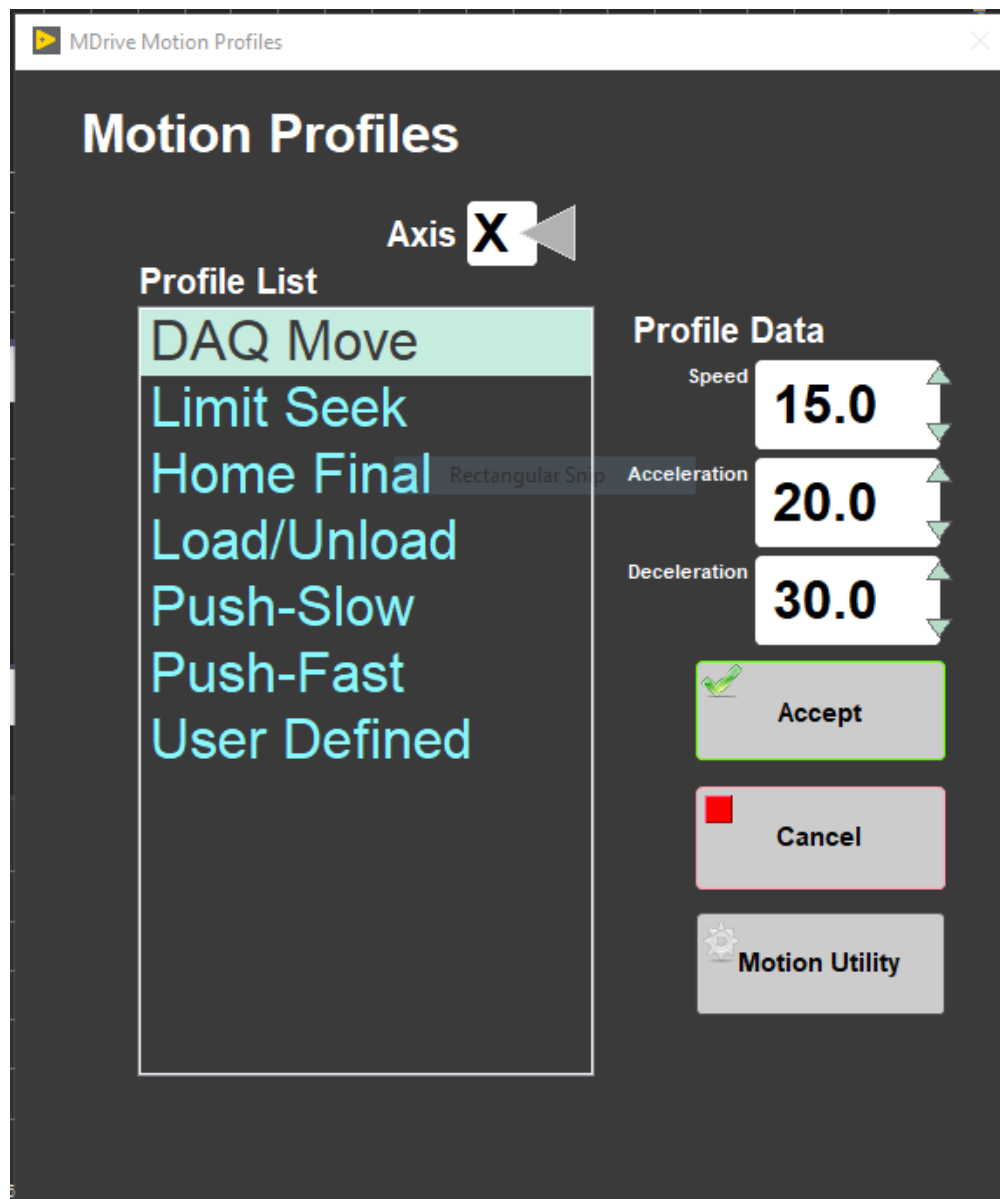**Limit Seek**: This profile finds the limit switch locations. Do not exceed 5 cm/sec and use a large deceleration value or the core could overrun the limit switch and hit the mechanical stop.

Home Final: This profile finds the final location of the home switch. Do not exceed 1 cm/sec and use a large deceleration value.

Load/Unload: This profile moves the pusher back to the load position. Set this to a reasonable but high speed with gradual acceleration and deceleration values. Setting this too slow will waste time, but keep safety in mind.

Push-Slow: This profile allows the pusher to move the new section into contact with the previous section and to locate the top of section. Use a speed a little less than the **DAQ Move** speed with slightly lower acceleration and deceleration values.

Push-Fast: This profile allows the pusher to move quickly to the TOS switch. Typically, it is set the same as the **Load/Unload** values.

User Define: This profile is used for testing only in the **Motion Utilities** program.

Click **Motion Utility** to test these settings.
Click **Accept** to save the values or **Cancel** to return to the previous values.

LIMS Integration

Uploading Data To LIMS

To up load the images into the database MegaUploadaTron must be running in background. If not already started do the following:

1. On the desktop click the **MUT** icon on the bottom task bar (*Figure 20*) and login.
2. The **LIMS Uploader** window will appear (*Figure 21*).
3. Check **Automatic Upload** in the lower right hand corner and then click the minimize window and MUT will run in background.
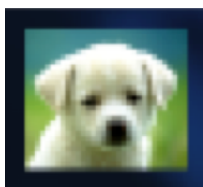
Figure 20. MUT icon
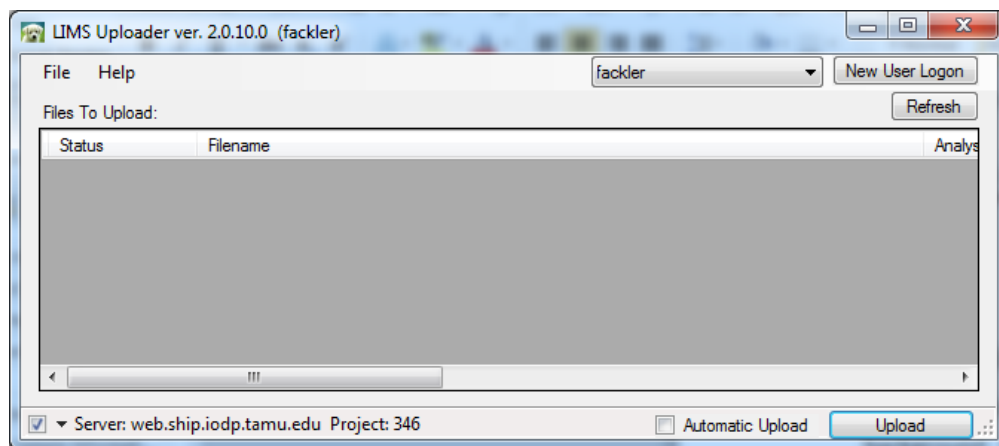
Figure 21. LIMS Uploader window.

Data File Formats

The files generated by the whole round tracks (WRMSL and STMSL) include:

GRA Files

- **i_pi_gra.ini:** A file containing the configuration information related to the GRA setup at the time of the measurement
- **.GRA:** A data file containing all of the GRA raw measurements for a section of core. Data include: offset, bulk density, total counts per second and a time stamp.

Magnetic Susceptibility Files

- **i_pi_ms.ini**: A file containing the configuration information related to the MS loop at the time of the measurement.
- **.MS:** A data file containing all of the magnetic susceptibility 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.
- *_MS.csv: A .csv file, saved in C:/Aux_Data, 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.

P-Wave Files

- **i_pi_pwave.ini:** A file containing the configuration information related to the PWAVE instrument at the time of the given measurement
- **.PWAVE_L:** A data file containing the pwave logger measurements for a section of core. Data include: offset, distance in the caliper, travel time, and the velocity.
- *_PWAVE-L.csv: A .csv file containing the raw waveform data for a section of core as well as the offset, velocity, travel time, distance between calipers, liner thickness, system delay, a time stamp, and laser distance.
  - System Delay is the sum of delays and includes: Travel time across the transducer caps, and electronic delays in the pulser and the digitizer.

Data Available in LORE

Each data set from the Whole Round Logger tracks (WRMSL/STMSL) is written to a file by section. The data for the GRA, MS Loop, and P-wave are each displayed under a different report in LORE. These reports are found under the Physical Properties heading and include Gamma Ray Attenuation Bulk Density (GRA). Magnetic Susceptibility Pass-through (MS), and P-wave Velocity Logger System (PWL). The expanded reports include the linked original data files and more detailed information regarding the measurement.

GRA 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.
- **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.
- **Bulk density (GRA) (g/cm^3):** computed bulk density of sample.
- **Timestamp (UTC):** point in time at which an observation or set of observations was made on the logger.
- **Instrument:** abbreviation or mnemonic for the GRA sensing device used to make this observation (GRA1 or GRA2).
- **Instrument group:** abbreviation or mnemonic for the data collection device (logger) used to acquire this observation (WRMSL or STMSL).
- **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 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 (instr. units):** magnetic susceptibility of the sample, not volume corrected.
- **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 MS sensing device used to make this observation (MSLP_477 or MSLP_476).
- **Instrument group:** abbreviation or mnemonic for the data collection device (logger) used to acquire this observation (WRMSL or STMSL).
- **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.

P-Wave 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.
- **P-wave velocity xy (m/s):** velocity of pressure wave through sample in the x-y plane (dependent on orientation of the material).
- **Caliper separation (mm):** displacement between the faces of the transducers in contact with the sample.
- **Sonic traveltime (μs):** traveltime of the sonic wave from transducer to transducer through the sample.
- **Timestamp (UTC):** point in time at which the observation or set of observations was made on the logger.
- **Instrument:** an abbreviation or mnemonic for the P-wave sensing device used to make this observation (PWL).
- **Instrument group:** abbreviation or mnemonic for the data collection device (logger) used to acquire this observation (WRMSL).
- **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.

Credits

This manual is edited from various versions and has several authors including but not limited to David Houpt, Ty Cobb, Sandra Herrmann, Beth Novak, Sherry Frazier.

Appendices

Appendix 1: P-wave: Waveform Acquisition and First Arrival Detection

Signal Processing

Figure 22 helps summarize the following signal processing discussion.
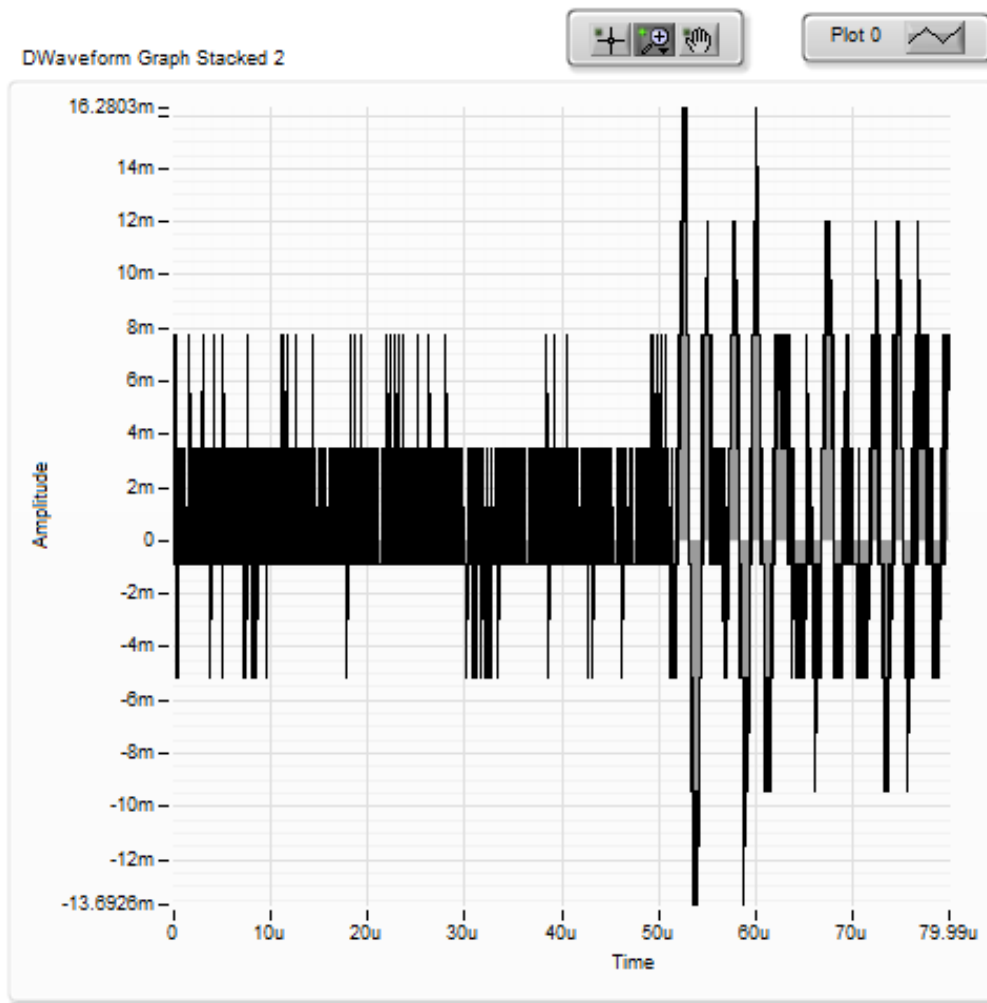
Acquisition and Ensemble Averaging

Figure 22. Shipboard P-wave signal.

In *Figure 22* the received waveform is 60 µsec long and digitized at 10 nsec intervals. The first 10 µsec of the waveform is replaced with zeros to remove a large spike that occurs at the beginning of the outgoing pulse. We believe that this noise is generated by the electrical "cross-talk" within the pulser-receiver.

A Butterworth Bandpass filter is applied to the waveform to reject frequencies less than 0.4 MHz and above 1.0 MHZ. The results of this filtering is stacked, summed, and averaged (ensemble averaging). The size of the stack is pre-set by the user to a value between 10 and 100. Even with this initial filtering and ensemble averaging, the resulting signal can still contain significant noise generated by the shipboard environment. *Figure 22* is typical of the signal quality.

Picking the 1st Arrival

Attempts to use a cross-correlation method (popular in seismic analysis) have not been successfully applied to IODP data. Coefficients developed for one type of lithology, fail when the lithology changes. Therefore, we depend on a threshold-crossing process to determine first arrival time. The weakness of this method is that any high-amplitude noise can cause a false, early pick.

To increase the likelihood of a correct pick, the P-wave Logger software on the WRMSL and STMSL uses a series of mathematical and data manipulation techniques to suppress the noise relative to the peak of the first arrival. Another goal is to eliminate the constant adjustment of the threshold value as the amplitude of the waveform changes due to variation in signal attenuation along the core. As the P-wave Logger is an automated system, constant supervision and adjustment is not practical.

Signal-to-Noise Ratio (SNR) Enhancement

Methods employed are partly based on Dr. Tom O'Haver's 2006 publication: A Pragmatic Introduction to Signal Processing (*http://terpconnect.umd.edu /~toh/spectrum/IntroToSignalProcessing.pdf*). (*Figure 23*).

STACK and ADD

Waveform Acquisition → Suppress the first 10µs → IIR Fourth-Order Butterworth Bandpass Filter 0.4-1 MHz

↓

Average Waveform

↓

Savitzky-Golay FIR Smoothing Filter 126 side point 6th order polynomial

↓

1st Derivative

↓

FIR Filter

↓

Normalize Waveform Between -1 and 1

↓

Absolute Value

↓

Find 1st Waveform Value That Exceeds The Threshold → Find The First Zero Crossing
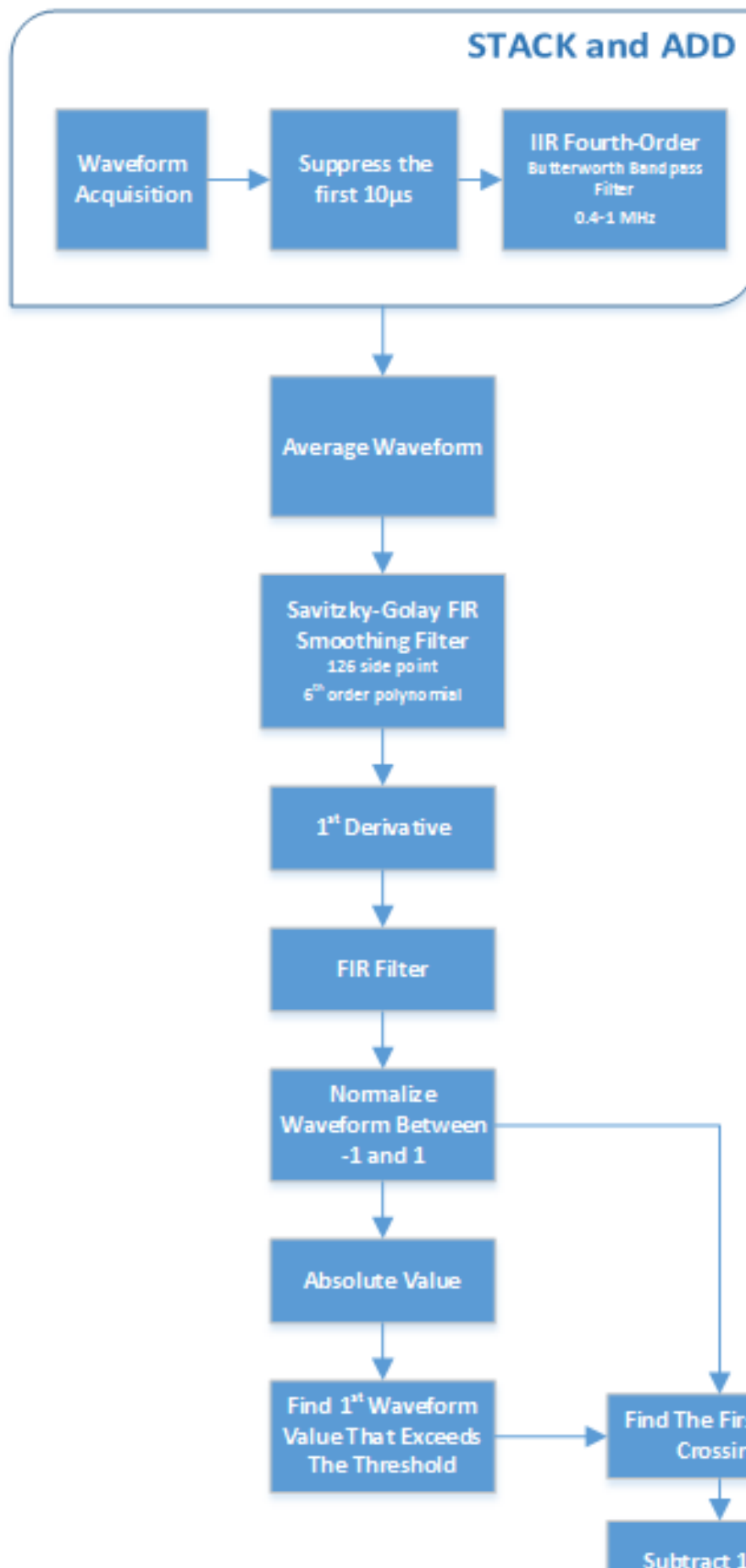
↓

Subtract 1.5 µs

Figure 23. Signal to Noise Enhancement.

The ensemble averaging done at the acquisition stage is effective at eliminating nearly all of the random noise. Unfortunately, our signals contain a great deal of systematic environmental noise that shielding signal cables cannot fully eliminate. To suppress this noise, we need to exploit small differences between the noise and the acoustic pulse. The parameters used in the smoothing operators were developed empirically by measuring a variety of materials and by degrading the signal by attenuation at the pulser-receiver. Time was limited on Expedition 361 to select the best smoothing operators and their parameters. Further experimentation is needed to improve the process and validate that it will work for all possible lithologies recovered by IODP.

The SNR enhancement process consists of 3 steps: (1) smoothing, (2) 1st derivative, and (3) smoothing.

1. The first smoothing step passes the waveform through a Savitzky-Golay filter that applies a polynomial least-square fit step-wise through the data (similar to a running average). Experimentation shows that using a 6th-order polynomial across a 126 data point window will reduce high-amplitude, high-frequency noise while retaining the shape of the acoustic pulse.
2. After the first smoothing operation, we take the 1st derivative (central-difference) which suppresses the low-frequency noise. The downside to the differentiation is that the process adds back in high-frequency noise.
3. A second smoothing step using FIR operator is then used to reject this noise. The FIR filter coefficients were calculated using LabVIEW tools.

Waveform as absolute values

Figure 24 shows the waveform (as absolute values) before and after the 3-step process and illustrates the significant noise suppression achieved. Attempting to find the first arrival on the unprocessed data would have failed because the amplitude of the noise is greater than the first arrival peak.
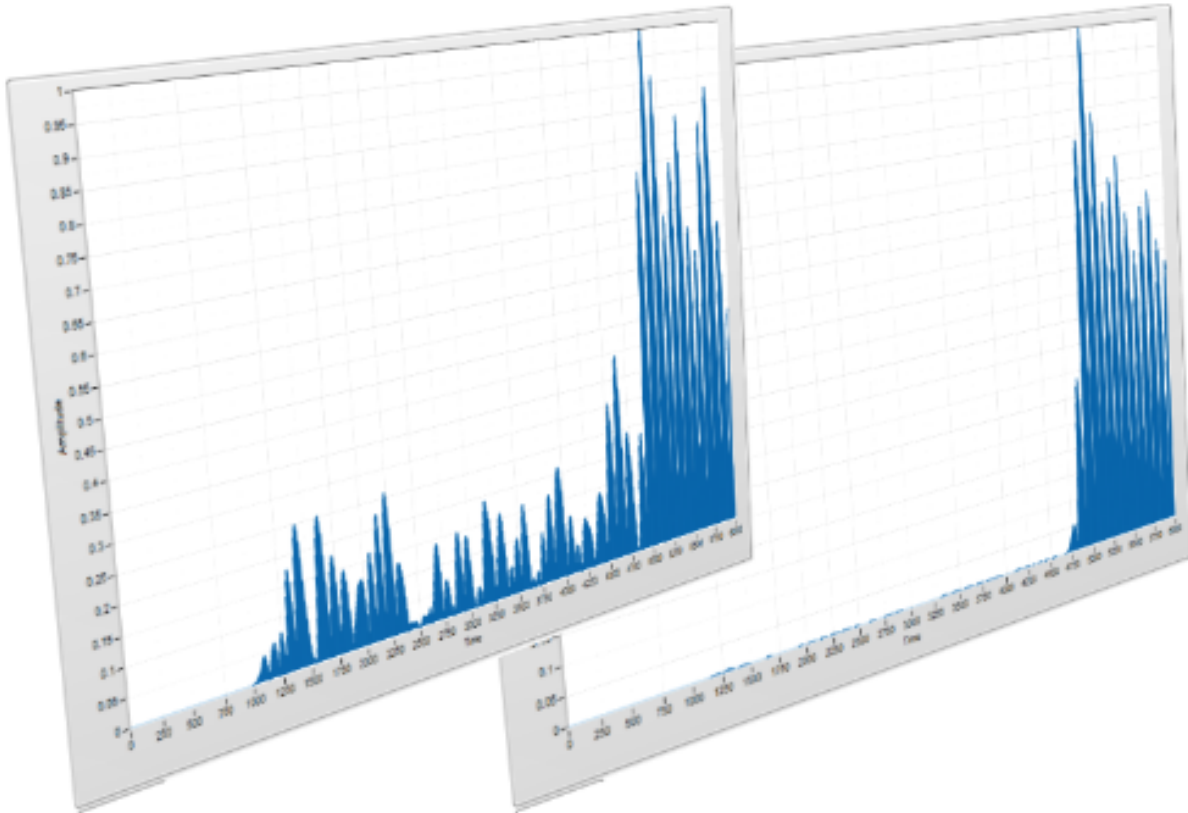

Figure 24. Waveform before and after 3-step process.

Normalization

At this point in the process, a copy of the waveform is normalized to scale between the values of −1 and 1. A copy of the processed waveform is converted to its absolute value and then normalized with the waveform scaled between values of 0 and 1. This normalization is critical to making the threshold picking process indifferent to either amplification or attenuation of the signal. Experience has shown that the threshold value needs little adjustment once chosen unless there is a significant lithology change.

1st Arrival Time

The threshold crossing is performed on the absolute copy of the waveform. The crossing time is then used as the starting point to find the first zero-crossing in the derivative waveform. From this time value, we subtract 1.5 μsec to account for ¼ wavelength phase shift caused by the 1st derivative operation and ½ wavelength correction back to the first arrival. See *Figure 25*.
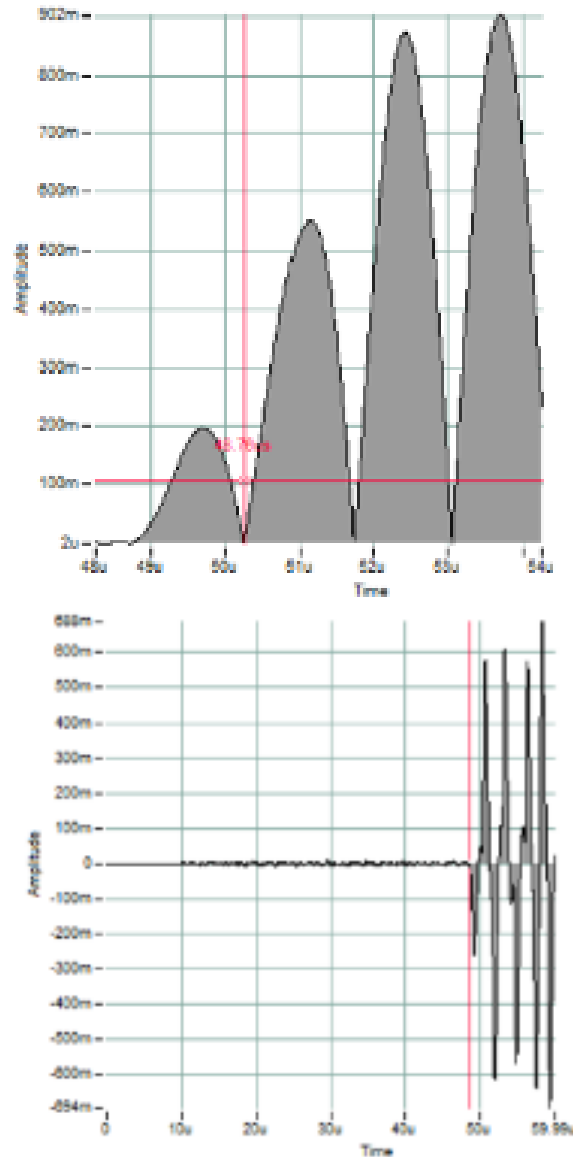

Figure 25: The upper graph shows the threshold (Horizontal cursor) crossing the first peak of the acoustic pulse and the 1st zero-crossing (vertical cursor). After correcting the time, the lower graph shows the pick on the original stacked waveform.

Waveform Data

The process described above greatly distorts the original waveform. Artificially induced time shifts are eliminated by the P-wave calibration and rolled into the system time delay value. The waveform archived in the JR_LIMS database is taken after the original signal has been band-pass filtered and ensemble averaged. The data from further processing is discarded after the 1st arrival has been determined.

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.

Credits

This document originated from Word document WRMSL UG v.362P2.docx (see Archived Versions below for a pdf copy) that had contributions from multiple authors including David Houpt, Ty Cobb, Sandra Herrmann, Beth Novak, Sherry Frazier, and Bill Mills. Credits for subsequent changes to this document are given in the page history.

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