February 2011

HARDWARE USER'S MANUAL

RibEye™ Multi-Point Deflection Measurement System

3-Axis Version for the WorldSID 50th ATD

Model # 10000

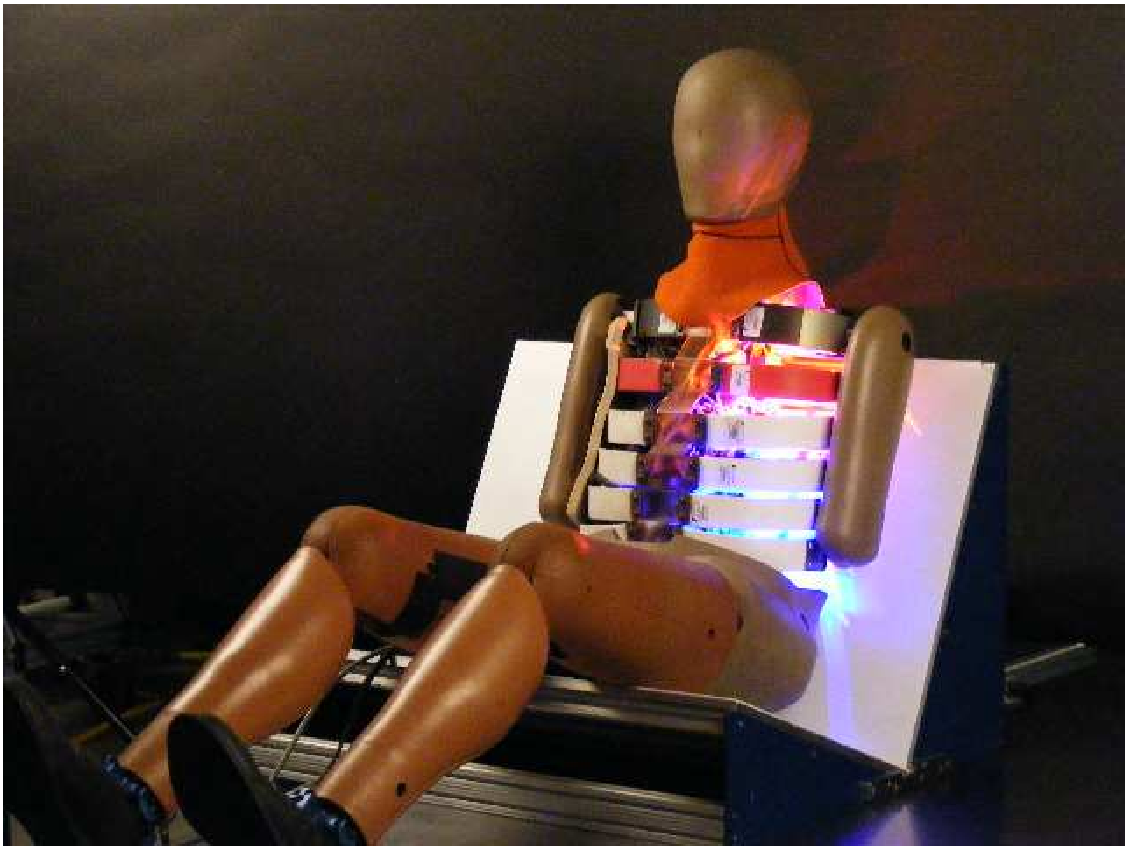

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Table of Contents

List of Figures and Tables

HARDWARE USER'S MANUAL
RibEye™ Multi-Point Deflection Measurement System
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Model #10000

1.0 WorldSID RibEye Description

The RibEye for the WorldSID anthropomorphic test device (ATD) provides X,Y, and Z position data for 18 light-emitting diodes (LEDs) mounted on the WorldSID ribs. Three LEDs are mounted on each of the 6 ribs. Up to 25 seconds of data can be collected at a 10 kHz sample rate. Flash memory is used to store 1.7 seconds (-200 ms to 1500 ms) of data that is retained after power is turned off.

Two sets of three sensors are used to monitor the LED positions as shown in **Figure 1**. The top set of sensors uses red optical filters and monitors red LEDs mounted on the first three ribs: shoulder, thoracic #1 and thoracic #2. The bottom set of sensors uses blue optical filters and monitors blue LEDs mounted on the lower three ribs: thoracic #3, abdominal #1, and abdominal #2.

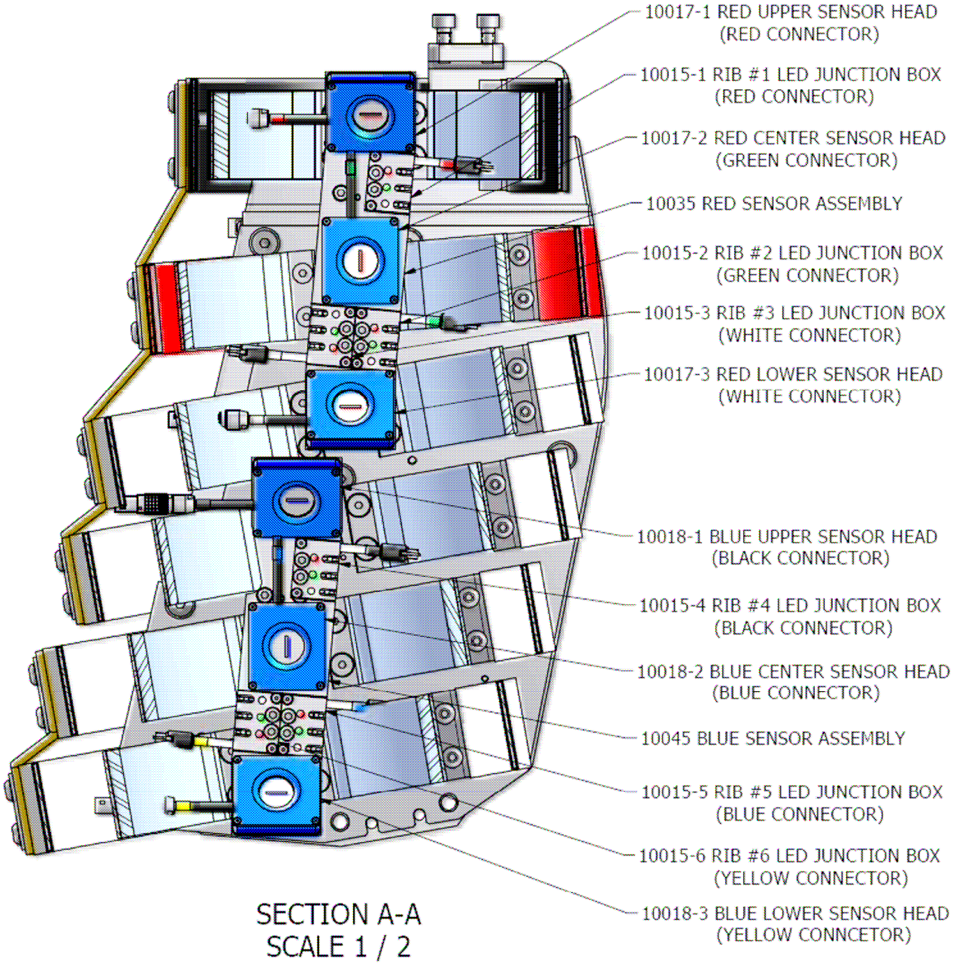

Figure 1. RibEye sensor sets

LED wiring junction boxes are mounted between the sensors. The junction boxes have a hard-wired, color-coded cable for connecting the junction boxes to the controller. The LEDs have color-coded plugs that plug into sockets on the junction boxes.

Figure 2 shows the sensors, mounting brackets, and sensor cable assemblies. The LED junction boxes are not shown in this picture. Note that each of the three sensor cables are terminated with 7 pin Lemo 0B color-coded connectors that plug into color-coded sockets on the controller. The red (top) sensors are shown on the right, and the blue (bottom) sensors are shown on the left.

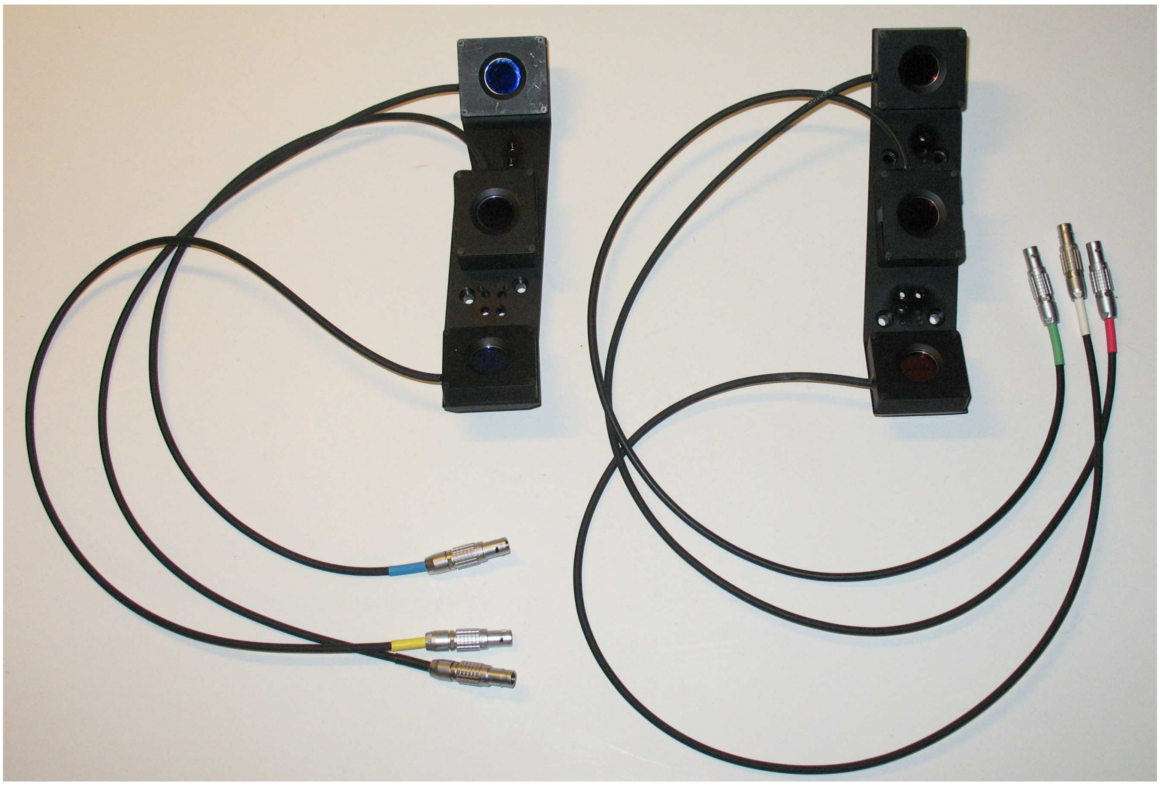

Figure 2. Sensors on mounting bracket

The RibEye controller and battery pack are mounted on the non-struck side of the ATD as shown in **Figures 3, 4, and 5.**

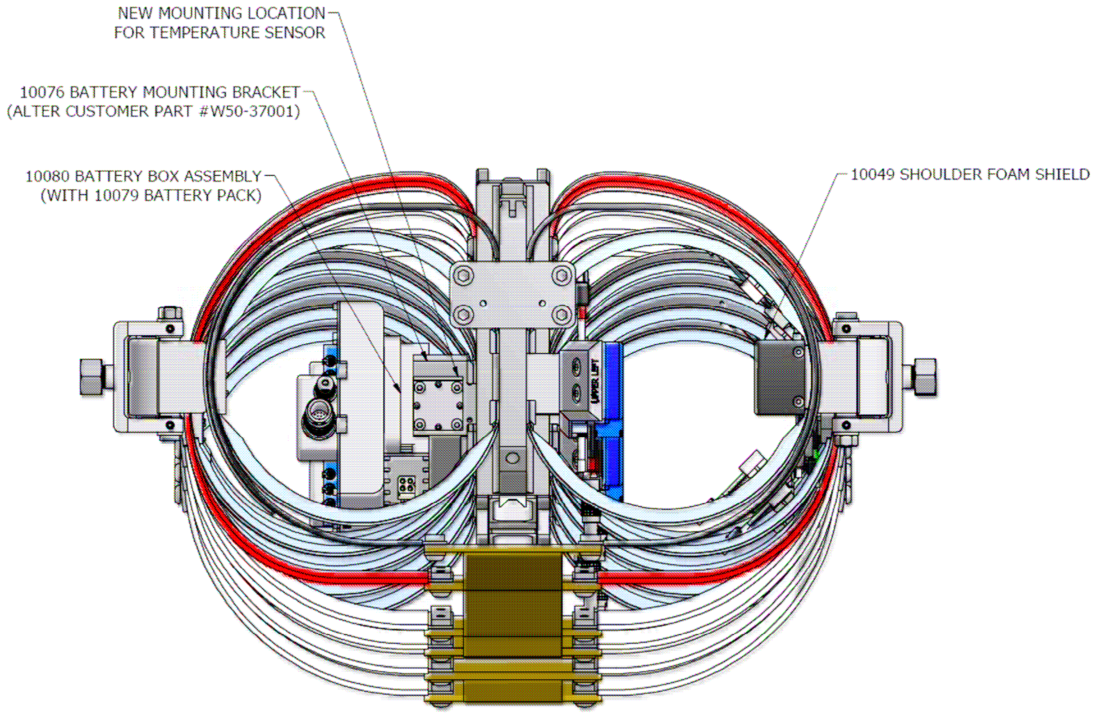

Figure 3. Controller, top view

The 4 pin Lemo connector is used to connect the controller to the battery pack. The 19- pin connector is used for external power, Ethernet communications, and control signals. The mating cable connects the controller to the Messring interface box

Figure 4 shows a side view of the controller with the connections for the battery, power and control cable, LED junction box connections, and sensor connections. Note that the sensor connection and LED junction box connections are color-coded, and the mating cables have matching colors on them.

Figure 5 shows details of the controller attachment to the battery assembly, the battery assembly to the battery bracket, and the battery bracket to the spine assembly.

Figure 6 shows the LEDs mounted on the ribs. The center LEDs are built into the accelerometer mounting blocks. The rearward and forward LEDs on each rib are attached with double-sided tape and held in place with heat-shrink tubing. The figure shows the connector color codes for each LED.

Figure 7 shows a single rib with the LEDs mounted.

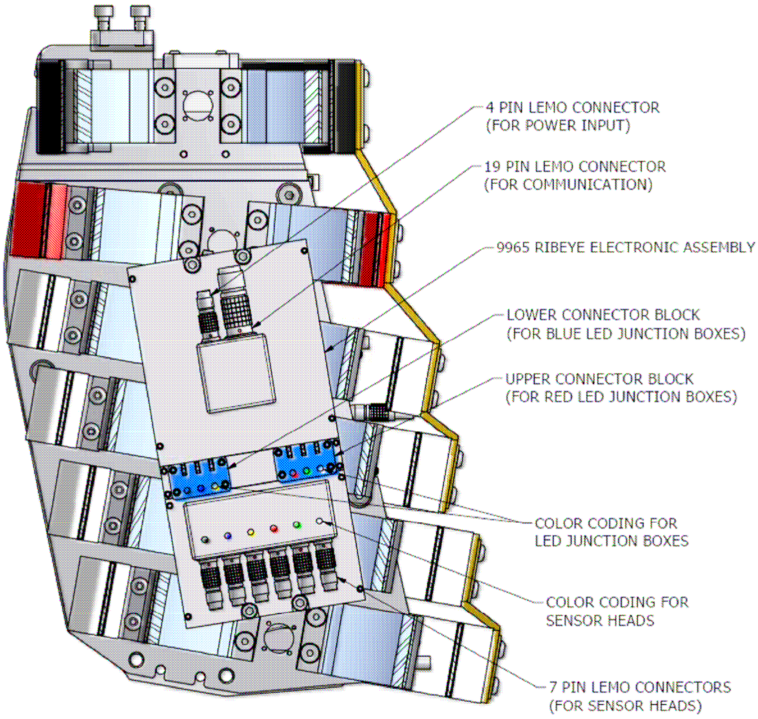

Figure 4. Side view of controller

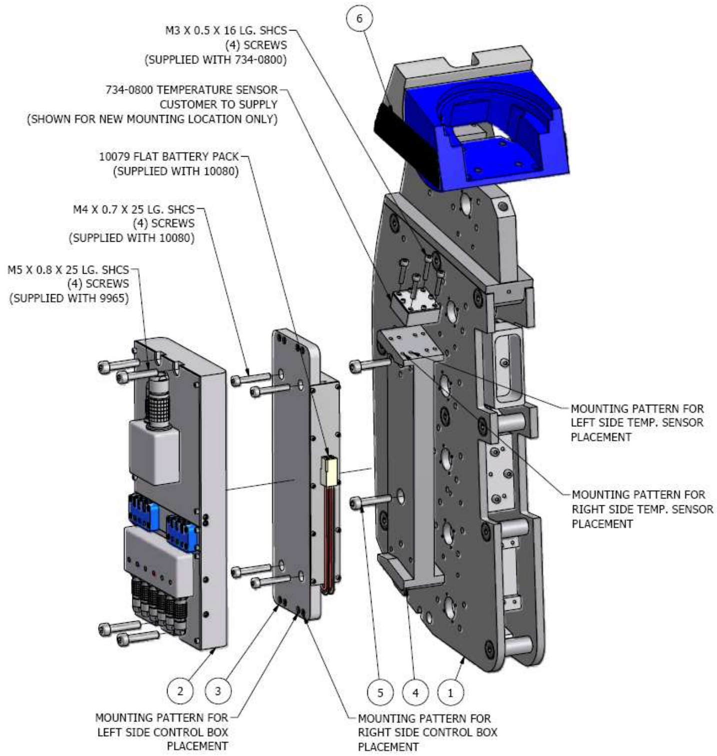

Figure 5. Controller and battery pack mounting

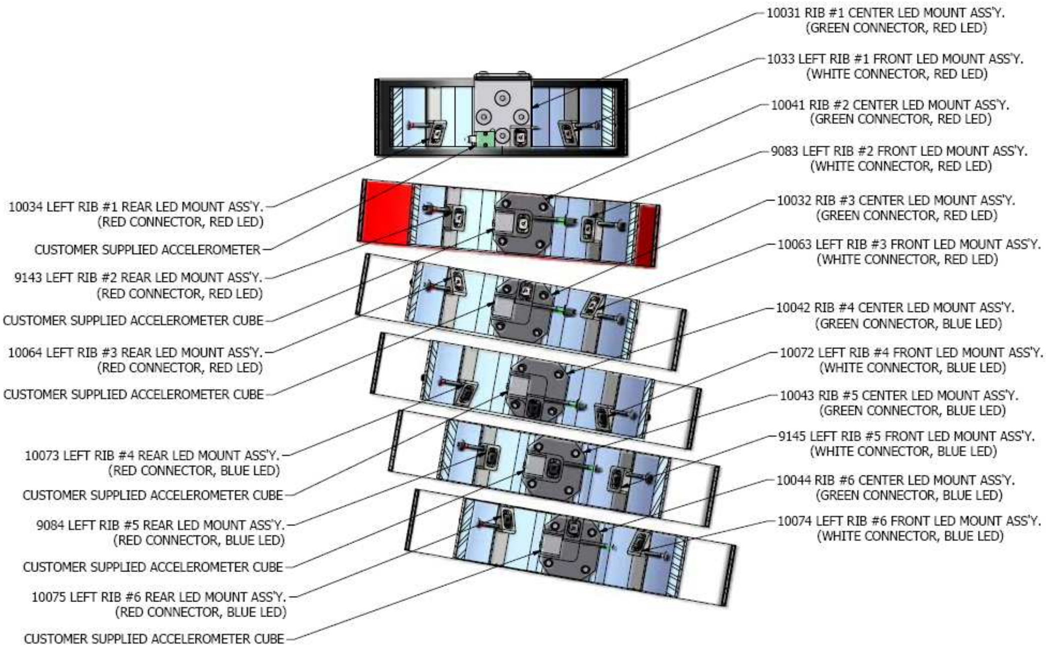

Figure 6. LEDs mounted on the ribs

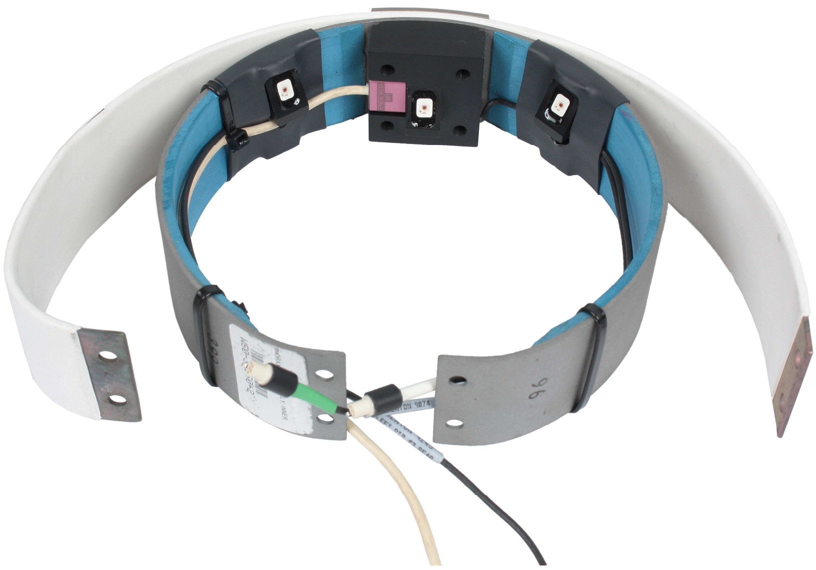

Figure 7. LEDs mounted on a single rib

Position data from each sensor set is reported with respect to a coordinate system that has its origin at the center of the center sensor of each set. The RibEye coordinate systems are aligned with the ATD coordinate system. **Table 1** shows the nominal positions of the LEDs with the

RibEye mounted on the left side of the ATD. The front and back LEDs may vary slightly from these positions as they are mounted with double-sided tape and heat-shrink tubing.

Table 1. Nominal LED positions with the RibEye on the ATD left side

LED	X (mm)	Y (mm)	Z (mm)
Shoulder Rear	-50.1	75.2	-45.6
Shoulder Center	5.6	92.6	-43.4
Shoulder Front	37.1	75.3	-45.7
Thoracic #1 Rear	-35.6	86.6	10.2
Thoracic #1 Center	7.4	101.3	13.9
Thoracic #1 Front	50.4	86.6	17.7
Thoracic #2 Rear	-35.8	88.6	52.3
Thoracic #2 Center	9.1	101.3	58.5
Thoracic #2 Front	53.4	88.6	68.0
Thoracic #3 Rear	-62.0	89.2	-46.8
Thoracic #3 Center	-17.2	102.0	-37.2
Thoracic #3 Front	28.1	89.2	-30.9
Abdominal #1 Rear	-45.3	85.3	-4.6
Abdominal #1 Center	-4.0	101.5	2.7
Abdominal #1 Front	37.4	85.3	10.0
Abdominal #2 Rear	-34.7	87.8	36.5
Abdominal #2 Center	9.3	102.0	42.5
Abdominal #1 Front	52.7	87.8	51.9

Figure 8 is a picture of the controller and battery pack.

Figure 9 is a picture of the controller and battery pack with all cables connected.

The battery pack is used to provide power for the RibEye if the power and communications cable is disconnected or damaged during a test. The RibEye batteries each consist of nine AA 1.2 volt, 2.7 amp-hour batteries. A fully charged battery can run the RibEye for over 10 minutes while collecting data.

Figure 10 shows the Patco model 8050 battery charger provided to charge the NIMH battery pack. The charger has lights to indicate that it is charging, ready to charge, and when the charge is complete. While the Patco charger is connected to the battery pack, the 4-pin Lemo battery connector that plugs into the controller should be disconnected at the controller.

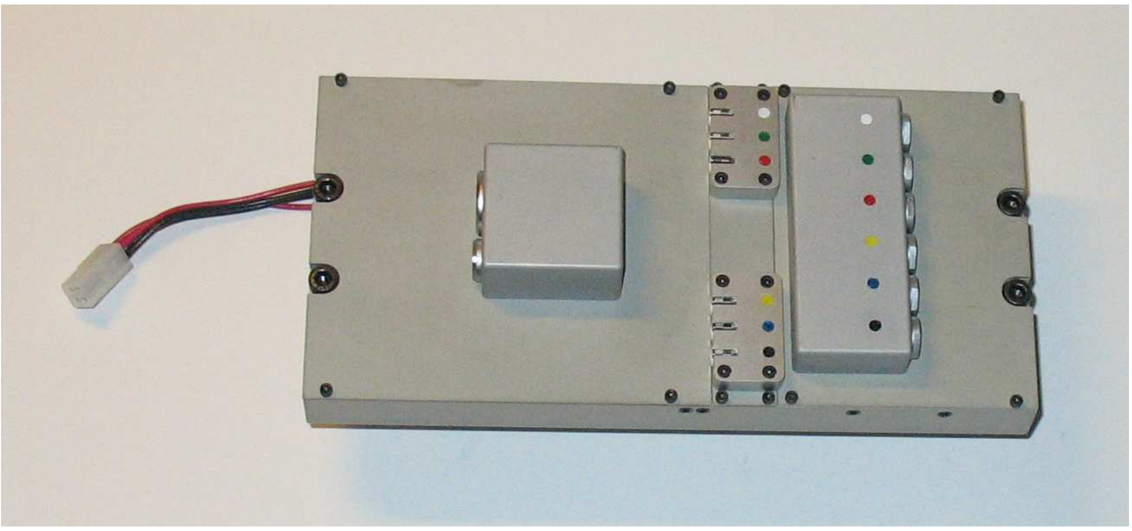

Figure 8. Controller and battery pack

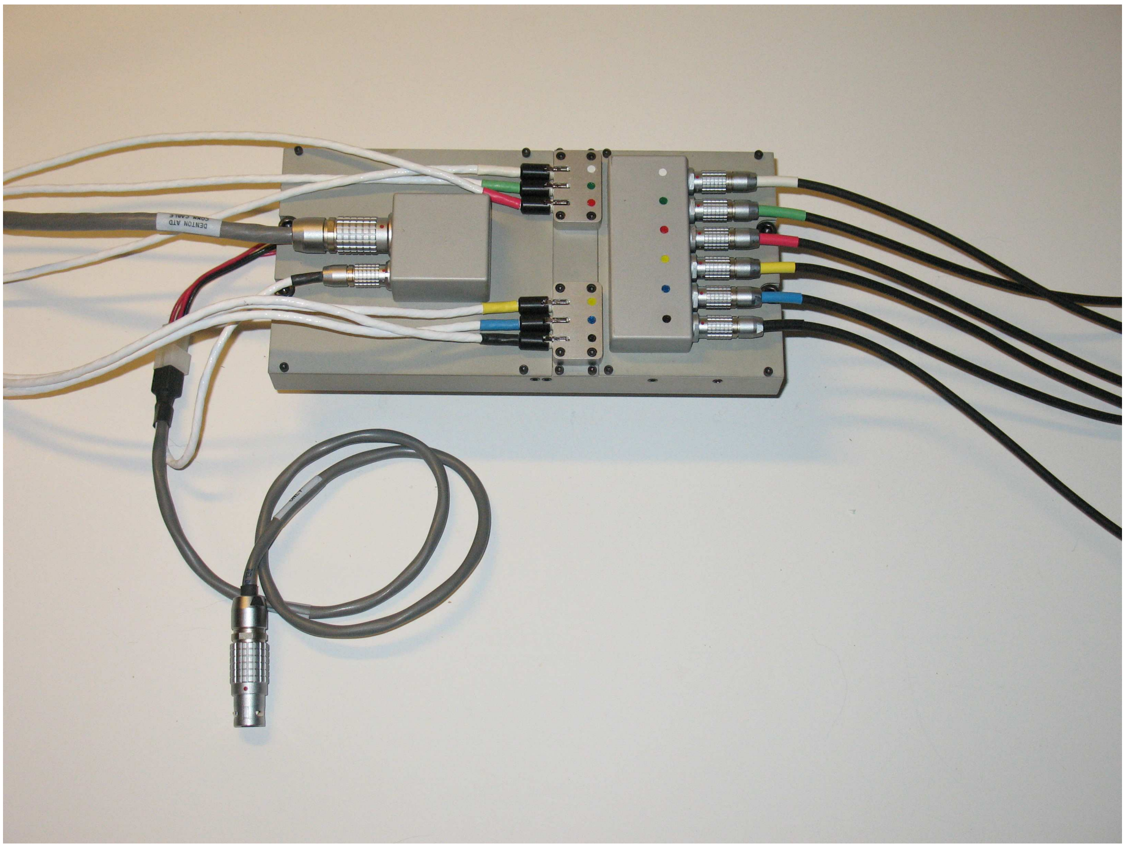

Figure 9. Controller and battery pack with all cables installed

Figure 10. Patco Model 8050 battery charger

2.0 Cable Assemblies

Figure 11 shows the cable (#9096) for power and communications. This cable connects from the RibEye controller to the Messring interface panel. The connector pin details are shown in **Table 2**.

Figure 12 shows the cable (#9095) that connects the battery to the RibEye controller and the battery charger. The two-pin Lemo goes to the charger, the four-pin Lemo goes to the RibEye controller, and the four-pin Molex goes to the battery pack.

An overview of the LED and sensor wiring is shown in **Figure 13**. Note that the LED cables that plug into the controller and into the junction boxes are color-coded. The cables from the junction boxes to the controller are also color-coded. **Figure 14** shows where the LED junction boxes are mounted on the sensor brackets. The mounting of the LED junction boxes, and the color codes are also shown in **Figure 14.** **Figure 15** is a picture of a LED junction box with the attached cable and connector for plugging into the controller.

2.1 Cable Routing

To prevent noise in the RibEye data, the LED cables must be kept as far away from the sensor cables as possible. **Do not** bundle the LED cables with the sensor cables. The sensor cables should also be separated from the DTS G5 power and communications cables. Where the sensor cables cross the LED or Messring cables, they should cross at 90-degree angles.

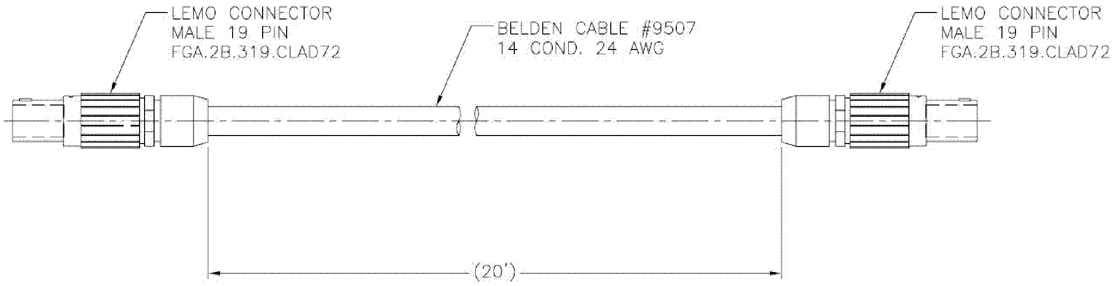

Figure 11. Power and communications cable

Table 2. Power and communication cable connector pins

Pin #	RibEye Controller Receptacle	At end of Power and Communication Cable
1	Spare Input	not connected
2	Spare Output	Spare Output
3	shield - connected to Power Ground in controller	shield
4	Spare Input	spare input
5	Power Control	Power Control - Pull to Power Ground to turn RibEye power on
6	not used	not used
7	Spare Output	not connected
8	+20VDC Power	+20VDC Power
9	+20VDC Power	+20VDC Power
10	not used	not used
11	Ethernet Rx-	Ethernet Rx-
12	Ethernet Rx+	Ethernet Rx+
13	Ethernet Tx-	Ethernet Tx-
14	Ethernet Tx+	Ethernet Tx+
15	Trigger Input	Trigger Input - Pull to power ground to trigger.
16	Status LED	Connect to status LED cathode.
17	Power Ground	Power Ground
18	Power Ground	Power Ground
19	Power Ground	Power Ground

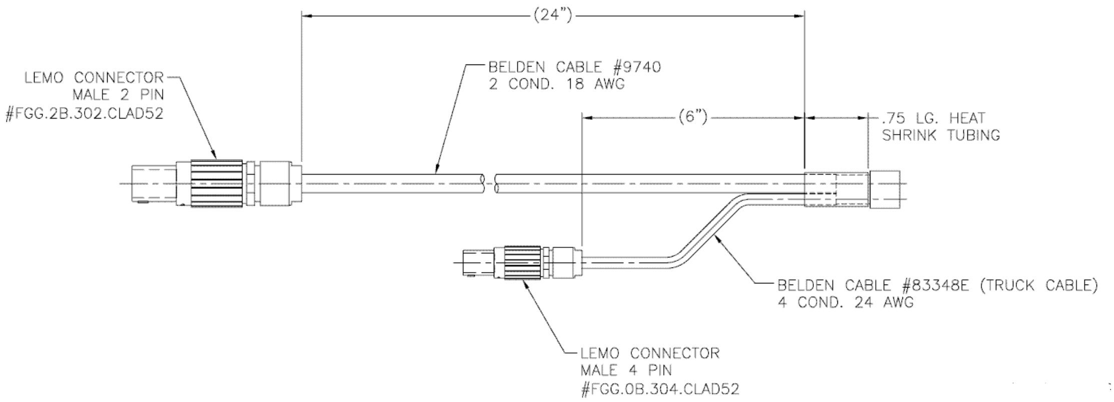

Figure 12. Battery/charger cable

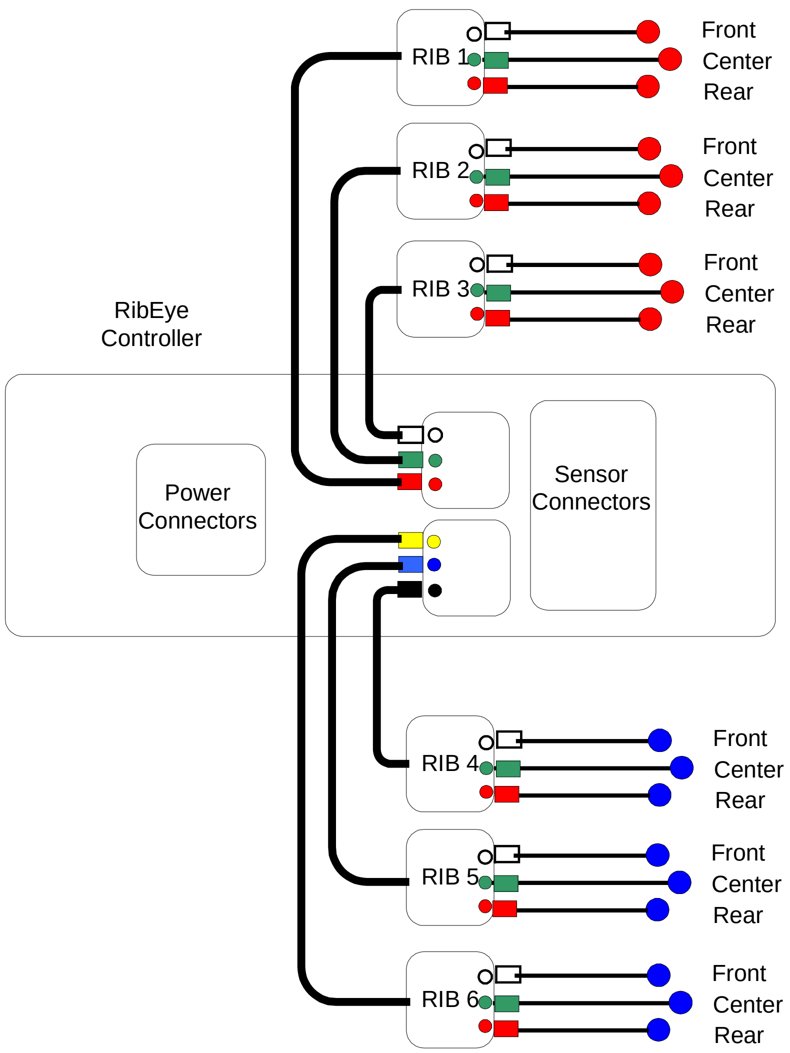

Figure 13. LED wiring

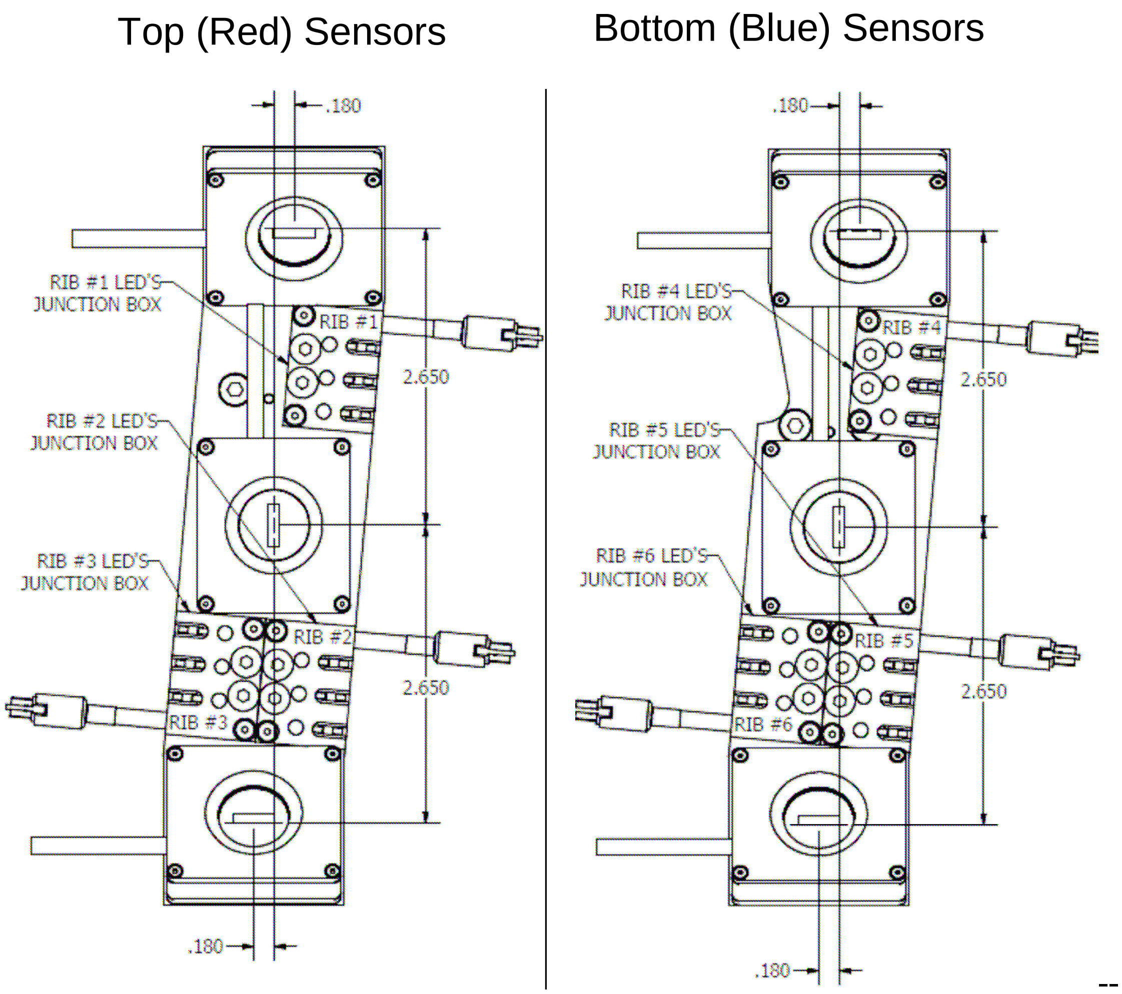

Figure 14. LED junction box locations on sensor brackets

Figure 15. LED junction box

3.0 Operation

3.1 Software

The WorldSID RibEye is set up, operated and data is downloaded via a PC program. Refer to the RibEye Software User's Manual for installation and operation of the software. For operation of the Messring software that will control the RibEye, refer to the Messring documentation.

The Live Display tab is slightly different for each of the RibEye models, so it is described below for the WorldSID RibEye.

The RibEye reports positions with respect to the center sensors of the red and blue sets. However, for the live display screen, when set to show the LED positions in the Y-Z plane, the LED Z positions are reported with respect to the midpoint of the thorax, approximately half-way between ribs 3 (thoracic 2) and rib 4 (thoracic 3). Examples of the live display are shown in **Figure 16** for the Y-Z plane and **Figure 17** for the X-Y plane. The live display plots shown are zoomed around the LED positions. See the software manual or press on the Help button for instructions on zooming plots.

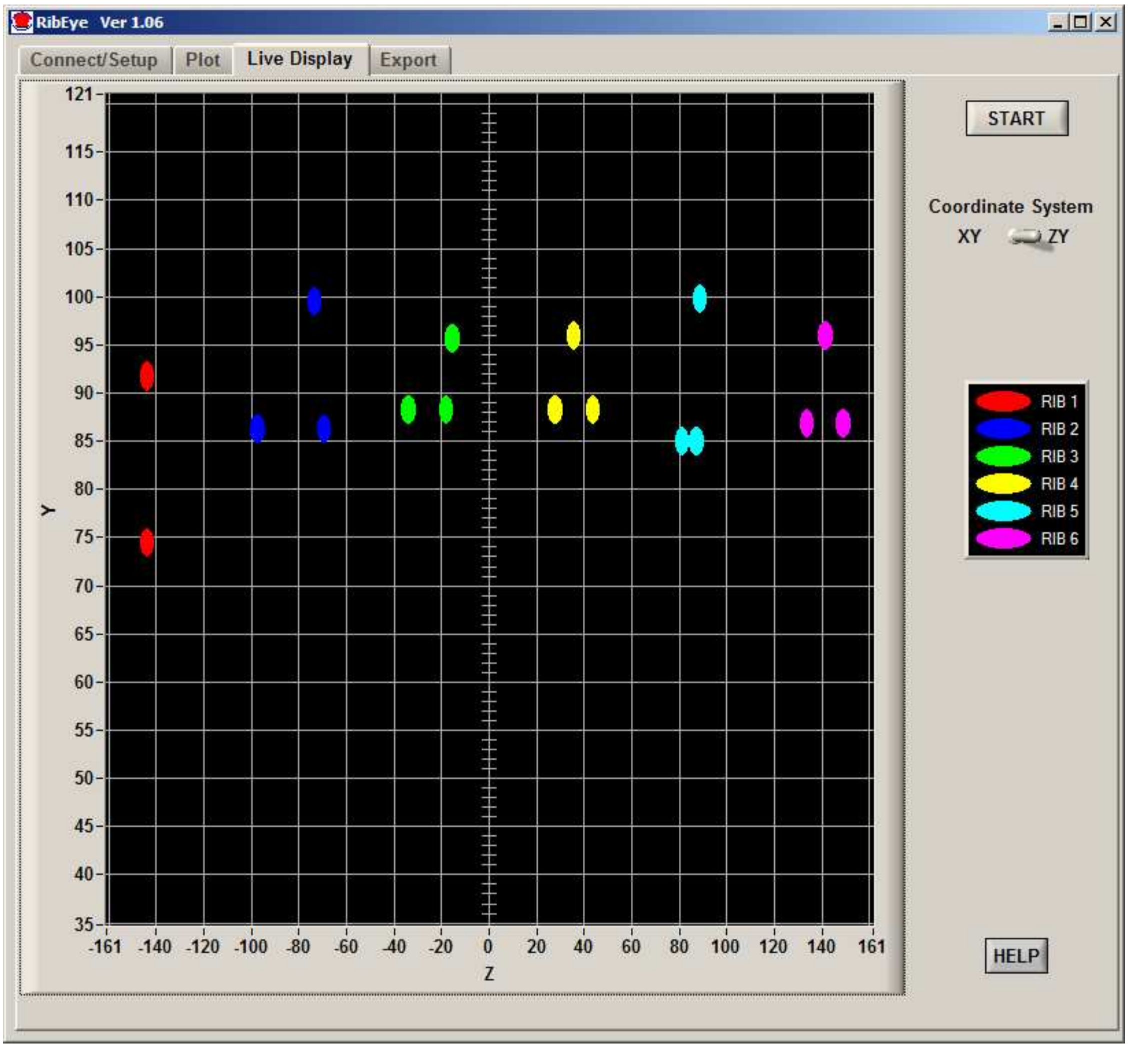

Figure 16. "Live Display" tab with data shown in the Y-Z plane

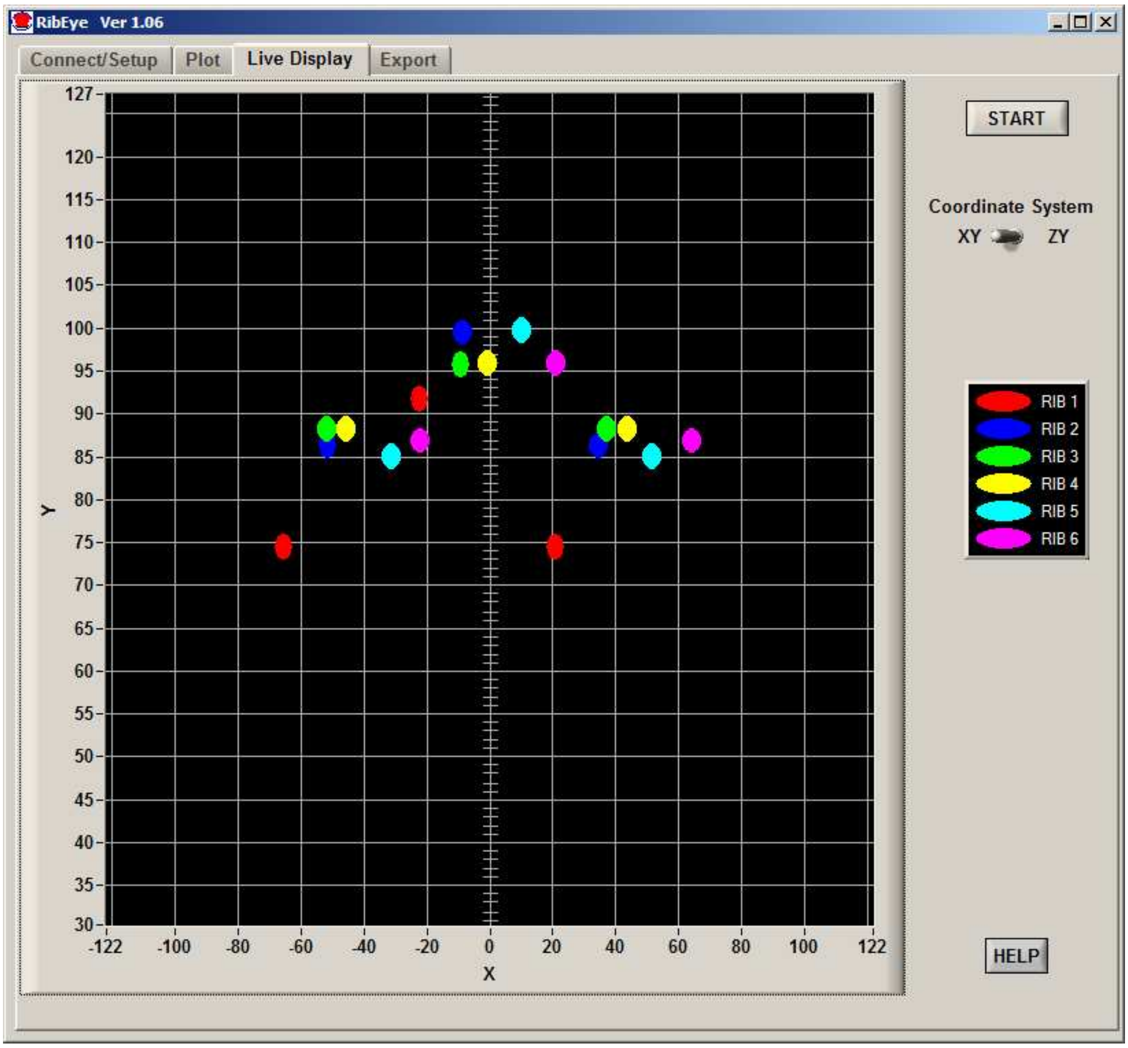

Figure 17. "Live Display" tab with data shown in the X-Y plane

3.2 RibEye Power Control

A locking toggle switch on the Messring interface panel is used to turn the RibEye power on and off. The power switch indirectly controls the RibEye power, and if the RibEye is busy acquiring or storing data, or communicating with the PC program, it will not shut down immediately. The RibEye must be idle for 10 minutes to shut down. The purpose of the power switch is to prevent the RibEye from draining the battery pack if it is left plugged in.

3.2.1 RibEye Battery Pack

The RibEye battery pack should be charged with the Patco charger. A fully charged battery can power the RibEye for at least 10 minutes while acquiring data. The charger should be disconnected when operating the RibEye. When the charger is plugged in to the RibEye battery, the 4 pin Lemo battery connector should be disconnected from the controller. The battery pack is diode-isolated from the main RibEye power input, so the RibEye will continue to operate even if the main power input is shorted out.

3.3 Status Light on the Messring interface panel

The status light on the Messring interface panel is powered by the external power from the Messring interface panel. If the Messring system is powered down, and the RibEye is running from battery power, the status light will not flash.

The status light flashes at varying rates to indicate the status of the RibEye:

• 0.5 Hz = idle with data in memory
• 1.0 Hz = idle with memory erased
• 2.0 Hz = acquiring data
• 5.0 Hz = storing data in flash memory
• 10 Hz = erasing flash memory and downloading data

3.4. Arming the RibEye

The RibEye is armed via the RibEye or Messring software.

3.5 Trigger Input

The WorldSID RibEye receives its trigger from the Messring interface panel through the 19-pin power/control cable. The trigger setting on the RibEye software "Connect/Setup" tab should be set to "Switch, Rising Edge."

4.0 Data Processing

4.1 Error codes in the data

If the RibEye cannot calculate a LED position it will insert error codes in the data. Usually this will occur if the light from a LED is blocked to one of the sensors. Typically this happens if a loose cable gets between the LED and the sensor. Also, if the center rib on each set of three ribs compresses significantly more than the upper or lower ribs of the set, it can block the light from the upper or lower rib LEDs to one of the sensors.

Too much ambient light can also cause the RibEye to generate error codes. If an error code occurs, data from all three axes, X, Y, and Z will be forced to the same error code.

The error codes for each sensor set are:

1. The top sensor is blocked or sees too much ambient light
2. The bottom sensor is blocked or sees too much ambient light
3. Both top and bottom sensors are blocked or see too much ambient light
4. The middle sensor is blocked or sees too much ambient light
5. The middle and top sensors are blocked or see too much ambient light
6. The middle and bottom sensors are blocked or see too much ambient light
7. All three sensors are blocked or see too much ambient light
8. A divide-by-zero condition occurred in the data processing.

Note that the error code numbers will be changed if the data is processed to give the relative motion of each LED by subtracting the pre-event data from each data sample. Also, filtering the data can mask error codes that occur for a short time. We recommend that all data be reviewed unfiltered, and as absolute position data, to make sure that there are no error codes. If an error code does occur, the data a few milliseconds before and after the error condition should be discounted because something partially blocking a LED can cause reflections that corrupt the position measurement.

4.2 Estimating IR TRACC readings

The IR TRACC does not give true Y compression if there is X and Z motion of the ribs.
The RibEye reports the LED positions with respect to the center of the center sensor for the top and bottom sensor sets and LEDs. If the pre-trigger data is used to remove the initial offsets from the data, the zeroed data is the change in the LED positions in the X, Y, and Z directions.

The 3D RibEye data from the center LED can be used to calculate what the output would be for an IR-TRACC, giving only the compression of the IR-TRACC. **Figure 18** shows the relationship between the RibEye zeroed data and the IR-TRACC in the X-Y plane. To calculate the IR-TRACC output from the RibEye data, use the following formula:

$$\text{IR-TRACC reading} = Py - \text{sqrt}[\, (Py - |Ry|)^2 + Rx^2 + Rz^2 \,]$$

Where:
Py is the IR-TRACC pivot-to-pivot dimension for an unloaded rib (see **Table 2**)
Ry is the RibEye change in the Y direction
Rx is the RibEye change in the X direction
Rz is the RibEye change in the Z direction

Table 3 has the IR-TRACC pivot to pivot dimensions in millimeters for the WorldSID ribs in the unloaded positions. **Table 3** shows the pivot to pivot dimensions based on the CAD model of the dummy. Actual production ribs can be 3-4 mm different from the CAD model, and the ribs can yield slightly during testing, while still passing the thorax calibration tests.

Table 3 IR-TRACC pivot to pivot dimension for all ribs

Rib	Pivot to pivot dimension (mm)
Shoulder	133.78
Thoracic #1	133.50
Thoracic #2	133.07
Thoracic #3	131.80
Abdominal #1	133.78
Abdominal #2	133.78

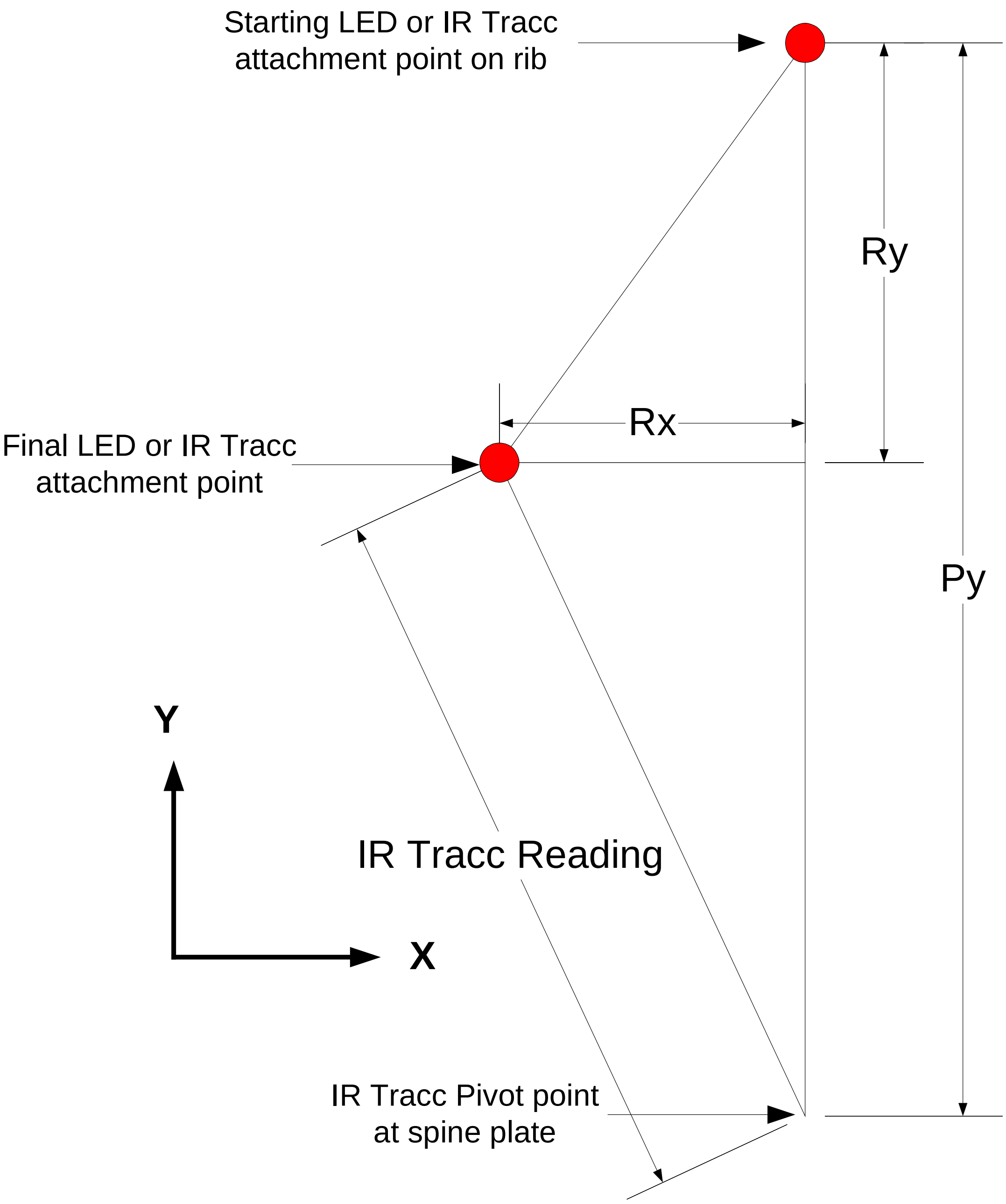

Figure 18. Calculation of IR-TRACC output from RibEye data in X-Y plane

5.0 Maintenance

The only maintenance required for the RibEye is to keep the lenses clean.

A dirty camera lens will create a fuzzy photo, and smudged eyeglasses will cause distorted vision. The same holds true for RibEye: If the lenses are not clean, the data will be less accurate.

Make sure that the lenses are clean before each test.

If the lenses need to be cleaned —

1. Blow dust off the lenses with clean, dry air.

2. If there is grease or dirt on the lenses, clean them with eyeglass or camera-lens cleaning solution and lens cleaning paper or a lens cleaning cloth. You can also use isopropyl alcohol.

3. Make sure there is no residue from the cleaner on the lens.

WARNING: DO NOT USE cotton-tipped swabs like Q-Tips. (They leave fibers on the lens.)

Note: If you can't get enough light into the thorax to see the lenses well, you can arm the RibEye to turn on the LEDs.

DANGER: Do not look directly at the LEDs as they are very bright.

Appendix A. RibEye Specifications

A1. Measurement Accuracy and Range

The RibEye meets the requirements of SAE J211/1 (July 2007) as a combined sensor and data acquisition system. **Figure A1** shows the RibEye measurement range in the RibEye X-Y plane. **Figure A2** shows the RibEye measurement range in the RibEye Y-Z plane. The maximum error for the Y and Z data is less than 1 mm, and the maximum X error is less than 2 mm.

The maximum and average errors for each rib for each axis are shown in **Table A1 f**or WorldSID RibEye Model 10000, serial number 0075. For each rib, the total number of points tested in the measurement range is shown in the last column.

The maximum error is the maximum of the absolute value of the calculated errors. The average error is taken by summing the absolute value of all errors and dividing by the number of points collected for the rib.

Table A2 shows the SAE J211 Channel Amplitude Class (CAC) for each axis, and the maximum error as a percentage of the CAC.

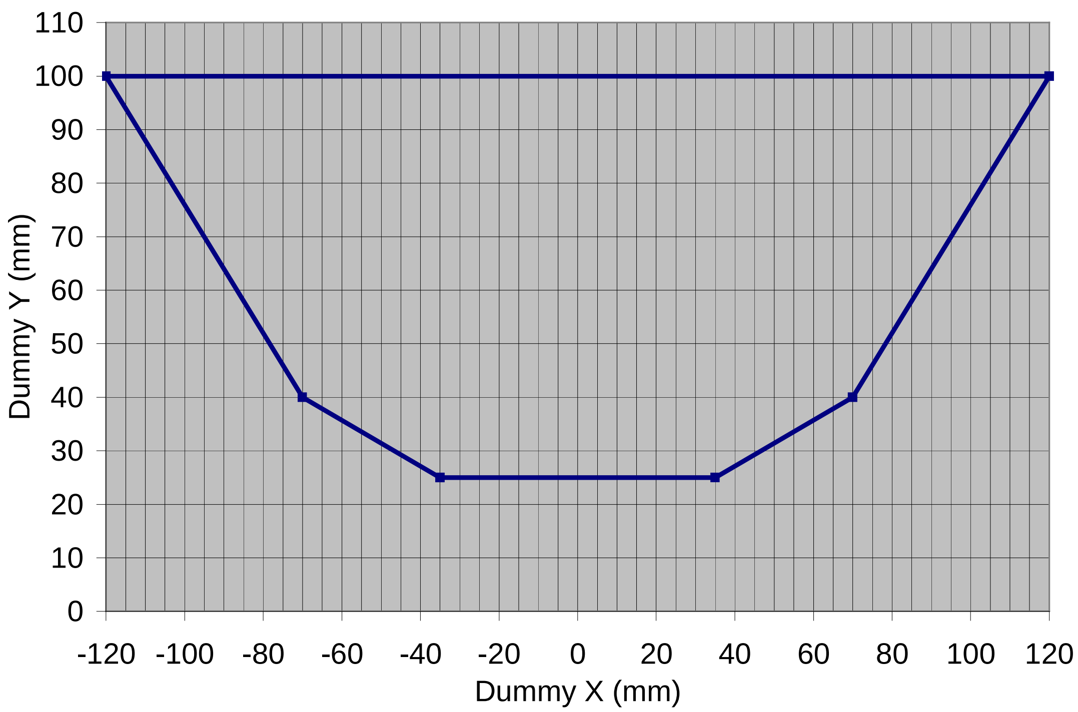

Figure A1. RibEye measurement range in X-Y plane

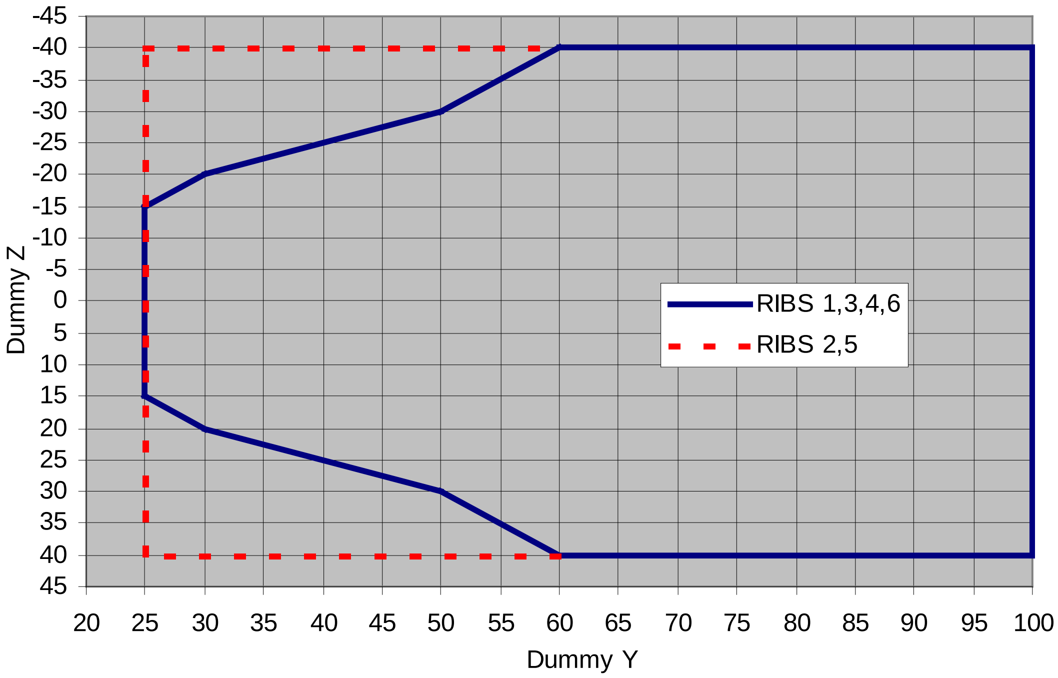

Figure A2. RibEye measurement range in Y-Z plane

Rib	X Errors (mm)		Y Errors (mm)		Z Errors (mm)		# of points
	maximum	average	maximum	average	maximum	average	
Shoulder	1.31	0.15	0.72	0.07	0.55	0.04	7238
Thoracic 1	0.83	0.12	0.63	0.07	0.57	0.08	8252
Thoracic 2	1.31	0.14	0.58	0.08	0.74	0.09	7238
Thoracic 3	1.88	0.19	0.86	0.16	0.52	0.06	7236
Abdominal 1	0.92	0.1	0.37	0.07	0.59	0.04	8250
Abdominal 2	0.82	0.11	0.84	0.08	0.9	0.07	7236

Table A1. Calibration check data for WorldSID RibEye Model 10000, serial number 0075

Axis	Channel Amplitude Class (CAC)	Max Error (mm)	Error as a % of CAC
X	240 (+/-120)	2	0.83 %
Y	76	1	1.32 %
Z	80 (+/-40)	1	1.25 %

Table A2. The SAE J211 Channel Amplitude Class (CAC), and the maximum error as a percent of the CAC

A2. Power Requirements

The RibEye can be powered by a high quality DC voltage source from 12 to 36 Volts, and it is intended to be powered by the Messring MBUS system at 20 VDC. At idle the RibEye will draw 8 watts. When collecting data it will draw 12 watts typically, and 20 watts maximum. If all LEDS were blocked and driven to full power, the RibEye could draw 40 watts.

The backup battery pack can power the RibEye while collecting data for over 10 minutes when the batteries are fully charged. After running the RibEye for 10 minutes, it will take about 4 hours to fully recharge the batteries.

The RibEye controller has a self-resetting polymer fuse on its power input. If this fuse ever opens, it can take up to 4 hours to self-reset.

A3. Data Acquisition and Storage

Sample rate: 10,000 samples per second per LED

Modes: Linear or circular buffer

Total acquisition time: 25 seconds

Data storage: 25 seconds in RAM, 1.7 seconds in flash (non-volatile)

Data is collected to RAM memory and stored post-test in flash memory.

A4. Ethernet Communication

Communication between the RibEye and the PC software is via 10/100 MBS Ethernet. The IP address can be set by the user. (Factory default = 192.168.0.240.)

Refer to the RibEye Software User's Manual for information on changing the RibEye IP address.

The RibEye communicates with the PC software using port 3000. An open protocol is used to send commands to the RibEye and to receive data. See the Boxboro Systems web page (www.boxborosystems.com), Manuals tab, for the protocol document.

A5. Trigger Circuit

The Trigger circuit inside the RibEye Controller is shown in **Figure A3.**

The external trigger source is shown as a switch in the figure, but it can be any type of circuit that will pull the trigger line (pin 15 in the power/communications cable) to the power supply ground.

WARNING: Although the RibEye can operate on 12 to 36 VDC input power (pins 8 and 9 of the power/communication cable), if the power supply is above 20 VDC, the 0.2 watt series resistors will get overheated if the trigger line is pulled to ground continuously. If the power input is above 20VDC, limit the width of the external trigger pulse to less than 10 seconds.

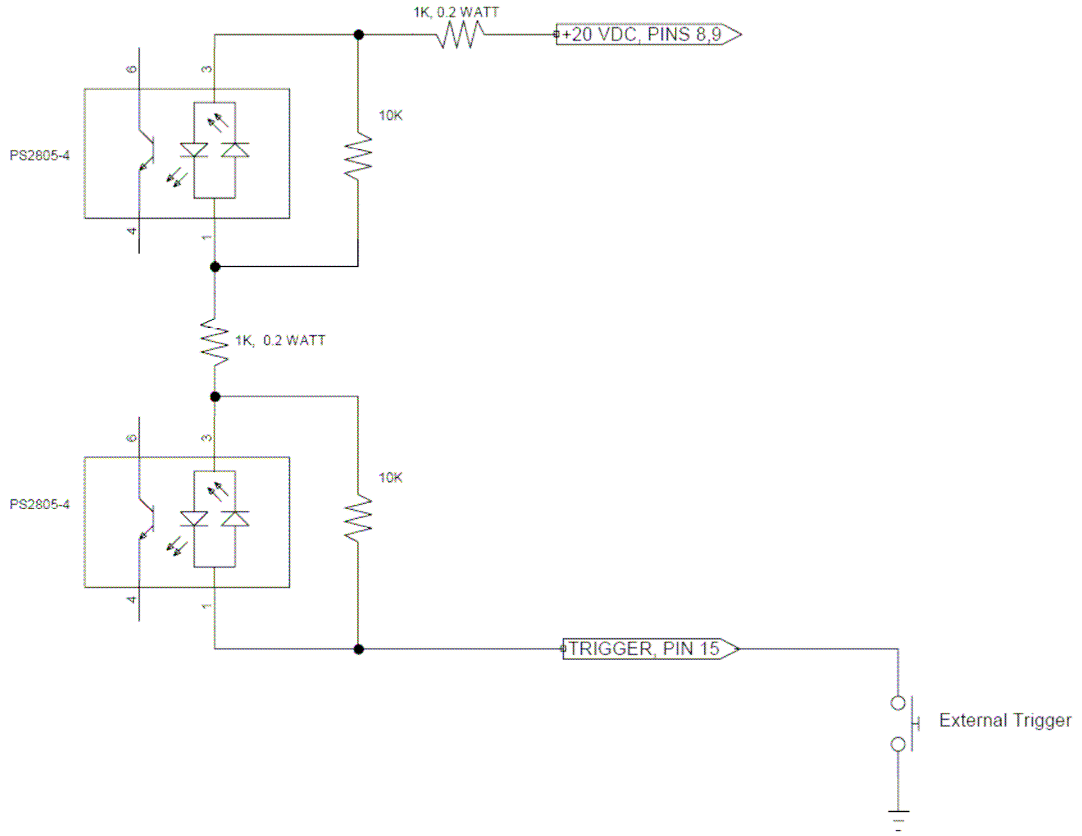

Figure A3 Trigger input circuit