SECTION 15- INSTRUMENTATION AND WIRING

15.1 Overview of Instrumentation and Wiring

The advanced frontal dummy, THOR is capable of carrying a total of 132 channels of data. Forty of these channels are included in the lower extremities of the dummy, called THOR-LX (THOR-LX is considered to be the components of the lower extremity from the knee to the foot.). **Figure 15.1** is a plot showing the relative location of all the instrumentation for THOR (**Note:** The knee shear, knee rotation, and Achilles tendon instruments are not shown in this figure.). The layout of the instrumentation in the THOR dummy was designed to maintain a high degree of modularity, which was one of the main goals of this dummy. Each instrument has an individual lead wire to allow for easy removal and insertion for calibration and inspection.

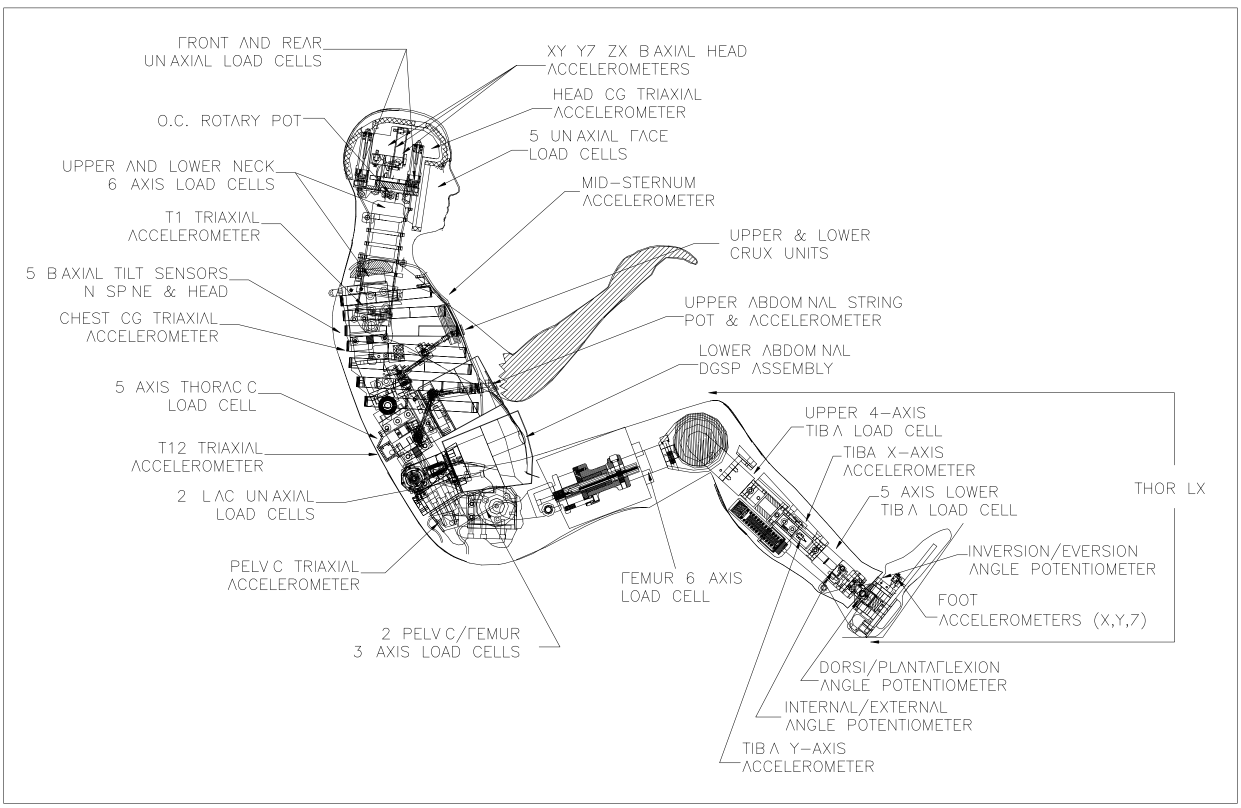

Figure 15.1- Relative location of THOR Instrumentation

15.1.1 Available Instrumentation

The THOR dummy is currently capable of supporting the following instrumentation:

Head:	9 Uniaxial Accelerometers 1 Biaxial Tilt Sensor
Face:	Five Uniaxial Load Cells
Neck:	Upper Neck Load Cell (6 channels) Lower Neck Load Cell (6 channels) Front Neck Spring Load Cell Rear Neck Spring Load Cell Head Rotation Potentiometer
Thorax:	CRUX Deflection Units - 3 Dimensional Thoracic Deflection Measurement (4 units - 3 channels each) 1 Triaxial Accelerometer at the C.G.
Mid Sternum:	1 Uniaxial Accelerometer
Upper Abdomen:	Uni-directional Displacement String Potentiometer Uniaxial Accelerometer
Lower Abdomen:	DGSP Deflection Units - 3 Dimensional Lower Abdomen Deflection Measurement (2 units - 3 channels each)
Spine:	1 Triaxial Accelerometer at the T1 location 1 Triaxial Accelerometer at the T12 location T12 (5-axis) Load Cell 4 Biaxial Tilt Sensors
Pelvis:	Acetabular Load Cell (left and right, 3 channels each) Iliac Crest Load Cells (left and right) 1 Triaxial Accelerometer at the Pelvis C.G.
Femur:	Femur Load Cell (left and right, 6-axis each)
Knee	Knee Shear (Displacement) Knee Rotation
Lower Ex.	Upper Tibia Load Cell (4 Channels) Lower Tibia Load Cell (5 channel) Tibia Acceleration (X, Y)

Achilles Tendon Load Cell
Ankle Joint Rotation Potentiometers (X, Y, Z)
Foot Acceleration (X, Y, & Z)

15.1.2 Instrumentation Description

Head: The THOR head assembly is instrumented with a nine-accelerometer array (9 uniaxial units) and a biaxial tilt sensor. The purpose of the accelerometers is to allow the reconstruction of the head kinematics. The purpose of the dual-axis tilt sensor is described in this section under the Spine section.

Face: Five uniaxial load cells are positioned at five distinct points to measure impacts to the facial region. The load cell positions include: left and right orbital regions (eye sockets), left and right maxillae (upper jaw bones), and mandible (lower jaw bone).

Neck: The neck instrumentation consists of a pair of six-axis load cells located at the top and bottom of the flexible neck assembly. These load cells provide the primary loading data for the neck structure, which includes the forces in the X, Y, and Z directions, as well as the moments in the X, Y, and Z directions. In addition, a pair of uniaxial load cells is used to measure the cable tension (or spring force) on the fore and aft neck cables. Finally, a rotary potentiometer is centered at the condyle bolt to measure the rotation of the head relative to the neck. The loading data from the head / neck assembly is analyzed using the THORTEST software program (supplied and documented separately).

Thorax: The thorax assembly is instrumented with four CRUX units. These units operate as a two-bar linkage system as described in Section 15 - CRUX Units. The units are located at the level of rib #3 and rib #6 on the left and right sides. Each of these units measures the three-dimensional deflection of the rib cage at the attachment point. This system provides a four-point measurement system for thoracic deflection. The data from the CRUX units is analyzed using the THORTEST software program (supplied and documented separately). In addition to the CRUX units, a triaxial accelerometer is located at the thorax CG to measure the accelerations in the three principle directions.

Mid Sternum: The mid-sternum assembly is instrumented with a uniaxial accelerometer on the back-side of the plate. This unit is designed to measure the sternal accelerations, such as those caused by an airbag or steering wheel impact.

Upper Abdomen: The upper abdomen assembly is instrumented with a uni-directional displacement measuring device - the string potentiometer. This unit consists of a high strength miniature cable which is wound around a spring-tensioned drum. As the abdomen is compressed, the string is wound around the drum and the rotation is converted to a linear deflection. In addition, the upper abdomen assembly is instrumented with a uniaxial accelerometer, mounted in the interior of the front bag face. This unit is designed to measure the uni-directional acceleration of the bag, such as those caused by an airbag or steering wheel impact.

Lower Abdomen: The lower abdomen assembly is instrumented with a pair of double gimballed string potentiometer (DGSP) units. These units consist of a string potentiometer housed within a telescopic column which provides three-dimensional deflection data for two points (left and right) in the lower abdomen assembly. The data from the DGSP units is analyzed using the THORTEST software program (supplied and documented separately).

Spine: The spine is instrumented with the five-axis thoracic load cell located at the anthropomorphic level of T12. This load cell provides the primary loading data for the spine structure, which includes the forces in the X, Y, and Z directions, as well as the moments in the X, Y, and Z directions. In addition, the spine is instrumented with two triaxial accelerometers - located at the anthropomorphic levels of T1 and T12. An additional four dual-axis tilt sensors are located along the spine between the head and the pelvis. The tilt sensors are capable of measuring the relative angular orientation of the dummy to allow very repeatable posture setups between tests.

Pelvis: The pelvis assembly is instrumented with a pair of acetabular load cells located at the ball joint of the hip. These load cells measure the forces in the three primary directions of the loads transferred from the femur to the pelvis. A pair of uni-directional load cells are built into the iliac crest region of the pelvic casting. The purpose of these load cells is to determine whether or not the belt is loading the pelvis in the iliac notch region. Lack of a load reading on these iliac load cells may indicate a condition of submarining. In addition, a triaxial accelerometer is located at the pelvis CG to measure the accelerations in the three principle directions.

Femur: The femur assemblies are each instrumented with a six-axis femur load cell located between the knee and the compliant femur bushing. These load cells provide the primary loading data for the femur structure which includes the forces in the X, Y, and Z directions, as well as the moments in the X, Y, and Z directions.

Knee: The knee assemblies are each instrumented with a miniature string potentiometer to measure the knee translation (shear) along the given axis of motion.

Lower Extremity: Each lower extremity (left and right) is instrumented with the following:

- A pair of tibia load cells, located at the top and the bottom of the tibia tube. These load cells provide the primary loading data for the lower leg structure which includes the forces in the X, Y and Z, as well as the moments in the X and Y.
- Three rotary potentiometers are used to measure the rotation of the ankle joint about the X, Y, and Z axes.
- A uniaxial load cell can be installed to measure the Achilles Cable tension.
- Five uniaxial accelerometers, two singles and a set of three on a mounting block, provide data on the acceleration of the tibia and foot assemblies.

15.1.3 Standard Instrumentation Specifications

Table 15.1 shows the typical vendor reference for the instrument.

Table 15.1

Instrument	Vendor Reference
Uniaxial Accelerometer	Entran # EGE-73BQ-2000HD Endevco # 7264-T
Triaxial Accelerometer	Entran # EGE3-73-2000 Endevco # 7267A
CRUX	Thor Manufacturer
Rotary Potentiometer	Contelec # PD210-4B
DGSP	THOR Manufacturer
Rotary Potentiometer #1	Contelec # PD210-4B

Rotary Potentiometer #2	Sfernice # 20x78RBA102-1K-9641
String Potentiometer	Space Age Controls # 160-0321-VL
Knee Shear String Potentiometers	Space Age Controls # 150-0121 VR, VL
Ankle Rotary Potentiometers	Contelec # PD210-4B
*Upper Neck Load Cell	Denton # 3454J
*Lower Neck Load Cell	Denton # 2357J
*Thoracic Spine Load Cell	Denton # 1911J
*Acetabular Load Cell - Left	Denton # 3855J
*Acetabular Load Cell - Right	Denton # 3455J
*Femur Load Cell	Denton # 1914J
Iliac Uniaxial Compression Load Cell	AL Designs # ALD-MINI-T-3K
Neck Spring Load Cell	Transducer Tech. # LWO-1K-GES
Face Uniaxial Compression Load Cell	Denton # 4168
*Upper Tibia Load Cell	Denton # B-4353J
*Lower Tibia Load Cell	Denton # B-4929J
Tilt Sensor	Advanced Orientation # DX045D-045

* Load cell output polarity must conform to SAE J-211 standard.

15.2 WIRE ROUTING AND STRAIN RELIEF FOR THOR INSTRUMENTATION WIRES

15.2.1 Wire Routing and Strain Relief for the Individual Instruments

Wire routing for the individual instruments in the THOR dummy is discussed in detail in their associated assembly sections. The strain relief for the individual instrumentation wires has been provided in several manners to prevent damage to the wiring during testing. Each instrument has some form of strain relief at the instrument housing to prevent the electrical connections from receiving any loading during movement of the wires. This initial strain relief is provided in various ways, depending upon the instrument. Some instruments use a zip-tie to attach the wire to a solid structure, some use a special wire clamp to hold the wire in position.

A second method of strain relief, which is used throughout the dummy, is the use of plastic wire crimp clamps. These clamps use a thru-bolt to compress the clamp around the wires and hold them in place. Instructions on how to use these clamps is described throughout this manual, as necessary, to hold various groups of wires in place.

A third method of strain relief is provided along the spine using the spine wire cover, as described below, to secure the instrument wires from the head and neck.

15.2.2 Wire Routing and Strain Relief for the Head and Neck Instrumentation

After the completed head and neck assemblies have been properly attached on the THOR thorax and spine assemblies, the bundle of wires from all the instrumentation needs to be properly restrained. Details of this procedure are covered in Section 7.2.2- Assembling the Thorax Components. The instrumentation wires from the head and neck instrumentation should be bundled together. This wire bundle should be clamped in place along the rear of the spine using aluminum spine wire cover (T1TXM040) as described in the procedure below.

1. Gather the wire bundle from the head and neck instrumentation (except the lower neck load cell wire). Holding the bundle together, measure 13.5" down along the wire bundle from the bottom of the head mounting plate. Centered at this point, wrap the wire bundle with electrical tape to provide enough thickness to allow the spine wire cover (T1TXM040) to hold it securely in place. This measurement will provide the necessary slack in the wires.

NOTE: It is critical to provide the correct amount of slack wire above this clamp to allow the head and neck to have free motion in flexion and extension.

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2. Center the nylon sling on the Spine Wire Cover Shaft (T1TXM042) and use two #10-32 x 5/8" BHSCS {1/8} to secure the Spine Wire Cover Assembly and the bundled wires to the top of the Upper Thoracic Spine Weldment (T1SPW120).

15.2.3 Wire Routing and Strain Relief for the Main Bundle of Instrumentation Wires

All of the instrumentation wires (except from the femurs and THOR-LX) are grouped together and strained relieved at the base of the spine. The procedure for securing the wires at this location is described in detail below.

1. Attach the adjustable cable support grip (strain relief mesh grip) to the rear of the Lower Abdomen Rear Attachment Plate (T1LAM010) using the Strain Relief Mounting Plate (T1INM010) and a 5/16-18 x 1" FHSCS {3/16}, as shown in **Figure 15.2**.

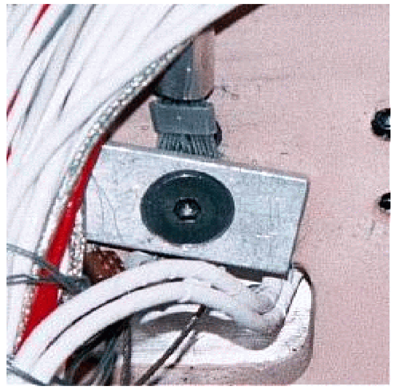

Figure 15.2- Strain relief attachment

2. Position the bundle of instrumentation wires in the strain relief mesh, and secure the mesh using several zip-ties as shown in **Figure 15.3**.

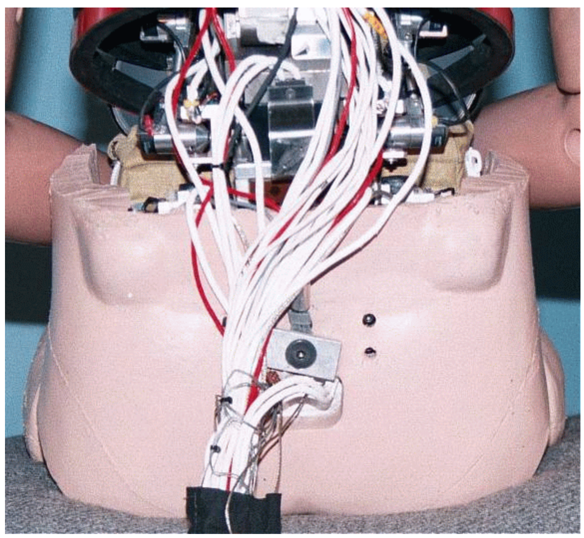

Figure 15.3- Wire bundle secured in mesh

3. Cover all the wires and the mesh using the Nylon Wire Cover (T1INF000). Zip the cover shut and secure it to the mesh using two zip-ties through the grommets at the end of the cover, as shown in **Figure 15.4**.

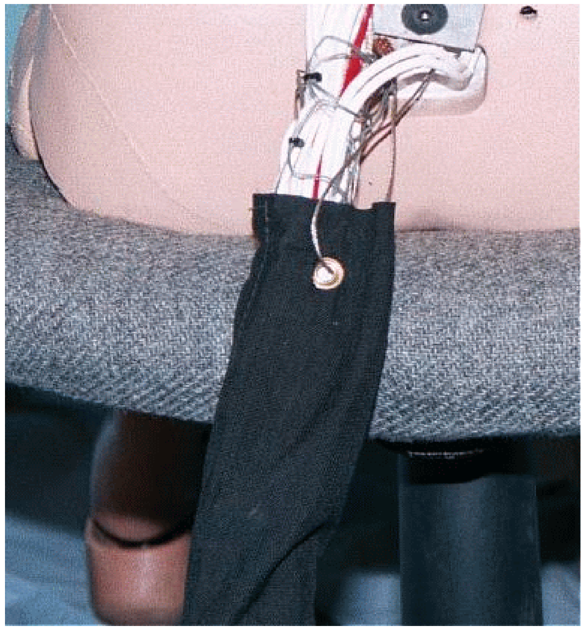

Figure 15.4- Mesh cover properly positioned

15.2.4 Wire Routing and Strain Relief for the Femur Instrumentation

The instrument wires from the six axis femur load cell are pre-strain relieved by the manufacturer at the housing of the instrument**.** After the load cell and the femur skin are installed on the mechanical femur assembly. The wires are routed in the grooves provided in the femur flesh at the knee/femur interface. These wires are then routed to the backside of the femur assembly where it is connected to the data acquisition system.

15.2.5 Wire Routing and Strain Relief for THOR-LX Instrumentation

The wire routing and strain relief for the instrumentation in the THOR-LX assembly is fairly straightforward. Each instrument is first strain relieved to a mechanical component to prevent damage to the wires during testing. Then the wires are grouped into bundles and further strain relieved at various points in the assembly. The skin was designed to provide a wire channel up each side of the tibia assembly, as described in Section 13, Step 35 describes this routing and provides a photo. Additional information is provided for each instrument below:

Upper Tibia Load Cell: The wire from this load cell exits through the hole provided at the rear of the tibia skin - just below the knee. The hole is at the top of the tibia skin zipper assembly.

Lower Tibia Load Cell: The wire from this load cell is routed up the right side of the lower leg and is bundled with the wires from the Y & Z axis rotary potentiometers. These wires continue up and exit through the hole provided at the rear of the tibia skin - just below the knee.

Tibia Uniaxial Accelerometers: The wires from these accelerometer units exit the right side of the tibia guard and are strain relieved to the right side of the Achilles Spring Tube Base using a 3/16" wire clamp and a #6-32 x ½" BHSCS {5/64}. These wires continue up and exit through the hole provided at the rear of the tibia skin - just below the knee. See **Figure 15.5** for additional details.

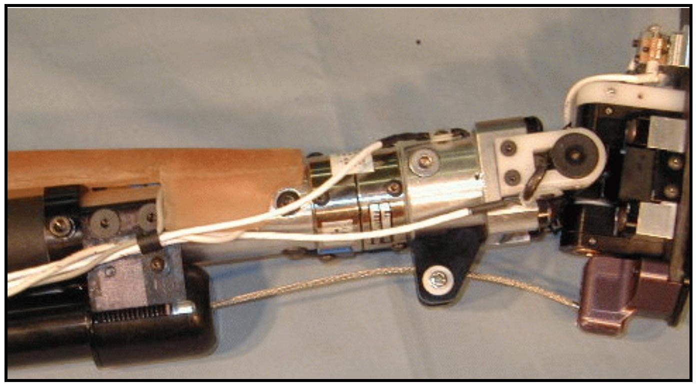

Figure 15.5- Tibia Uniaxial Accelerometers

Foot Triaxial Accelerometer Array: The wires from this accelerometer cube exits the molded foot cavity to the left and are bundled with the X-axis potentiometer wire and strain relieved to the front left side of the Y axis bearing housing with a 1/4" wire clamp using a #6-32 x 3/8" BHSCS {5/64}. **Figure 15.6** shows additional details of this wire routing. A small amount of slack must be provided in this wire between the instrument and the strain relief to allow for dorsi / plantar flexion motion of the foot. These wires are then routed up the left side of the leg tube and are strain relieved to the left side of the Achilles Spring Tube Base using a 3/16" wire clamp and a #6-32 x ½" BHSCS {5/64}. These wires continue up and exit through the hole provided at the rear of the tibia skin below the knee.

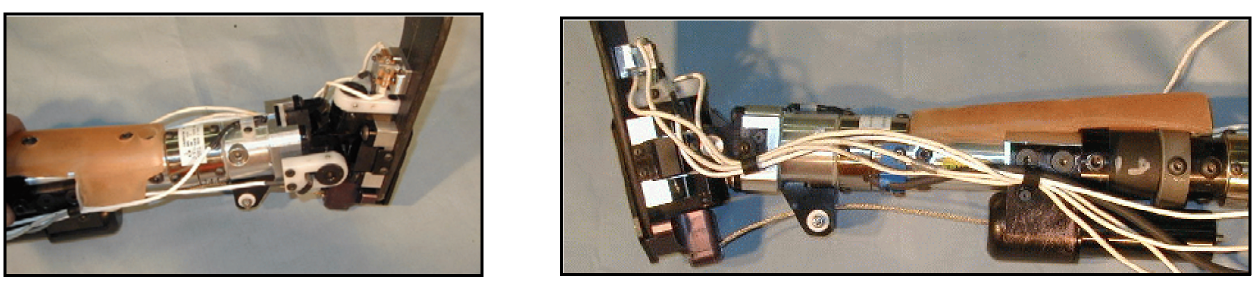

Figure 15.6- Foot Accelerometer and X-axis potentiometer routing

X axis rotary potentiometer: This wire is strain relieved to the potentiometer housing with a 1/8"wire clamp using a #6-32 x 3/8" BHSCS {5/64}. This wire is bundled with the foot triaxial accelerometer wires and strain relieved again at the front left side of the Y axis bearing housing with a 1/4" wire clamp using a #6-32 x 3/8" BHSCS {5/64}. A small amount of slack must be provided in this wire bundle between the instruments and the strain relief to allow for dorsi / plantar flexion motion of the foot. These wires are routed up the left side of the tibia tube and strain relieved to the left side of the Achilles Spring Tube Base using a 1/4" wire clamp and a #6-32 x ½" BHSCS {5/64}. These wires continue up and exit through the hole provided at the rear of the tibia skin - just below the knee. Refer to drawing T1AKE000 and **Figure 15.6** for additional information.

Y axis rotary potentiometer: This wire is strain relieved to the potentiometer housing with a 1/8"wire clamp using a #6-32 x 3/8" BHSCS {5/64}. This wire then runs up the right side of the leg and is bundled with the wire from the Z axis potentiometer. These wires are strain relieved to the right side of the Achilles Spring Tube Base using a 3/16" wire clamp and a #6-32 x ½" BHSCS {5/64}. These wires continue up and exit through the hole provided at the rear of the tibia skin - just below the knee. Refer to drawing T1AKE000 and **Figure 15.7** for additional information.

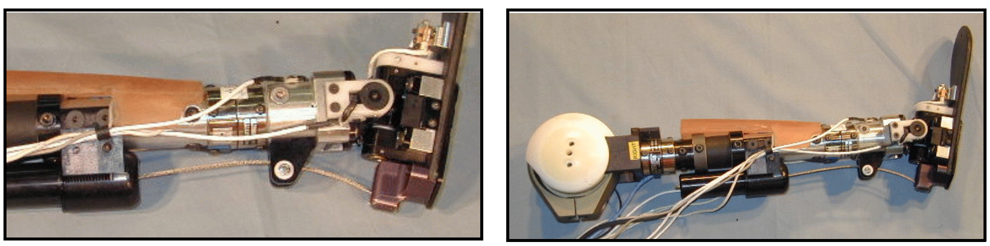

Figure 15.7- Y & Z Potentiometer Wire Routing

Z axis rotary potentiometer: This wire is strain relieved to the front of the Upper Joint Base with a 1/8"wire clamp using a #6-32 x 3/8" BHSCS {5/64}. The wire is routed up the right side of the lower leg and is bundled with the wire from the Y axis rotary potentiometer. These wires are strain relieved to the right side of the Achilles Spring Tube Base using a 3/16" wire clamp and a #6-32 x ½" BHSCS {5/64}. These wires continue up and exit through the hole provided at the rear of the tibia skin - just below the knee. Refer to drawing T1AKE000 and **Figure 15.7** for additional information.

15.3 Wire Markers

In order to keep track of the instrumentation wiring used for the THOR dummy, a wire marking system has been employed. This system involves an alpha-numeric marking strip for each instrument wire and connector wire, as well as, a color coded marker to denote the instrument type. **Table 15.2** provides a reference to the colors and their meanings.

Table 15.2

Wire Marker Color	Instrument Type
ORANGE	LOAD CELLS
RED	ACCELEROMETERS
BLUE	POTENTIOMETERS
BLACK	DGSP UNITS
YELLOW	TILT SENSORS

A complete listing of the instrumentation and related wire markers is listed in **Table 15.3** for reference. Please refer to the notes at the bottom of the table for further information.

Table 15.3

THOR COMPONENT AND SENSOR	WIRE
	MARKER
HEAD	
Uniaxial Accelerometer - CG (X axis)	HCGX{Red}1
Uniaxial Accelerometer - CG (Y axis)	HCGY{Red}1
Uniaxial Accelerometer - CG (Z axis)	HCGZ{Red}1
Uniaxial Accelerometer - Top (X axis)	HTX{Red}1
Uniaxial Accelerometer - Top (Y axis)	HTY{Red}1
Uniaxial Accelerometer - Side (X axis)	HSX{Red}1
Uniaxial Accelerometer - Side (Z axis)	HSZ{Red}1
Uniaxial Accelerometer - Rear (Y axis)	HRY{Red}1
Uniaxial Accelerometer - Rear (Z axis)	HRZ{Red}1
FACE	
Eye Uniaxial Compression Load Cell (Right)	FEER{Orange}LC
Eye Uniaxial Compression Load Cell (Left)	FEEL{Orange}LC
Cheek Uniaxial Compression Load Cell (Right)	FCKR{Orange}LC

Cheek Uniaxial Compression Load Cell (Left)	FCKL{Orange}LC
Chin Uniaxial Compression Load Cell (Middle)	FCNM{Orange}LC
NECK	
Lower Load Cell (6 axis)	LN{Orange}**
Upper Load Cell (6 axis)	UN{Orange}**
Neck Rear Spring Load Cell	NKR{Orange}LC
Neck Front Spring Load Cell	NKF{Orange}LC
Neck Condyle Pin Rotary Potentiometer	NKC{Blue}RP
MID-STERNUM	
Mid-Sternum Uniaxial Accelerometer	MID{Red}1
UPPER ABDOMEN	
Upper Abdomen Uniaxial Accelerometer	UA{Red}1
Upper Abdomen String Potentiometer	UA{Blue}SP
LOWER ABDOMEN	
Left Hand Side DGSP - 3 Dimensional Deflection	DP#{Black}L
Right Hand Side DGSP - 3 Dimensional Deflection	DP#{Black}R
THORAX	
Triaxial Accelerometer - Thorax CG	TX-*{Red}3
Upper Left CRUX Unit - 3 Dimensional Deflection	CX#-UL
Upper Right CRUX Unit - 3 Dimensional Deflection	CX#-UR
Lower Left CRUX Unit - 3 Dimensional Deflection	CX#-LL
Lower Right CRUX Unit - 3 Dimensional Deflection	CX#-LR
SPINE	
T12 - Thoracic Load Cell (Fx, Fy, Fz, Mx, My)	T12{Orange}**
Triaxial Accelerometer - T1 Location	T1-*{Red}3
Triaxial Accelerometer - T12 Location	T12*{Red}3
PELVIS	
Triaxial Accelerometer - Pelvis CG	PL-*{Red}3
Pelvic Acetabular Load Cell (Right)	PAR{Orange}F*
Pelvic Acetabular Load Cell (Left)	PAL{Orange}F*

Pelvic Iliac Crest Load Indicator (Right)	ICR{Orange}LC
Pelvic Iliac Crest Load Indicator (Left)	ICL{Orange}LC
FEMUR	
Femur Load Cell (Right)	FMR{Orange}**
Femur Load Cell (Left)	FML{Orange}**
KNEE	
Knee Rotation	K@{Blue}RP
Knee Shear Displacement	K@{Blue}SD
LOWER EXTREMITY	
Lower Tibia Load Cell (Fx, Fy, Fz, Mx, My)	LT@{Orange}**
Upper Tibia Load Cell (Fx, Fz, Mx, My)	UT@{Orange}**
Ankle Rotation	AK@{Blue}R*
TILT SENSORS	
Neck Tilt Sensor	T{Yellow}NECK
Thoracic Tilt Sensor	T{Yellow}LTS
Lumbar Tilt Sensor	T{Yellow}LUM
Pelvic Tilt Sensor	T{Yellow}PEL
Head Tilt Sensor	T{Yellow}HEAD

Notes:

Colors in { } indicate a blank space of the corresponding color.
*   Indicates X, Y, or Z axis
** Indicates Force X,Y,Z or Moment X, Y, Z (i.e. FX, MX)
#   Indicates POT # 1, 2, or 3
@   Indicates L for left, R for right

15.4 THOR Instrumentation Wiring

Based on the user's preference and requirements, the THOR can be supplied with either of the two possible wiring options described below. Select the description that matches your configuration and follow the wiring instructions.

15.4.1 Wiring Option #1

The THOR units may be sold with the instrument wires left unterminated (bare ends) for the individual users to attach the connector of their choice. This allows the user to select the appropriate connector to mate with their DAS system. All of the load cells and accelerometers will be provided with their own individual calibration sheets which contain the necessary wiring information. For the CRUX, DGSP, string potentiometer, and the rotary potentiometers, refer to the wiring directions provided below.

Neck Condyle Pin Rotary Potentiometer- (wire marker NKC{Blue}RP)
Upper Abdomen String Potentiometer- (wire marker UA{Blue}SP)
Knee Shear Displacement- (marked KL{Blue}SD or KR{Blue}SD)
Ankle- X Rotary Potentiometer- (marked AKL{Blue}RX or AKR{Blue}RX)
Ankle- Y Rotary Potentiometer-(marked AKL{Blue}RY or AKR{Blue}RY)
Ankle- Z Rotary Potentiometer- (marked AKL{Blue}RZ or AKR{Blue}RZ)

Function	Wire Color
+ Excitation	Red
Ground	Black
+ Signal	Green

DGSP Assemblies- (wire marker DP#{Black}L and DP#{Black}R)
where # indicates Pot #1, 2, or 3

Potentiometer:	Function:	Wire Color:
String Pot (#1)	+ Excitation	Red
	Ground	Black
	+ Signal	Green
Top Pot (#2)	+ Excitation	Orange
	Ground	Black Stripe
	+ Signal	Blue
Side Pot (#3)	+ Excitation	Red Stripe
	Ground	Gray
	+ Signal	White

CRUX Assemblies- (wire marker CX*-UR, CX*-UL, CX*-LR, CX*-LL)
where * indicates Pot #1, 2, or 3

Potentiometer:	Function:	Wire Color:
Base Pot (#1)	+ Excitation	Red
	Ground	Black
	+ Signal	Green
Mid Pot (#2)	+ Excitation	Orange
	Ground	Black Stripe
	+ Signal	Blue

Elbow Pot (#3)	+ Excitation	Red Stripe
	Ground	Gray
	+ Signal	White

15.4.2 Wiring Option #2

As an alternative, the manufactures may supply the THOR units pre-wired with 4 pin LEMO connectors to mate with a set of connector wires as described below. This option is particularly advantageous if numerous test labs will be sharing the same THOR, or the labs will use different DAS systems which have incompatible connectors. Several sets of bundle wires can be made up for THOR which will allow compatibility with various DAS connector configurations. In this wiring option, all of the THOR instrumentation is pre-wired with male 4 Pin LEMO connectors. The Connector Wires feature a mating 4 pin LEMO connector on one end to fit the THOR unit's LEMO connectors and a bare wire at the other end. The bare end of the connector wire can be soldered to the appropriate connector necessary for mating with the testing laboratory data acquisition system. Each connector wire is individually marked to mate with a specific instrument on the THOR. **Table 15.4** describes the correct wire color assignments for the connector wires. This table should provide all of the necessary information to correctly wire the appropriate mating connectors for the laboratory data acquisition system.

TABLE 15.4

Face Compression Load Cells- (wire marker F***{Orange}LC, where *** donates position)
Neck Spring Load Cells- (wire marker NKF{Orange}LC and NKR{Orange}LC)
Pelvic Iliac Load Indicators- (wire marker ICL{Orange}LC and ICR{Orange}LC)

Function	Wire Color
+ Excitation	Red
- Excitation	Black
+ Signal	Green
- Signal	White

Uniaxial Accelerometers- (wire marker ***{Red}1, where *** donates position)

Function	Wire Color
+ Excitation	Red
- Excitation	Black
+ Signal	Green
- Signal	White

Upper Neck Load Cell- (wire marker UN{Orange}**)
where ** indicates Force X, Y, Z or Moment X, Y, Z

Lower Neck Load Cell- (wire marker LN{Orange}**)
where ** indicates Force X, Y, Z or Moment X, Y, Z

Femur Load Cell - (marked FML{Orange}** and FMR{Orange}**)
where ** indicates Force X, Y, Z or Moment X, Y, Z

Forces:

Axis:	Function:	Wire Color:
X,Y,Z	+ Excitation	Red
	- Excitation	Black
	+ Signal	Green
	- Signal	White

Moments:

Axis:	Function:	Wire Color:
X,Y,Z	+ Excitation	Red
	- Excitation	Black
	+ Signal	Green
	- Signal	White

T12 Load Cell - (wire marker T12{Orange}**)
where ** indicates Force X, Y, Z or Moment X, Y

Lower Tibia Load Cell - (marked LTL{Orange}**and LTR{Orange}**)
where ** indicates Fx, Fy, Fz, Mx, or My

Upper Tibia Load Cell - (marked UTL{Orange}**and UTR{Orange}**)
where ** indicates Fx, Fz, Mx, or My

Forces:

Axis:	Function:	Wire Color:
X,Y*,Z	+ Excitation	Red
	- Excitation	Black
	+ Signal	Green
	- Signal	White

Moments:

Axis:	Function:	Wire Color:
X,Y	+ Excitation	Red
	- Excitation	Black
	+ Signal	Green
	- Signal	White

* Upper Tibia Load cell excludes Fy capability.

Neck Condyle Pin Rotary Potentiometer- (wire marker NKC{Blue}RP)
Upper Abdomen String Potentiometer- (wire marker UA{Blue}SP)
Knee Shear Displacement- (marked KL{Blue}SD or KR{Blue}SD)

Ankle- X Rotary Potentiometer (marked AKL{Blue}RX or AKR}Blue}RX)
Ankle- Y Rotary Potentiometer (marked AKL{Blue}RY or AKR}Blue}RY)
Ankle- Z Rotary Potentiometer (marked AKL{Blue}RZ or AKR}Blue}RZ)

Function	Wire Color
+ Excitation	Red
Ground	Black
+ Signal	Green

DGSP Assemblies- (wire marker DP#{Black}L and DP#{Black}R)
where # indicates Pot #1, 2, or 3

Potentiometer:	Function:	Wire Color:
String Pot (#1)	+ Excitation	Red
	Ground	Black
	+ Signal	Green
Top Pot (#2)	+ Excitation	Red
	Ground	Black
	+ Signal	Green
Side Pot (#3)	+ Excitation	Red
	Ground	Black
	+ Signal	Green

CRUX Assemblies- (wire marker CX*-UR, CX*-UL, CX*-LR, CX*-LL)
where * indicates Pot #1, 2, or 3

Potentiometer:	Function:	Wire Color:
Base Pot (#1)	+ Excitation	Red
	Ground	Black
	+ Signal	Green
Mid Pot (#2)	+ Excitation	Red
	Ground	Black
	+ Signal	Green
Elbow Pot (#3)	+ Excitation	Red
	Ground	Black
	+ Signal	Green

Pelvic Acetabular Load Cell- (wire marker PAL{Orange}F*and PAR{Orange}F*)
where * indicates Force X, Y, or Z

Forces:

Axis:	Function:	Wire Color:
X,Y,Z	+ Excitation	Red
	- Excitation	Black
	+ Signal	Green
	- Signal	White

15.5 Instrumentation Excitation and Ground Requirements

For all the instrumentation on the THOR dummy, the excitation voltage and ground requirements are supplied below. All instrumentation for this dummy was designed for the same excitation requirements, thus simplifying the power requirements. The current requirements are minimal, i.e. 100 mA per instrument is more than sufficient.

All + Excitation Terminals must be connected to a 10.00 (+/- 0.05) V DC power supply.
All - Excitation Terminals must be connected to a ground (i.e. 0.0 V DC) source.
All Ground Terminals must be connected to a ground (i.e. 0.0 V DC) source.
All Shield Wires (which connect through the LEMO connector) must be terminated to ground at the DAS end of the wire.

15.6 Data Acquisition

Proper connection of the THOR instrumentation to the laboratory data acquisition system is essential to the correct measurement of the various forces, moments, accelerations, and deflections. **Table 15.5** provides a reference to the proper data acquisition requirements for each channel. These requirements include the channel configuration and range requirements for each of the THOR instruments.

The data acquisition channel configuration defines how to measure the voltage difference for the output of each channel. For all of the instruments of the THOR dummy, the channel configuration is either differential or referenced single-ended. The term DIFF denotes a differential configuration in which the + Signal lead is connected to a HI input channel and the - Signal lead is connected to a LO input channel. The data acquisition system is then configured as a differential input to measure the voltage difference between the HI and LO channel inputs.

WARNING: Do not connect the - Signal lead to ground or the instrumentation may be permanently damaged.

For typical data acquisition systems, differential input configurations require two channels of the data acquisition system for each instrument channel (i.e. a HI and LO channel for each axis of a load cell, etc.). All load cells and accelerometers used in the THOR instrumentation require a differential configuration for the proper data acquisition.

The term RSE denotes a referenced single-ended configuration in which the + Signal lead is connected to a HI input channel. The data acquisition system is then configured as a referenced single-ended input to measure the voltage difference between the HI channel input and the ground reference.

In addition to the channel configuration, the other critical information needed to set up the data acquisition for THOR is the expected output voltage range for each of the instruments. This output voltage range is used to adjust the individual channel sensitivity of the data acquisition system to obtain the highest possible data resolution. The use of the output voltage ranges listed in the table will ensure that none of the data is clipped for extreme loading that may occur.

In the following table, a "**" indicates that additional information has been provided for these instruments and further details can be found immediately following the table. In addition, the instruments which have multiple channels have been noted in the table.

TABLE 15.5

THOR COMPONENT AND SENSOR	DAQ Configuration	Output Voltage Range
HEAD		
Uniaxial Accelerometer - Head CG (X axis)	DIFF	-0.5 to 0.5 V
Uniaxial Accelerometer - Head CG (Y axis)	DIFF	-0.5 to 0.5 V
Uniaxial Accelerometer - Head CG (Z axis)	DIFF	-0.5 to 0.5 V
Uniaxial Accelerometer - Top (X axis)	DIFF	-0.5 to 0.5 V
Uniaxial Accelerometer - Top (Y axis)	DIFF	-0.5 to 0.5 V
Uniaxial Accelerometer - Side (X axis)	DIFF	-0.5 to 0.5 V
Uniaxial Accelerometer - Side (Z axis)	DIFF	-0.5 to 0.5 V
Uniaxial Accelerometer - Rear (Y axis)	DIFF	-0.5 to 0.5 V
Uniaxial Accelerometer - Rear (Z axis)	DIFF	-0.5 to 0.5 V
FACE		
Face Compression Load Cells (5 load cells)	DIFF	-20 to 20 mV
NECK		
Lower Load Cell	DIFF (6 CH)	-30 to 30 mV
Upper Load Cell	DIFF (6 CH)	-30 to 30 mV
Neck Rear Spring Load Cell	DIFF	-20 to 20 mV
Neck Front Spring Load Cell	DIFF	-20 to 20 mV
*Neck Condyle Pin Rotary Potentiometer	RSE	0 to 10 V
MID-STERNUM		
Mid-Sternum Uniaxial Accelerometer	DIFF	-0.5 to 0.5 V

UPPER ABDOMEN		
Upper Abdomen Uniaxial Accelerometer	DIFF	-0.5 to 0.5 V
*Upper Abdomen String Potentiometer	RSE	0 to 10 V
LOWER ABDOMEN		
*Left Hand Side DGSP - 3D Deflection	RSE (3 CH)	0 to 10 V
*Right Hand Side DGSP - 3D Deflection	RSE (3 CH)	0 to 10 V
THORAX		
Tri-pack Accelerometer - Thorax CG	DIFF (3 CH)	-0.5 to 0.5 V
*Upper Left CRUX Unit - 3D Deflection	RSE (3 CH)	0 to 10 V
*Upper Right CRUX Unit - 3D Deflection	RSE (3 CH)	0 to 10 V
*Lower Left CRUX Unit - 3D Deflection	RSE (3 CH)	0 to 10 V
*Lower Right CRUX Unit - 3D Deflection	RSE (3 CH)	0 to 10 V
SPINE		
T12 Thoracic Load Cell (Fx, Fy, Fz, Mx, My)	DIFF (5 CH)	-30 to 30 mV
Tr-pack Accelerometer - T1 Location	DIFF (3 CH)	-0.5 to 0.5 V
Tri-pack Accelerometer - T12 Location	DIFF (3 CH)	-0.5 to 0.5 V
PELVIS		
Tri-pack Accelerometer - Pelvis CG	DIFF (3 CH)	-0.5 to 0.5 V
Right and Left Pelvic Acetabular Load Cell	DIFF (3 CH)	-30 to 30 mV
**Right and Left Pelvic Iliac Crest Load Indicator	DIFF	-30 to 30 mV
FEMUR		
Right and Left Femur Load Cell	DIFF (6 CH)	-30 to 30 mV
KNEE		
*Right & Left Knee Shear Displacement	RSE	0 to 10 V
LOWER EXTREMITY		
Right and Left Lower Tibia Load Cell (Fx, Fy, Fz, Mx, My)	DIFF (5 CH)	-30 to 30 mV
Right and Left Upper Tibia Load Cell (Fx, Fz, Mx, My)	DIFF (4 CH)	-30 to 30 mV

Right and Left Tibia Accelerometer (X,Y axis)	DIFF	-0.5 to 0.5 V
Right and Left Foot Accelerometer (X,Y,Z axis)	DIFF	-0.5 to 0.5 V
*Right and Left Ankle Rotation (X,Y,Z)	RSE	0 to 10 V

* The output signal for all potentiometers are measured with reference to Ground for the data acquisition.

** The purpose of the iliac load indicators are to indicate if the lap belt is correctly loading the iliac crest or if the belt has slipped out of position. This instrument was not designed to provide a measurement of belt load or provide a quantitative measurement of belt loading.

15.6.1 Thor Instrumentation Polarity Check

Table 15.6 compares the polarity for the Thor dummy to the SAE-J211 standard for each sensor. All instruments to be checked are assumed to be properly assembled into the dummy as specified in this user's manual. Although, in order to perform the Crux manipulations, as described in the table below, the front of each Crux unit should be detached from the front of the rib. The Crux manipulations should be performed with care to prevent over ranging the potentiometers when manipulated past the design range of motion of each unit (refer to Section 16 - Crux Units, for more details). There is a mechanical stop internal to the sensor that will become damaged if rotated past this point. The unit only needs to be rotated slightly to see a voltage change to check for its polarity. After the Crux manipulations are complete, the units should be reattached to the front of the rib cage. Refer to Section 9.2.3- Installing the Upper Abdomen in Thor, for detailed instructions on how to reattach the front of each Crux unit to the front of the rib cage.

WARNING: The Crux manipulations should be performed with care to prevent over ranging the potentiometers when manipulated past the design range of motion of each unit.

The T1, T12, Chest CG, and Pelvis CG accelerometers listed in **Table 15.6** are the tri-pack configuration. The tri-pack configuration uses three uniaxial accelerometers mounted onto a tri-pack block (T1INM130) to measure accelerations along the X, Y, and Z axes at the seismic center of the three units attached to the block. **Table 15.7** describes the accelerometer polarity of the Thor dummy to the SAE J211 standard if the alternate units (triaxial accelerometers) are used at the T1, T12, Chest CG, and Pelvis CG locations on the dummy. The triaxial accelerometer is a single unit that measures accelerations along the X, Y, and Z axes. Due to the wire routing of the T1 triaxial accelerometer (T1INM120). The T1 triaxial accelerometer is assembled into the dummy as specified in Section 6.2.2 - Assembling the Spine Components, with the +X axis pointing rearward, +Y axis pointing downward, and +Z axis pointing to the right. This orientation does not agree with the SAE-J211 standard. Adjustments can be easily made at the software side of the data acquisition system or the wiring of the sensor at the connector end, to get it to agree with the SAE-J211 standard.

TABLE 15.6:THOR INSTRUMENTATION POLARITY CHECK

Head & Neck

Instrument	Direction	Motion	SAE-J211 Polarity	THOR Polarity
Head Accelerometers (CG, top, rear, & side)	Ax	Impact back of head	+	+
	Ay	Impact left side of head	+	+
	Az	Impact top of head	+	+
Upper Neck Load Cell[c]	Fx	Move head rear, chest forward	+	+
	Fy	Move head left, chest right	+	+
	Fz	Move head up, chest down	+	+
	Mx	Rotate left ear toward left shoulder	+	+
	My	Rotate chin toward sternum	+	+
	Mz	Rotate chin toward left shoulder	+	+
Lower Neck Load Cell[c]	Fx	Move head rear, chest forward	+	+
	Fy	Move head left, chest right	+	+
	Fz	Move head up, chest down	+	+
	Mx	Rotate left ear toward left shoulder	+	+
	My	Rotate chin toward sternum	+	+
	Mz	Rotate chin toward left shoulder	+	+
Front Neck Spring	Fz	Rotate head rearward	NA	+
Rear Neck Spring	Fz	Rotate chin toward chest	NA	+
O.C. Rotary Pot	2_y	Rotate chin toward chest	NA	+
Face Load Cells	Fx	Hold back of head, push face rearward	NA	+

Spine and Thorax

Instrument	Direction	Motion	SAE-J211 Polarity	THOR Polarity
T1 Accelerometer (Tri-pack)[b]	Ax	Impact back of spine	+	+
	Ay	Impact left shoulder	+	+
	Az	Impact top of shoulder	+	-

Instrument	Direction	Motion	SAE-J211 Polarity	THOR Polarity
Chest CG Accelerometer (Tri-pack)[b]	Ax	Impact back of spine	+	-
	Ay	Impact left shoulder	+	+
	Az	Impact top of shoulder	+	-
T12 Accelerometer (Tri-pack)[b]	Ax	Impact back of spine	+	-
	Ay	Impact left shoulder	+	-
	Az	Impact top of shoulder	+	-
T12 Load Cell[c]	Fx	Move chest rear, pelvis forward	+	+
	Fy	Move chest left, pelvis right	+	+
	Fz	Move chest up, pelvis down	+	+
	Mx	Rotate left shoulder toward left hip	+	+
	My	Rotate sternum towards front of legs	+	+
Upper Right Crux		Refer to **Figure 15.5** for illustration		
UR Base pot (Pot 1)	2_1	Hold base, rotate rear arm upward	NA	+
UR Mid pot (Pot 2)	2_2	Hold base, rotate rear arm CW[a]	NA	+
UR Elbow pot (Pot 3)	2_3	Hold rear arm, rotate front arm CW[a]	NA	+
Upper Left Crux		Refer to **Figure 15.6** for illustration		
UL Base pot (Pot 1)	2_1	Hold base, rotate rear arm downward	NA	+
UL Mid pot (Pot 2)	2_2	Hold base, rotate rear arm CW[a]	NA	+
UL Elbow pot (Pot 3)	2_3	Hold rear arm, rotate front arm CW[a]	NA	+
Lower Right Crux		Refer to **Figure 15.5** for illustration		
LR Base pot (Pot 1)	2_1	Hold base, rotate rear arm CCW[a]	NA	+
LR Mid pot (Pot 2)	2_2	Hold base, rotate rear arm downward	NA	+
LR Elbow pot (Pot 3)	2_3	Hold rear arm, rotate front arm downward	NA	+
Lower Left Crux		Refer to **Figure 15.6** for illustration		
LL Base pot (Pot 1)	2_1	Hold base, rotate rear arm CCW[a]	NA	+
LL Mid pot (Pot 2)	2_2	Hold base, rotate rear arm upward	NA	+
LL Elbow pot (Pot 3)	2_3	Hold rear arm, rotate front arm upward	NA	+

Abdomen

Instrument	Direction	Motion	SAE-J211 Polarity	THOR Polarity
Upper Abdomen Accelerometer	Ax	Impact front of abdomen	-	+
Upper Abdomen String pot	Dx	Move front face of upper abdomen rearward	-	+
Right DGSP		Refer to **Figure 15.7** for illustration		
R. string pot (Pot 1)	Dx	Move DGSP tube rearward	NA	+
R. Z-axis pot (Pot 2)	2	Rotate DGSP tube CCW[a]	NA	+
R. Y-axis pot (Pot 3)	R	Rotate DGSP tube downward	NA	+
Left DGSP		Refer to **Figure 15.8** for illustration		
L. string pot (Pot 1)	Dx	Move DGSP tube rearward	NA	+
L. Z-axis pot (Pot 2)	2	Rotate DGSP tube CCW[a]	NA	+
L. Y-axis pot (Pot 3)	R	Rotate DGSP tube upward	NA	+

Pelvis

Instrument	Direction	Motion	SAE-J211 Polarity	THOR Polarity
Pelvis CG Accelerometer (Tri-pack)[b]	Ax	Impact back of pelvis	+	+
	Ay	Impact left side of pelvis	+	+
	Az	Impact bottom of pelvis	-	-
L Acetabular LC[c]	Fx	Move femur forward, pelvis rear	+	+
	Fy	Move femur right, pelvis left	+	+
	Fz	Move femur down, pelvis up	+	+
R Acetabular LC[c]	Fx	Move femur forward, pelvis rear	+	+
	Fy	Move femur right, pelvis left	+	+
	Fz	Move femur down, pelvis up	+	+
L & R Iliac LC	Fx	Apply load front to back to the Iliac	-	+

Femur (L&R)

Instrument	Direction	Motion	SAE-J211 Polarity	THOR Polarity
Femur Load Cell[c]	Fx	Move knee upward, upper femur down	+	+
	Fy	Move knee right, upper femur left	+	+
	Fz	Move knee forward, femur rear	+	+
	Mx	Rotate knee left, hold upper femur	+	+
	My	Rotate knee up, hold upper femur	+	+
	Mz	Rotate tibia left, hold pelvis	+	+

Lower Extremity (L&R)

Instrument	Direction	Motion	SAE-J211 Polarity	THOR Polarity
Knee Rotation	2_y	Extension	NA	NA
Knee Shear Displacement	Dx	Hold Femur in Place, Tibia Forward	+	+
Upper Tibia Load Cell	Fx	Tibia Forward, Knee Rearward	+[d]	+
	Fz	Tibia Downward, Femur Upward	+	+
	Mx	Ankle Leftward, Hold Knee in Place	+	+
	My	Ankle Forward, Hold Knee in Place	+	+
Lower Tibia Load Cell	Fx	Ankle Forward, Knee Rearward	+	+
	Fy	Ankle Rightward, Knee Leftward	+	+
	Fz	Ankle Downward, Knee Upward	+	+
	Mx	Ankle Leftward, Hold Knee in Place	+	+
	My	Ankle Forward, Hold Knee in Place	+	+
Tibia Accelerometer	Ax	Impact rear of tibia below tibia puck	+	+
	Ay	Impact left of tibia below tibia puck	+	+
Achilles Tendon Load Cell	Dz	Tension in Cable	NA	NA
Ankle X-axis Rotation	2_x	Hold tibia, rotate foot bottom leftward [e]	NA	+
Ankle Y-axis Rotation	2_y	Hold tibia, rotate foot up	NA	+

Instrument	Direction	Motion	SAE-J211 Polarity	THOR Polarity
Ankle Z-axis Rotation	2_z	Hold tibia, rotate foot CW [f]	NA	+
Foot Accelerometer	Ax	Impact rear of foot	+	+
	Ay	Impact left side of foot	+	+
	Az	Impact top of foot	+	+

NA = Not Applicable
[a] = As seen from above, looking down
[b] = Tri-pack refers to three uniaxial accelerometers mounted onto a tri-pack block (T1INM130)
[c] = Output polarity has been adjusted to conform to SAE-J211
[d] = SAE J211 polarity output was defined by the right-hand rule
[e] = Rotation of foot clockwise as seen from behind, looking forward
[f] = As seen from above, looking down

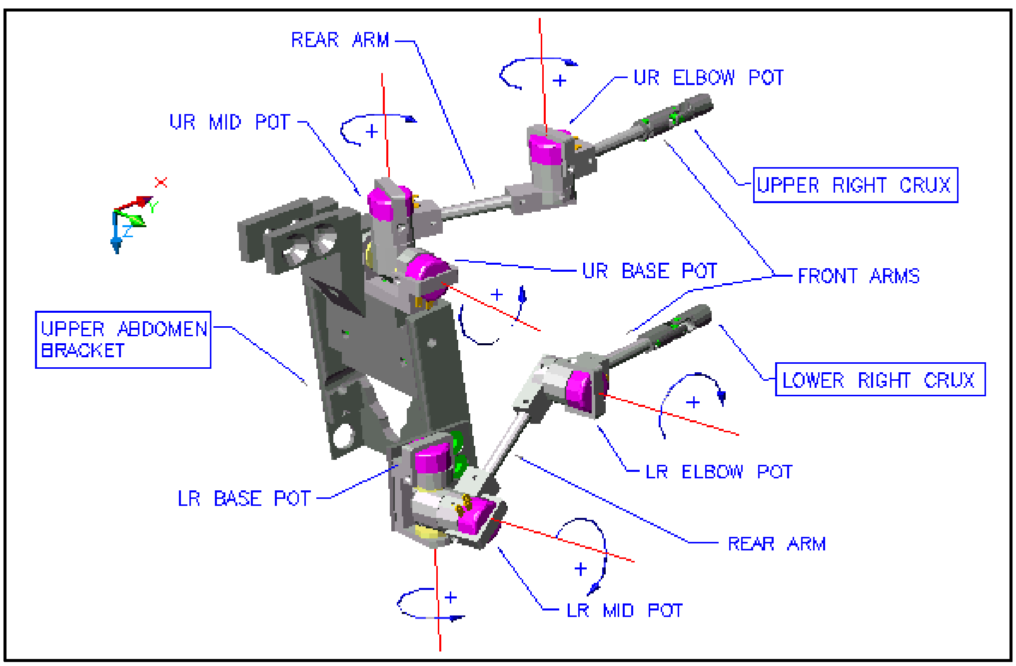

Figure 15.8- Thor polarity for the UR and LR Cruxes

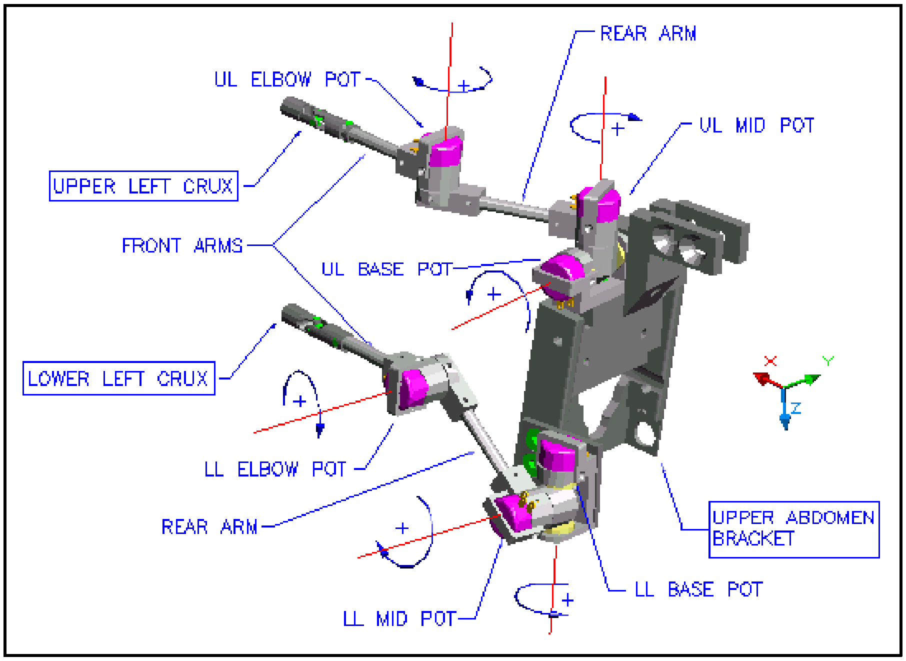

Figure 15.9- Thor polarity for the UL and LL Cruxes

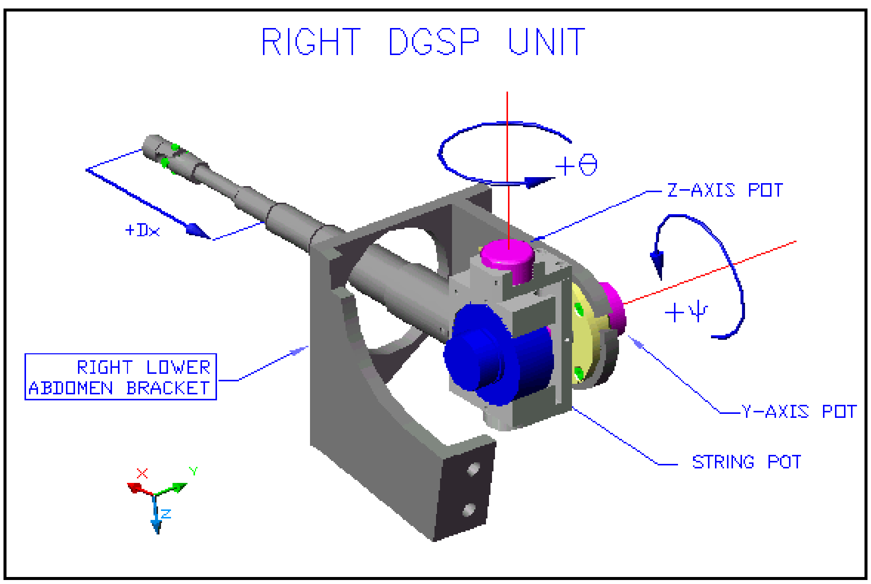

Figure 15.10- Thor polarity for the right DGSP unit

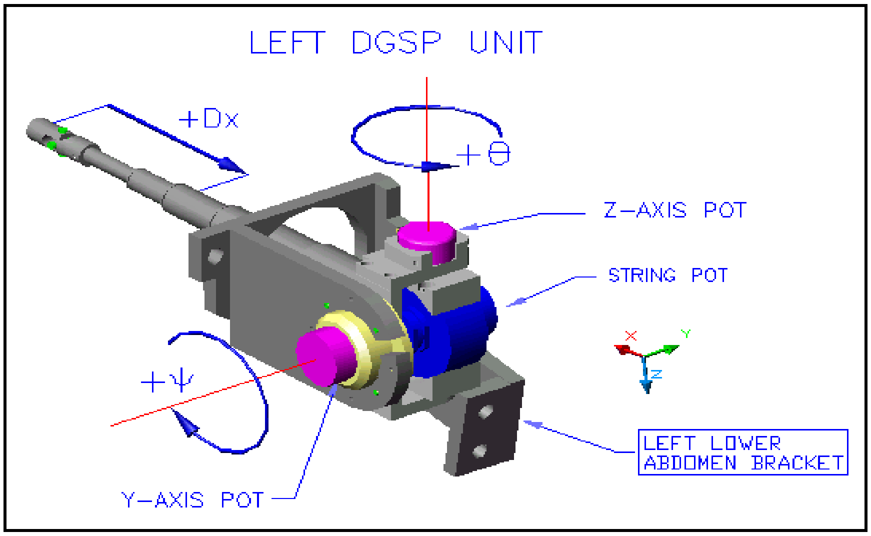

Figure 15.11- Thor polarity for left DGSP unit

TABLE 15.7:THOR TRIAXIAL ACCELEROMETERS POLARITY CHECK

Instrument	Direction	Motion	SAE-J211 Polarity	THOR Polarity
T1 Accelerometer (Triaxial cube)[a]	Ax	Impact back of spine	+	-
	Ay[b]	Impact left shoulder	+Ay	+Az
	Az[b]	Impact top of shoulder	+Az	+Ay
Chest CG Accelerometer (Triaxial cube)[a]	Ax	Impact back of spine	+	+
	Ay	Impact left shoulder	+	-
	Az	Impact top of shoulder	+	-
T12 Accelerometer (Triaxial Cube)[a]	Ax	Impact back of spine	+	+
	Ay	Impact left shoulder	+	+
	Az	Impact top of shoulder	+	+
Pelvis CG Accelerometer (Triaxial Cube)[a]	Ax	Impact back of pelvis	+	+
	Ay	Impact left side of pelvis	+	+
	Az	Impact bottom of pelvis	-	-

Note: THOR-Lx instrumentation polarities are included in the THOR-Lx (Mid-Male) Hybrid III Retrofit User's Manual.

[a] = Triaxial cube refers to a single unit triaxial accelerometer that measures accelerations in three axes.
[b] = In Thor, the +Z axis of the accelerometer is pointing toward the right of the dummy and the +Y axis is pointing down.

15.7 THOR Instrumentation - Sensor Evaluation Device (SED)

A hand-held sensor evaluation device (SED) has been designed for use with the THOR dummy. The SED is typically supplied with leased dummies, and is available for purchase as an accessory for commercial sales. This device helps to identify trouble with the instruments and wiring in a laboratory setting. The device was constructed to operate at 120 V AC power, and is designed for use with standard LEMO connectors provided on the leased THOR dummies. Adaptor cables are available for connecting the commercial THOR units to the laboratory's preferred connector system. The SED panel is shown in **Figure 15.12**.

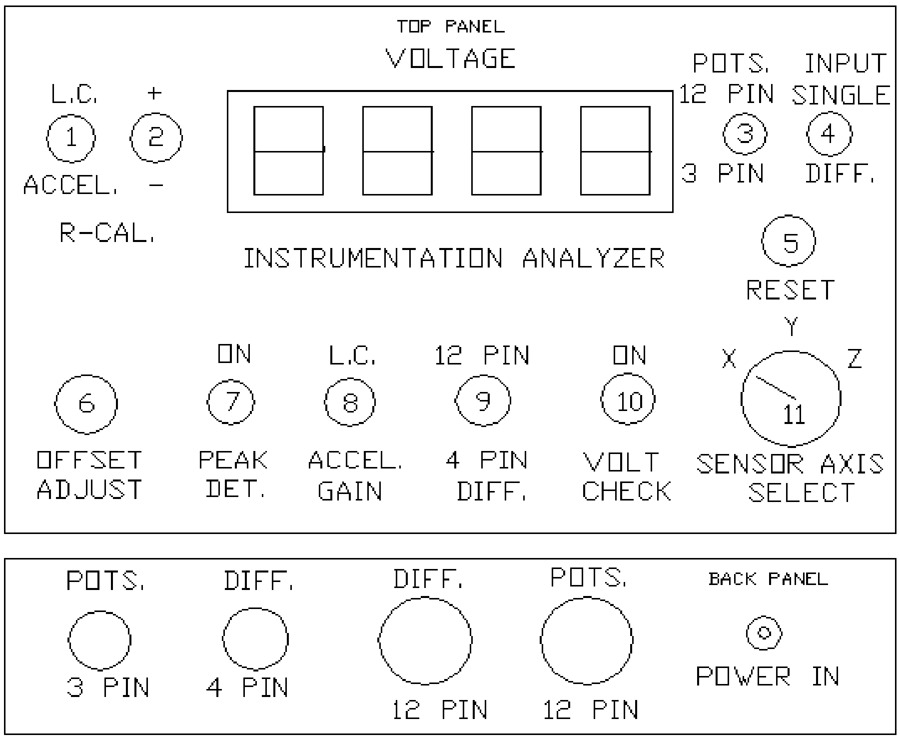

Figure 15.12- Sensor Evaluation Device (SED) Panel

The following procedure details the use and function of the SED.

1. Applying Power: The instrument may be powered using the 120 volt AC to 15 volt DC wall adapter, or using the banana plug adapter cable, connect the instrument to 15-18 volt DC from a DC power supply. Allow a 5-10 minute warm-up period for best results.

2. Excitation Voltage: First, ensure the calibration toggle switch #2 is in the center (OFF) position, and that the peak detector toggle switch #7 is in the down (OFF) position. The sensor bridge excitation voltage may be checked by placing toggle switch #10 in the up (ON) position. After the warm up-period, the display should read 10.00 ± .02 volts D.C.

max. Switch #10 should normally be in the down (OFF) position.

3. Load Cells: To qualitatively check load cells, first place toggle switch # 9 in the position for a 4-pin or 12-pin connector after inserting the LEMO plug into the differential socket on the rear panel; be sure you are not in the 12-pin potentiometer LEMO socket if testing a tri-axial unit (see diagram on back). Also, ensure the calibration toggle switch #2 is in the center, OFF, position, and that switch #7 is in the down (OFF) position. Make sure Toggle switch #4 is in the DIFF. (Differential)Position. The three- position rotary switch #11, alternately selects theX, Y, or Z axis. First, place toggle switch #8 in the UP position for load cell gains and then adjust the output voltage to a nominal 5.00 volts DC using the offset rotary potentiometer, #6. Next, activate the peak detector circuit by placing toggle switch #7 in the on (UP) position. The voltage display may read a voltage greater than 5 volts so reset the circuit by depressing momentary reset switch #5. The display voltage will then drift toward 5 volts. Apply a moderate force or torque to the load cell and observe a significant voltage change on the output display. If the display does not change more than a few tenths of a volt, repeat applying a larger force. If the voltage still does not change significantly, the sensor may not be functioning correctly.

4. Accelerometers: After plugging in the LEMO to the appropriate 12-triaxial or 4-pin uniaxial rear panel connector, select the 4- or 12-pin position with toggle switch #9. Put toggle switch #8 in the accelerometer (DOWN) position. Ensure switch #2 is in the center (OFF) position and that the peak detector, switch #7, is OFF. Toggle switch #4 should again be set to the DIFF position. Adjust the output to a nominal 5 volts D.C. using the offset adjust rotary potentiometer #6. Turn on the peak detector circuit, switch #7 and reset any residual voltage using the reset button #5. Apply a significant acceleration to the sensor in the direction of sensitivity and observe a significant voltage change on the output. If the display does not change more than a few tenths of a volt apply a larger acceleration. If the voltage still does not change more than a few tenths of a volt, the sensor may be defective.

5. Potentiometer Sensors: Potentiometers should use the 12-pin Pot connector or the single 3- pin Pot connector on the back panel. Again, make sure toggle switch #2 is in the center, OFF, position and that the peak detector circuit is OFF, with toggle switch #7 down. Select switch #3 for 3- or 12-pin connectors, and place toggle switch #4 in the Single-ended UP position. The output voltage display will read the wiper voltage of the potentiometer in volts. Because the Pots signals are not amplified, there will be no need to use the offset adjust. Varying the post of the dummy part on which the sensor is mounted will change the output voltage from ground to 10 volts DC.

6. Calibration: The calibration function applies a resistive shunt between the positive and negative voltage and the positive bridge output. Set both switches #1 and #8 to the load cell or accelerometer position. Turn off the peak detector switch, #7. Adjust the output voltage to a nominal 5 volts DC output using the offset adjust, #6. Push toggle switch #2 to the UP position, observe a voltage increase of several volts, and record the reading. Next, push switch #2 to the DOWN position and record the decreased voltage reading.

A perfectly balance bridge should be displaced by the same voltage in each direction. If the voltage is highly non-symmetric about the 5 volt value, the bridge could be outside of its specification tolerance. The instrument gains for the load cell and accelerometer switch positions are 5741.1 and 147.9 respectively. The shunt resistors for the load cell and accelerometer positions are 3.34 Meg. and 99.14K ohms respectively. Knowing the sensor sensitivity and shunt resistor loading from the sensor data sheet, the actual expected R-Cal offset voltage may be calculated.

15.8 Tilt Sensors and Readout Display

In the past, one of the most difficult problems with automotive crash testing has been the difficulty in reproducing the desired initial position of the dummies within the automobile. The task of positioning the THOR dummy within the test environment has been greatly simplified with the incorporation of five tilt sensors into the THOR dummy. One sensor has been mounted to each of the following segments of the dummy: the pelvis, the lumbar spine, the lower thoracic spine, the neck, and the head. These tilt sensors are used to provide a complete electronic orientation of the dummy's posture before and after the crash testing.

The tilt sensors must be installed into their mounting brackets with the proper orientation so the angular orientation of the components will be correctly displayed on the tilt sensor readout. Each tilt sensor is marked with a vertical line on the outside of the sensor housing. The tilt sensor must be positioned so this vertical line is toward the front (anterior) of the dummy. On each of the tilt sensor housings, there is a scribed line on the top surface to aid in aligning the vertical line on the tilt sensor with the line on the tilt sensor housing. The tilt sensors have been correctly positioned within their mounting brackets during the initial assembly of the dummy at GESAC. However, if it becomes necessary to remove the sensors from their brackets, it will be necessary to align the tilt sensors correctly during the reassembly.

During the positioning of the dummy within the automobile, each of the five tilt sensors are connected to a hand-held display. The tilt sensor display has been designed to accept the LEMO connectors directly from the five THOR tilt sensors. Each LEMO receptacle has been labeled for a particular tilt sensor. The calibration for each tilt sensor is stored in the tilt sensor display for a specific tilt sensor therefore the correct LEMO must be plugged into the correct receptacle. The sensitivity for each tilt sensor is preprogrammed into the tilt sensor display by the manufacturer. In the unlikely event that a tilt sensor becomes damage beyond repair by the customer, a new tilt sensor can be purchased from the manufacturer. However, the tilt sensor display must be returned to the manufacturer for reprogramming the new tilt sensor.

This display features an analog angle-conversion module and additional circuitry to convert the voltage output from the tilt sensor module to a display of the various angles in degrees. This tilt sensor unit was designed to make the task of repetitive dummy posture set-ups much easier. If the dummy is set into an initial desired posture - and the values for the various tilt sensors are recorded, then it is very easy to ensure that the same posture is used in a later test by positioning the dummy to obtain the same tilt sensor measurements. The tilt sensor wires are disconnected from the hand-held display prior to running the impact test. The use of the hand-held display is outlined in the process below.

1. Connect the five tilt sensor wires from the THOR dummy to the appropriate receptacle at the back of the hand-held display, as shown in **Figure 15.13**. (Note: All tilt sensor wires are marked with a yellow character in the marking strip to make identification easier.) Refer to the list below for the tilt sensor readout display instrumentation receptacle numbering scheme.

Sensor Wire Label	Tilt Sensor Readout Display Label
T{Yellow}HEAD	CH 0
T{Yellow}NECK	CH 1
T{Yellow}LTS	CH 2
T{Yellow}LUM	CH 3
T{Yellow}PEL	CH 4

Figure 15.13- Connecting tilt sensors to the display

2. Operate the tilt sensor readout display on a 9 V DC nominal power supply.

3. Press the power toggle switch, located at the front of the unit, to the "on" position. In addition, make sure that the RS232 toggle switch is in the "off" position. (**Note:** The RS232 toggle switch and the port located at the rear of the tilt sensor readout display are used by the manufacturer for programming the tilt sensor sensitivity values into the tilt sensor display unit. In the event that the sensitivity values will have to be modified from the pre-installed values (tilt sensor becomes damage), contact the manufacturer for assistance.) Rotate the centrally located knob to view the desired tilt sensor response. The tilt sensor numbering scheme for the various knob positions is the same as the instrumentation receptacle numbering scheme as described above. A picture of the front of the tilt sensor readout display is shown in **Figure 15.14**.

Figure 15.14- Front-view of tilt sensor readout display

NOTE: The tilt sensor readout display shows the rotation about the X and Y axis of the particular dummy component simultaneously.

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4. Read the displayed angles (X and Y angular orientation) for all five tilt sensors and record for future reference. This information will provide a reference which can be used to correctly position the dummy for future tests.

NOTE: The angle values produced by the tilt sensor display are absolute. It measures the angle of the particular dummy component relative to ground.
