USER MANUAL

3D IR-TRACC THOR-50M

THOR-50M 3D IR-TRACC User Manual TF-472-6000-9900

HUMANETICS
Innovative Solutions

Contents

1 Introduction

A 3D IR-TRACC (Infrared - Telescoping Rod for Assessment of Chest Compression) is a 3-dimensional chest and abdomen deformation sensor for application in the THOR frontal impact dummy. The purpose is to obtain deformation data of the dummy that represent body segment injury. The work flow of working with these sensors is a guideline for the structure of this manual. After this introduction, the 2nd paragraph is a general description of the sensors in the dummy and how individual sensors can be identified. In this section the coordinate systems for the 3- dimensional measurements are defined. In paragraph 3, details of the assemblies are shown, including exploded views, parts lists and assembly instructions. Section 4 talks about individual transducer calibration: IR-TRACC displacement calibration Tubes-In-Out and angle sensor calibration. In paragraph 5 detailed instructions are provided on zero-position verification, the use of the zero-position fixture and data collections template. Also, implementation of calibration parameters in data acquisition systems are presented and proposals for the use of ISO codes for data channels are provided. In paragraph 6 the focus is on 3D sensor data processing, coordinate system transformation from polar to Cartesian coordinate systems and results calculation. Paragraph 7 provides advice for dealing with 3D IR-TRACC transducers in day to day lab practice. Detailed definitions of parameters, symbols and units are given in Appendix A and the mathematical background of the formulas in this document is given in **Appendix B**.

2 3D IR-TRACCs

2.1 Description

The THOR-50M Frontal Anthropomorphic Test Device (ATD) is equipped with six 3-dimensional position transducers in the chest and abdomen to measure deformation as (chest and abdomen) injury parameters. The transducers are called 3D IR-TRACC and are an assembly consisting of 2 angle transducers and 1 displacement transducer, see **Figure 1**. The combined output of two angles (φ_Y, φ_Z) and displacement (DS0) allows to calculate a position of the front end of the device in 3D space (D_X, D_Y and D_Z). The front end is attached to the rib or abdomen and the rear end is attached to the spine of the dummy. The THOR dummy has six units all based on similar components and all look the same, but in fact none of the units in one dummy is the identical. There are left hand and right hand versions, upper thorax and lower thorax and abdomen versions. Identify the 3D IR-TRACC version using **Table 1**.

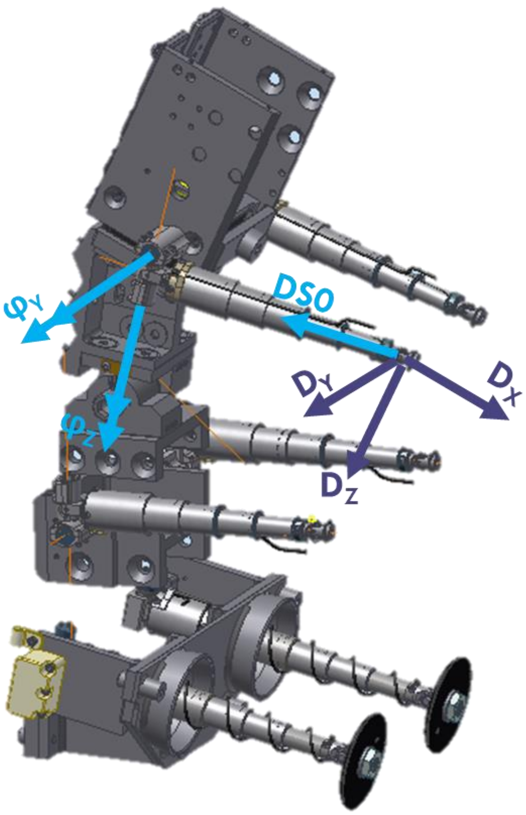
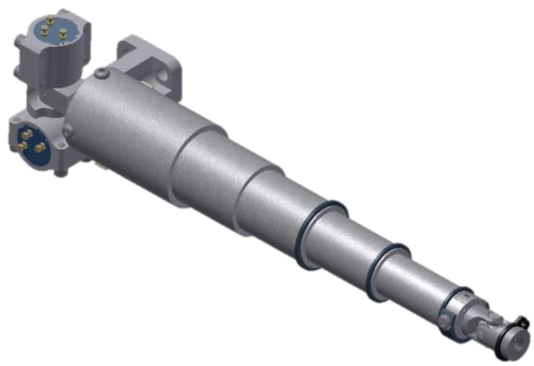


Figure 1: *Six versions 3D IR-TRACCs in the THOR dummy*

Table 1: How to identify the 3D IR-TRACC version (only right hand versions are show; left hand versions mirrored about sagittal plane)

	Part Number 472-XXXX	**Range [mm]**	**Base**	**Offset δ [mm]**	**Z-angle sensor**
	3550 Upper Left **3560 Upper Right (shown)**	90	Narrow	+15.65	Down
	**3570 Lower Right (shown)** 3580 Lower Left	90	Wide	-15.65	Up
	4730-1 Abdomen Left **4730-2 Abdomen Right (shown)**	120	-	0	Up

2.2 Coordinate Systems

The six transducers are attached to individual spine segments of the dummy, the upper spine, lower spine and lumbar spine. These segments are separated by flexible and/or adjustable elements (upper and lower) and do not have a fixed position with respect to each other. The 3D transducers measure three dimensional deflection with respect to the individual spine segments and therefore all units have their own local spine coordinate system. The local coordinate systems follow the generally accepted ATD coordinate system according SAE-J211, see **Figure 2**. The upper thorax transducers use the UTS (Upper Thoracic Spine), the lower thorax transducers use the LTS (Lower Thoracic Spine) coordinate system and the abdomen transducers use the LS (Lumbar Spine) coordinate system.

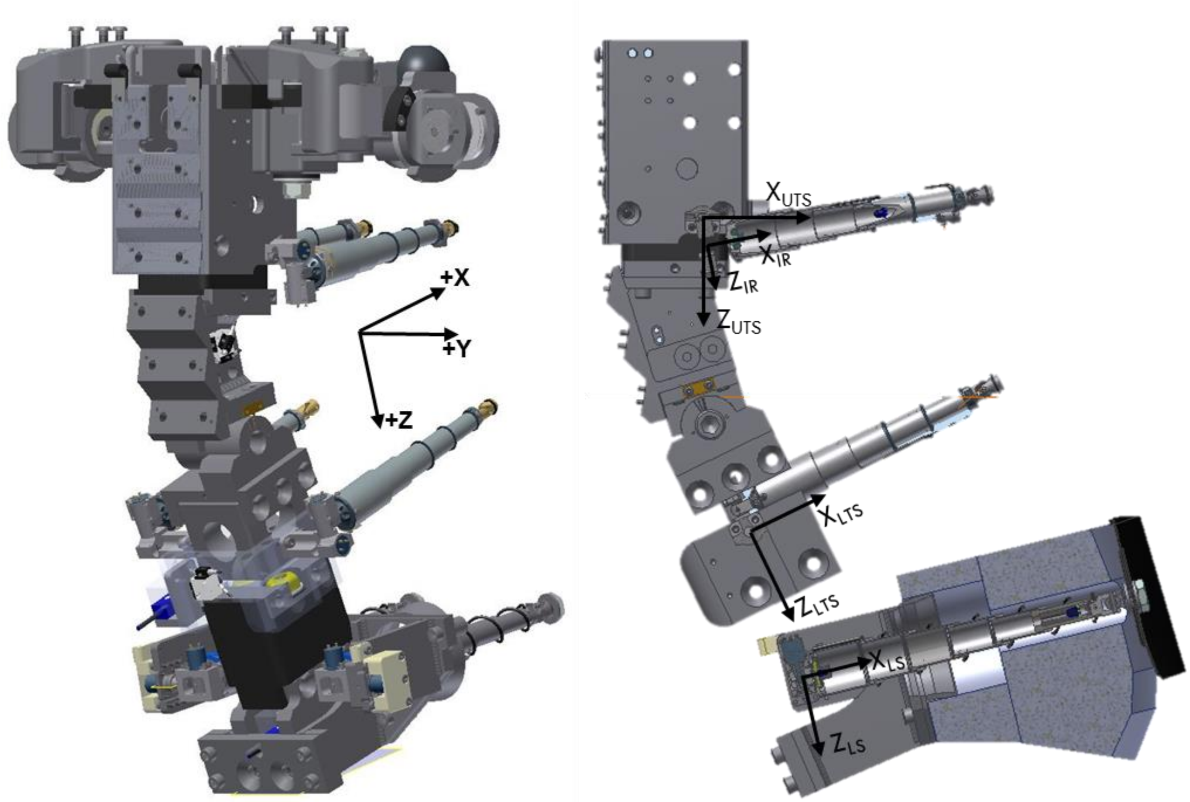


Figure 2: *Global dummy coordinate system (left) and Local Spine Coordinate Systems seen on the right side of the dummy (right)*

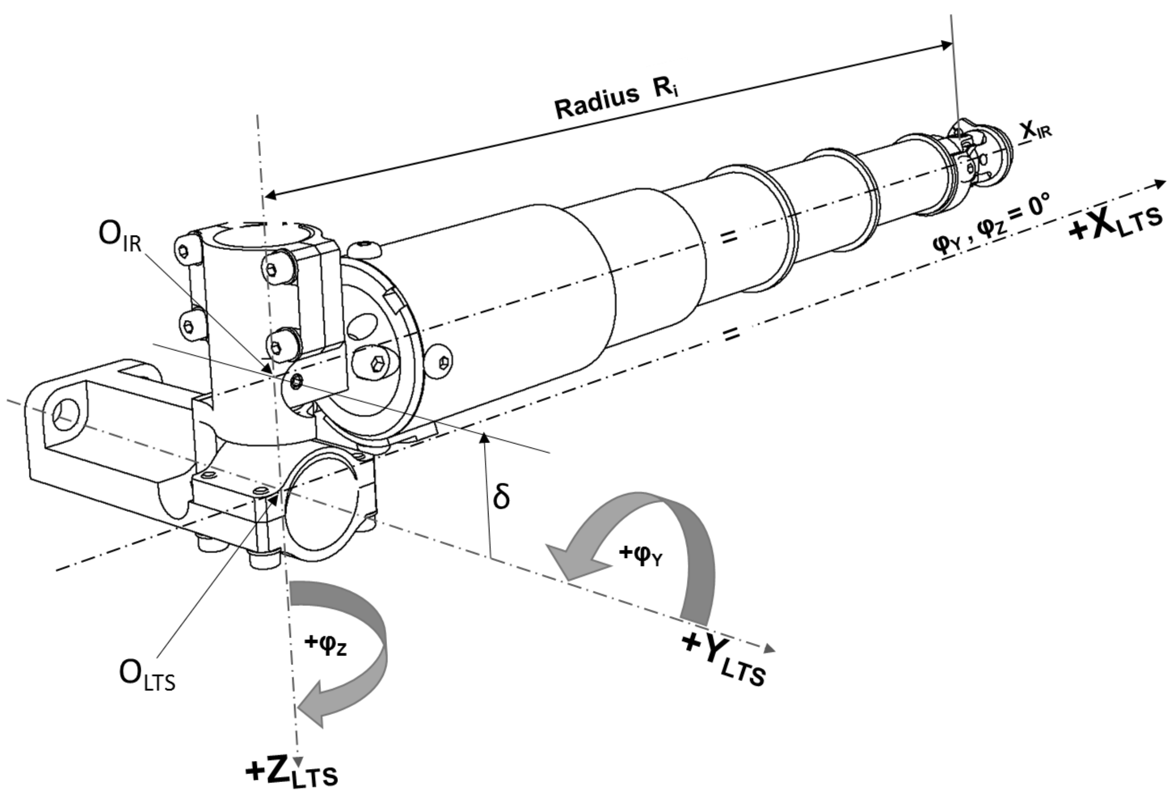


Figure 3: *3D IR-TRACC Lower Right aligned with LTS coordinate system (IR-TRACC axis parallel with X-axis)*

3 Thorax 3D IR-TRACC Assemblies

In the following paragraphs details are given on the thoracic 3D IR-TRACCs.

3.1 472-3550 Upper Left

Figure 4 shows an exploded assembly of the Upper Left IR-TRACC. The small (non-exploded) figure shows its orientations when mounted in the dummy. The parts list is given in **Table 2**.

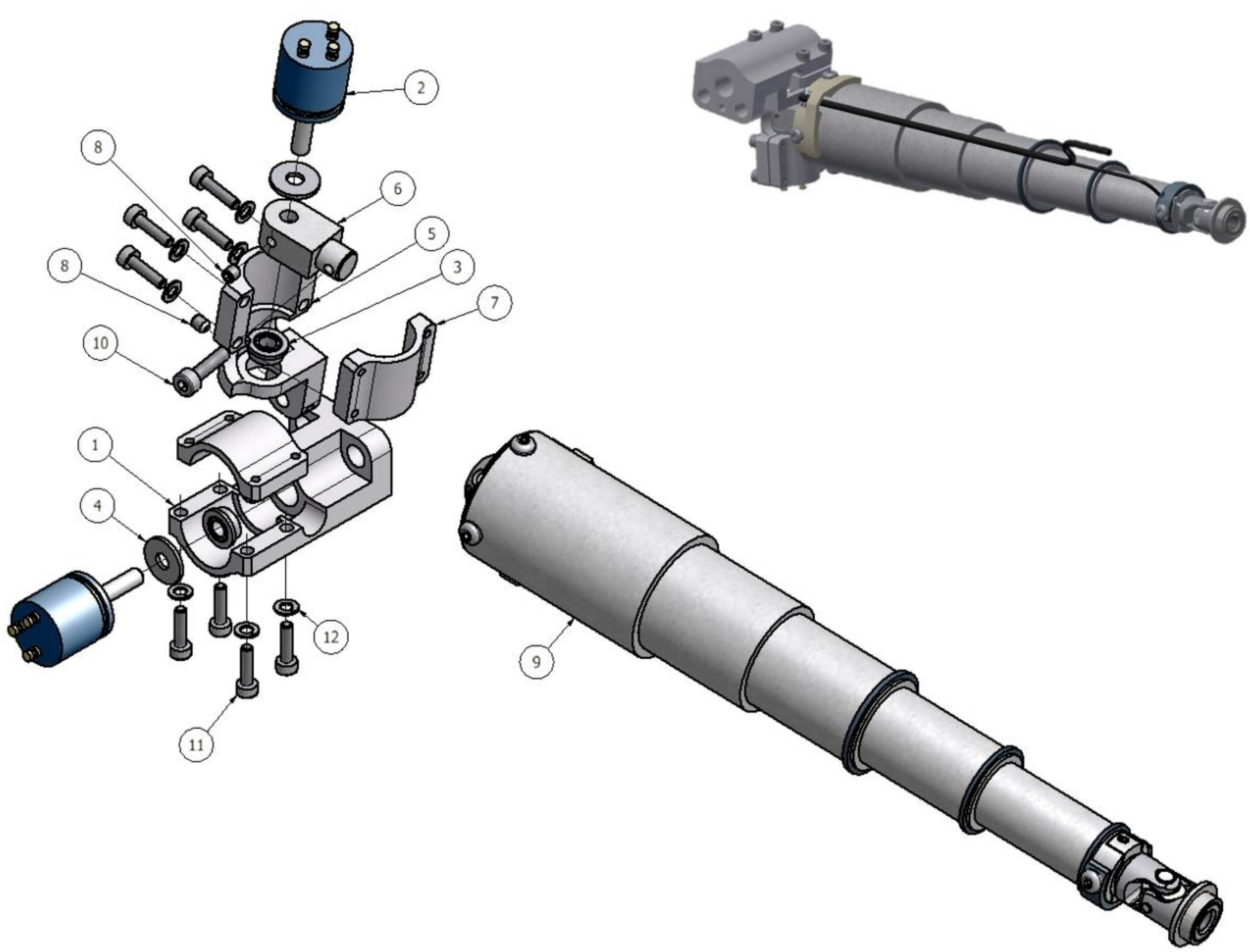


Figure 4: 472-3550 Upper Left Assembly (non-exploded: orientation mounted in the dummy)

3.2 472-3560 Upper Right

Figure 5 shows an exploded assembly of the Upper Right IR-TRACC. The small (non-exploded) figure shows its orientation mounted in the dummy.

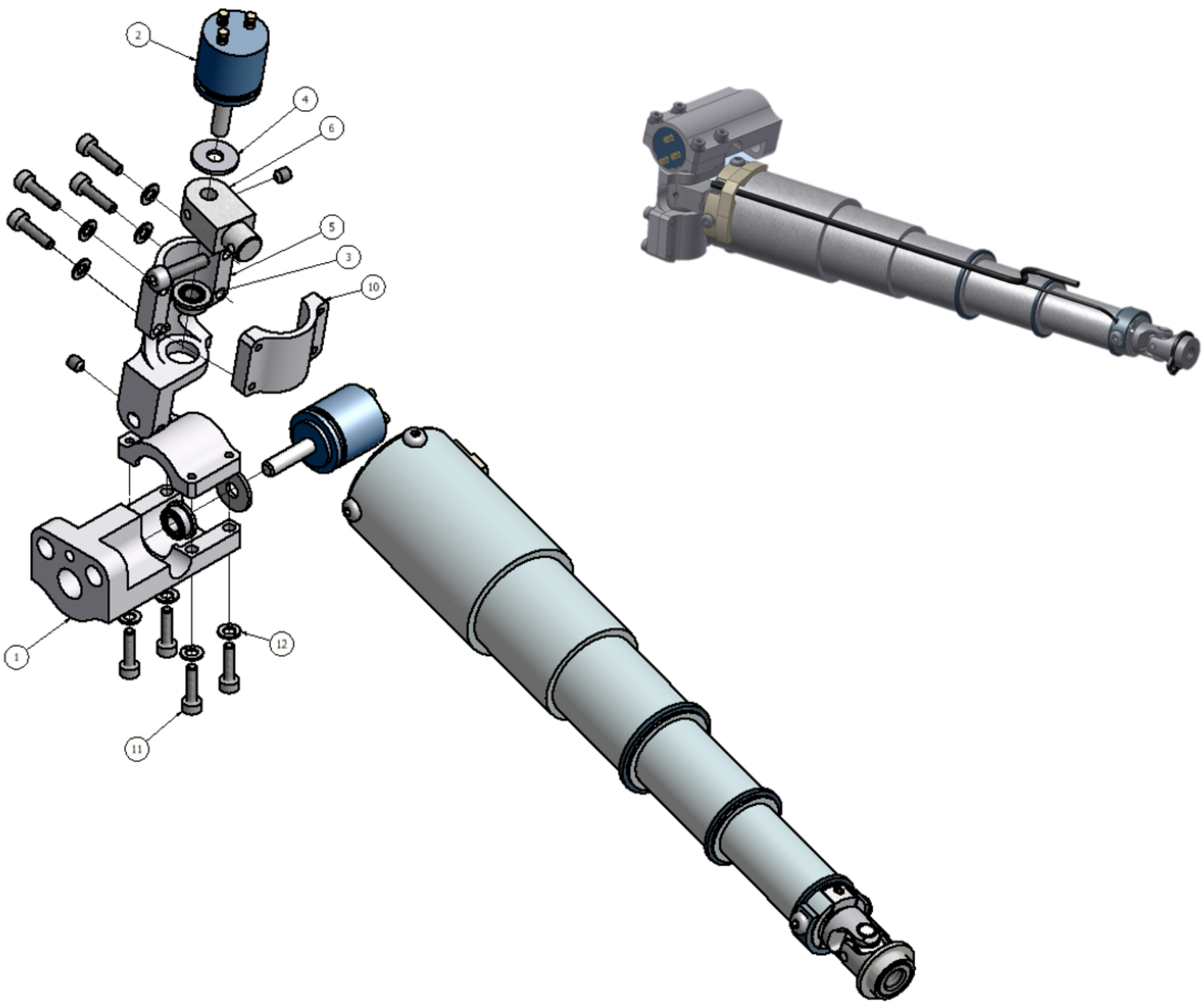


Figure 5: *472-3560 Upper Right Assembly (non-exploded: orientation mounted in the dummy)*

The parts list of the left and right upper thorax IR-TRACCs is given in **Table 2**. Note that the parts list for right hand and left version is the same except for item 5, part 472-3552 and 472-3562. The assembly instructions are given in the paragraph 3.5.

Table 2: *Upper IR-TRACC Assembly Parts List part 472-3550 (upper left) and 472-3560 (upper right)*

Item Number	Qty.	Part Number	Description
1	1	472-3551	UPPER IR-TRACC BASE
2	2	9945-U	ROTATIVE TRANSDUCER, UNTESTED
3	2	9002201	FLANGE BEARING (1/4" O.D. x 1/8" I.D.)
4	2	5000378	M3 FLAT WASHER LARGE OD SS
5*	1	472-3552	IR-TRACC ARM MOUNTING BRACKET
5*	1	472-3562	IR-TRACC ARM MOUNTING BRACKET
6	1	472-3553	ADAPTOR, SERVO/IR-TRACC
7	2	472-3554	CLAMP, IR-TRACC
8	2	5001359	M2.5 X 0.45 X 3 LG. SSCP NYLOK
9	1	3640-00-C-R5	IR-TRACC CHEST, THOR-M
10	1	5000456	M2.5 X 0.45 X 10 LG. SHCS
11	8	5000083	M2 X 0.4 X 8 LG. SHCS
12	8	5001216	M2 SPLIT LOCK WASHER SS

**Item 5, see note paragraph 3.5*

3.3 472-3570 Lower Right

Figure 6 shows an exploded view of the Lower Right IR-TRACC assembly.

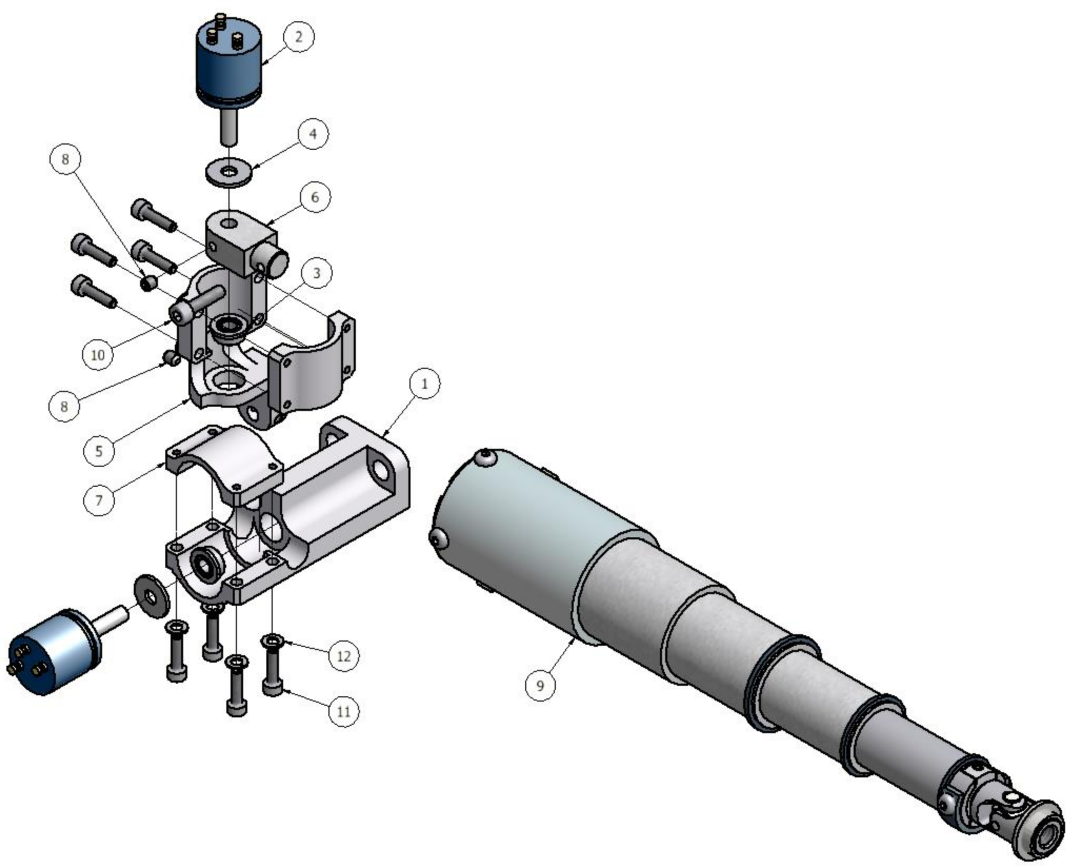


Figure 6: *472-3570 Lower Right Assembly*

3.4 472-3580 Lower Left

Figure 7 shows an exploded view of the Lower Left IR-TRACC assembly.

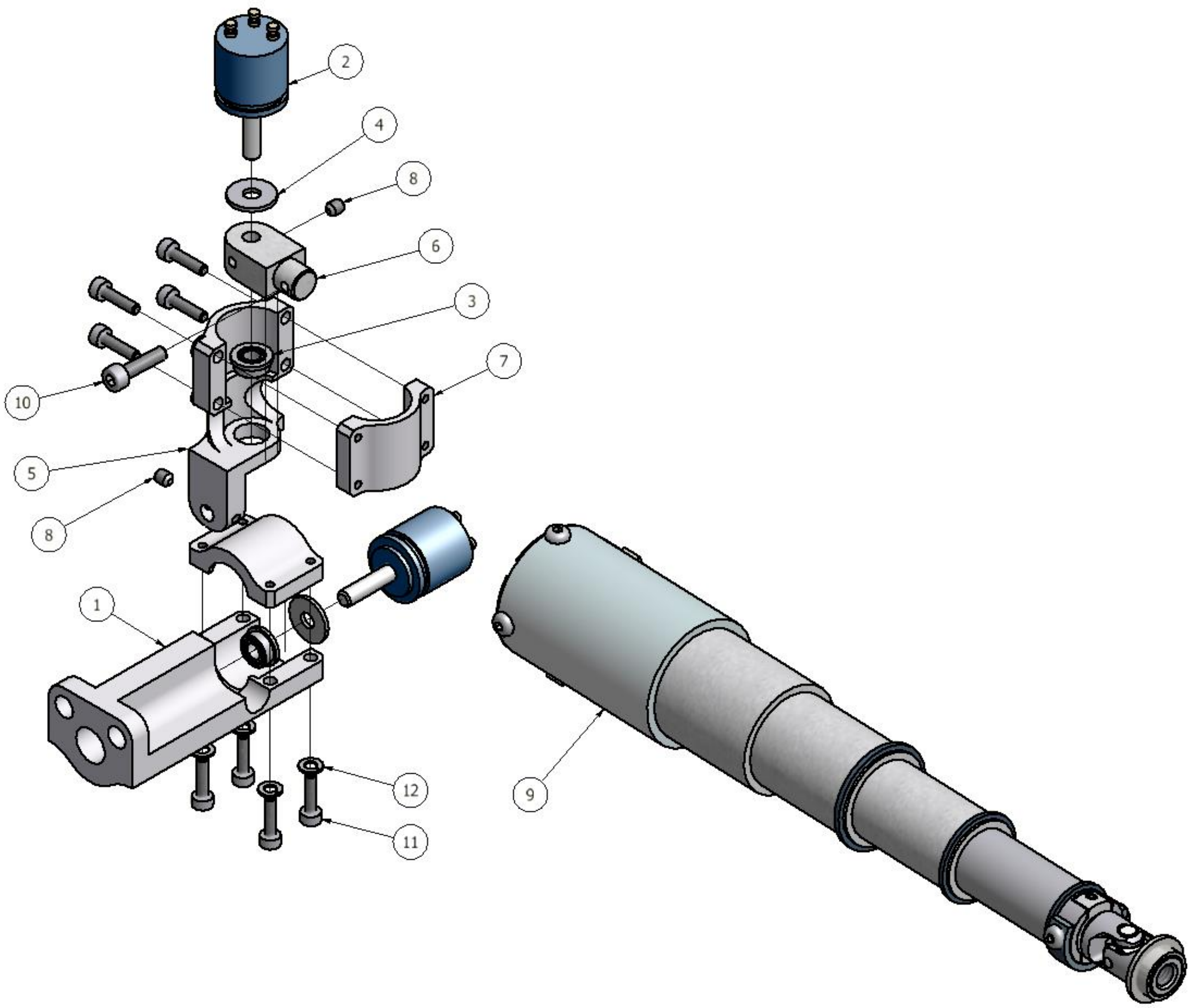


Figure 7: 472-3580 Lower Left Assembly

The parts list is given in **Table 3**. Note that the parts list for right hand and left version is the same except for item 5, part 472-3552 and 472-3562. The assembly instruction are given in the next paragraph 3.5.

Table 3: *Lower IR-TRACC Assembly Parts List part 472-3570 (lower right) and 472-3580 (lower left)*

Item Number	Qty.	Part Number	Description
1	1	472-3571	UPPER IR-TRACC BASE
2	2	9945-U	ROTATIVE TRANSDUCER, UNTESTED
3	2	9002201	FLANGE BEARING (1/4" O.D. x 1/8" I.D.)
4	2	5000378	M3 FLAT WASHER LARGE OD SS
5	1	472-3552	IR-TRACC ARM MOUNTING BRACKET
5	1	472-3562	IR-TRACC ARM MOUNTING BRACKET
6	1	472-3553	ADAPTOR, SERVO/IR-TRACC
7	2	472-3554	CLAMP, IR-TRACC
8	2	5001359	M2.5 X 0.45 X 3 LG. SSSCP NYLOK
9	1	3640-00-C-R5-XXX	IR-TRACC CHEST, THOR-M
10	1	5000456	M2.5 X 0.45 X 10 LG. SHCS
11	8	5000083	M2 X 0.4 X 8 LG. SHCS
12	8	5001216	M2 SPLIT LOCK WASHER SS

**Item 5, see note paragraph 3.5*

3.5 Upper and Lower 3D IR-TRACC Base Assembly

The following is a step by step description of the assembly of the IR-TRACC base.

*NOTE: the difference between the Upper and Lower IR-TRACC assemblies is in the base: the upper uses part 472-3551 (narrow); the lower uses part 472- 3571 (wide). See **Table 1**. Also, the Left Upper and Right Lower assemblies use a different Arm Mounting Bracket (Item 5) than the Left Lower and Right Upper assemblies. **Table 4** shows the distribution of the four different parts across all four 3D IR-TRACCs in the thorax.

Table 4: *Distribution part of Thoracic IR-TRACCs*

	Upper Right	Upper Left	Lower Right	Lower Left
472-3552, Bracket		X	X	
472-3562, Bracket	X			X
472-3571, Base			X	X
472-3551, Base	X	X		

3.5.1.1 Insert the Flange Bearing into the IR-TRACC Mounting Bracket (472-3552 or 472-3562). Check **Table 4** for the exact part number needed.

3.5.1.2 Insert the Rotary Potentiometer shaft through an M3 flat washer and the Servo/IR-TRACC Adaptor (472-3553). When properly positioned in the Mounting Bracket, the groove on the potentiometer body will mate with the clamping ring on the Mounting Bracket (**Figure 8**).

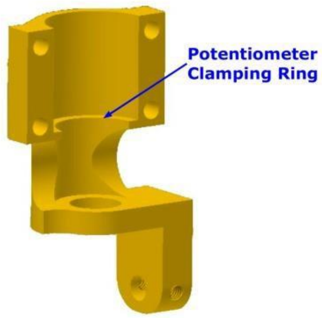


Figure 8: Mounting Bracket 472-3552 (Upper Left and Lower Right)

3.5.1.3 Install the IR-TRACC Clamp (472-3554) on the potentiometer and Mounting Bracket. Secure the Clamp using four M2 X 0.4 X 8 mm SHCS and four M2 Split Lock Washers.

3.5.1.4 Hook-up the potentiometer on a power supply and voltmeter and adjust the shaft in the middle position. First make sure that the potentiometer shaft is not in the dead zone. In the dead zone the potentiometer flips directly from a high positive output to a high negative output when rotating the shaft. Close to the middle position the output of the potentiometer changes gradually when rotating the shaft. Adjust the shaft between ±0.025V output at 5V excitation voltage (corresponds to ~ 1.5degrees).

3.5.1.5 The potentiometer shaft is secured in place using a M2.5 X 0.45 X 3 mm SSCP installed in the adaptor. The screw shall be tightened with 0.45Nm torque.

3.5.1.6 Insert the Flange Bearing into the IR-TRACC Base (472-3551 or 472-3571) and position the Mounting Bracket assembly (steps 1-4) in the IR-TRACC Base. Check **Table 4 f**or the exact part number needed.

3.5.1.7 Hook-up the second potentiometer on a power supply and voltmeter and adjust the shaft in the middle position. First make sure that the potentiometer shaft is not in the dead zone. In the dead zone the potentiometer flips directly from a high positive output to a high negative output when rotating the shaft. Close to the middle position the output of the potentiometer changes gradually when rotating the shaft. Adjust the shaft between ±0.025V output at 5V excitation voltage (corresponds to ~ 1.5degrees).

3.5.1.8 Insert the rotary potentiometer with a M3 flat washer into the IR-TRACC Base with the potentiometer shaft passing through the hole in the Mounting Bracket. Ensure that the potentiometer is correctly positioned on the Clamping Ring.

3.5.1.9 Install the IR-TRACC Clamp (472-3554) on the Base over the potentiometer body. Secure the Clamp in place using four M2 X 0.4 X 8 mm SHCS and four M2 Split Lock Washers. Lock the potentiometer shaft in place using M2.5 X 0.45 X 3 mm SSCP.

3.5.1.10 The IR-TRACC sensor is attached to the base assembly by placing the Adaptor (472-3553) end into the hole at the base of the IR-TRACC. Secure the IR-TRACC to the base using a M2.5 X 0.45 X 8 mm SHCS.

3.5.1.11 After assembly is complete, the 3D IR-TRACC assembly must be zeroed and have its initial position offset recorded. The procedure for accomplishing this is detailed in Section 5.

3.6 Left Abdominal 3D IR-TRACC Assembly

Figure 9 and **Figure 10** show exploded views of the assemblies of the Abdominal IR-TRACCs. The parts list is given in **Table 5** and **Table 6**. Assembly instructions are given in paragraph 3.7.

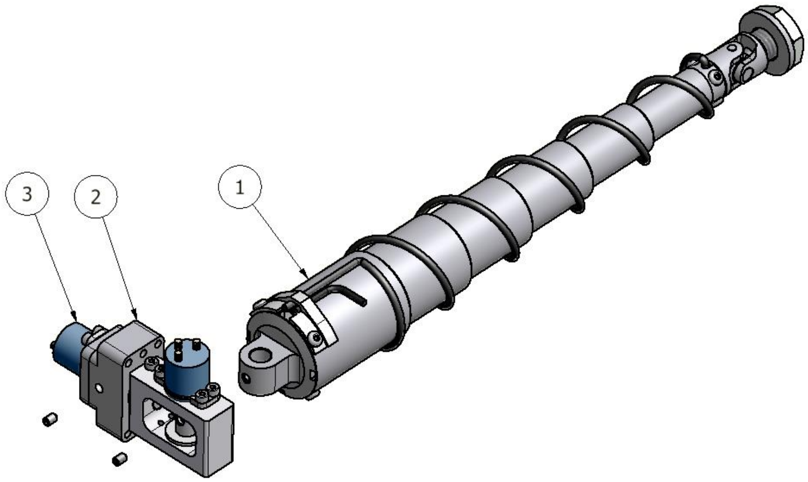


Figure 9: *Exploded view of 472-4730-1 Left Abdominal 3D IR-TRACC Assembly*

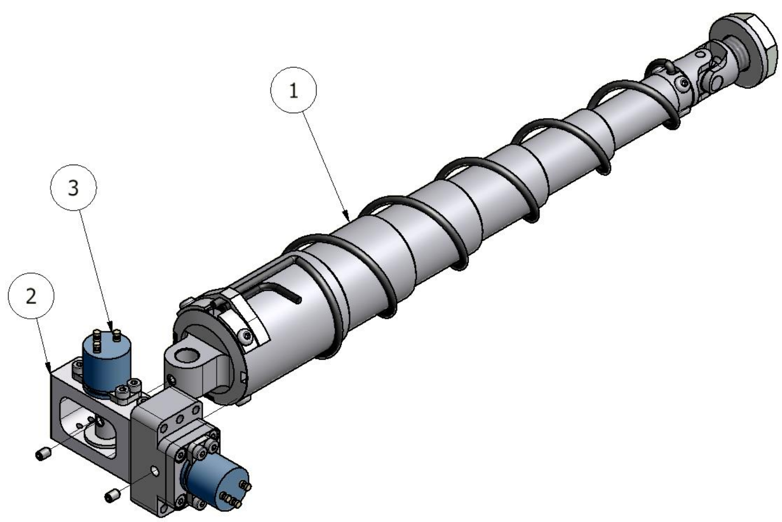


Figure 10: *Exploded view of 472-4730-2 Right Abdominal 3D IR-TRACC Assembly*

Table 5: *Abdominal IR-TRACC Assembly Parts List of 472-4730-1 and 472-4730-2*

Item Number	Qty.	Part N-umber	Description
1	1	472-4750-U	120mm IR-TRACC ASSEMBLY – METRIC UNTESTED
2	1	472-4740-1-U	PIVOT ASSEMBLY, LEFT UNTESTED
2	1	472-4740-2-U	PIVOT ASSEMBLY, RIGHT UNTESTED
3	2	9945-U	ROTATIVE TRANSDUCER, UNTESTED

3.7 Left Abdominal 3D IR-TRACC Pivot Assembly

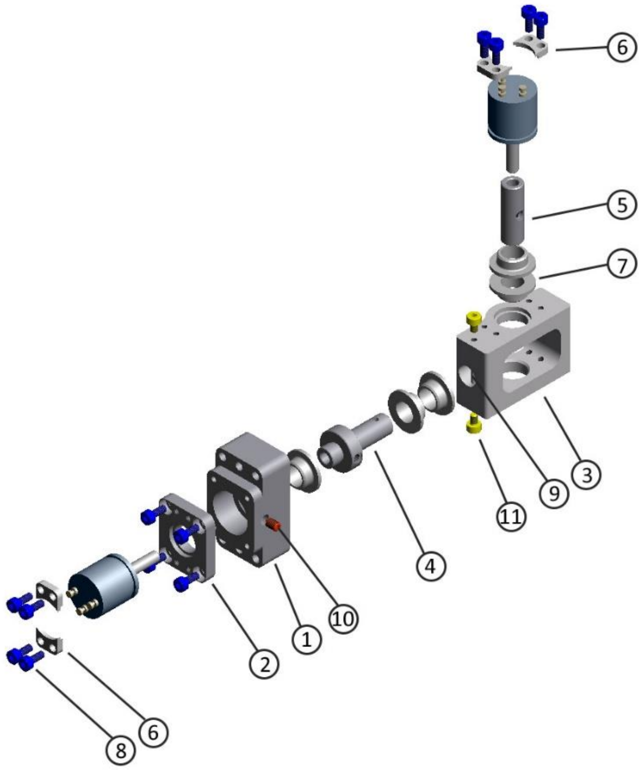


Figure 11: *Exploded view of 472-4740-1 Left Abdominal Pivot Assembly.*

Table 6: *Parts List of 472-4740-1 Left Abdominal Pivot Assembly*

Item Number	Qty.	Part Number	Description
1	1	472-4741	BLOCK MOUNTING
2	1	472-4742	COVER
3	1	472-4743	BLOCK PIVOT
4	1	472-4744	SHAFT HORIZONTAL
5	1	472-4745	SHAFT VERTICAL
6	4	472-4746	CLAMP POT
7	5	5000949	FLANGE BEARING 6 X 8 X 4 LG.
8	12	5001079	M2 X 0.4 X 5 LG. SHCS
9	1	5000514	M1.5 X 12 LG. DOWEL SS
10	1	5001043	M2.5 0.45 X 4 LG. SSCP SS
11	2	5001136	M2 X 0.4 X 3 LG. SHCS

3.7.1.1 Insert two Flange Bearings into the Pivot Block (472-4743) (**Figure 12**) and three Flange Bearings in the Mounting Block (472-4741).

3.7.1.2 Position the IR-TRACC assembly (472-4750) between the Flange Bearings on the Pivot Block.

3.7.1.3 Hook-up the first potentiometer on a power supply and voltmeter and adjust the shaft in the middle position. First make sure that the potentiometer shaft is not in the dead zone. In the dead zone the potentiometer output voltage flips directly from a high positive output to a high negative output when rotating the shaft. Close to the middle position, the output of the voltage changes gradually when rotating the shaft. Adjust the shaft between ±0.025V output at 5V excitation voltage (corresponds to ~ 1.5 degrees).

3.7.1.4 Insert the Vertical Shaft (472-4745) through the bearings in the Pivot Block and IR-TRACC assembly.

3.7.1.5 Insert the Rotary Potentiometer shaft into the Vertical Shaft. Place two Potentiometer Clamps (472-4746) on the Pivot Block with the clamping edge inserted in the Potentiometer clamping groove. Secure each clamp in position using two M2 X 0.4 X 5 mm SHCS.

3.7.1.6 Hook-up the second potentiometer on a power supply and voltmeter and adjust the shaft in the middle position. First make sure that the potentiometer shaft is not in the dead zone. In the dead zone the potentiometer output voltage flips directly from a high positive output to a high negative output when rotating the shaft. Close to the middle position, the output of the potentiometer changes gradually when rotating the shaft. Adjust the shaft between ±0.025V output at 5V excitation voltage (corresponds to ~ 1.5degrees).

3.7.1.7 Attach the Shaft Cover (472-4742) to the second Rotary Potentiometer using two Potentiometer Clamps and four M2 X 0.4 X 5 mm SHCS.

3.7.1.8 Insert the second Rotary Potentiometer Shaft into the shorter end of the Horizontal Shaft (472-4744) and secure it in place using a M2.5 X 0.45 X 4 mm SSCP. Ensure the set screw is beneath the surface of the Horizontal Shaft collar.

3.7.1.9 Secure the cover to the mounting block using four M2 X 0.4 X 5 mm SHCS.

3.7.1.10 Install one M2 X 0.4 X 3 mm SHCS on each side of the Pivot Block into the dowel pin access holes.

3.7.1.11 Insert the Horizontal Shaft/Potentiometer assembly into the Mount Block through the Flange Bearings.

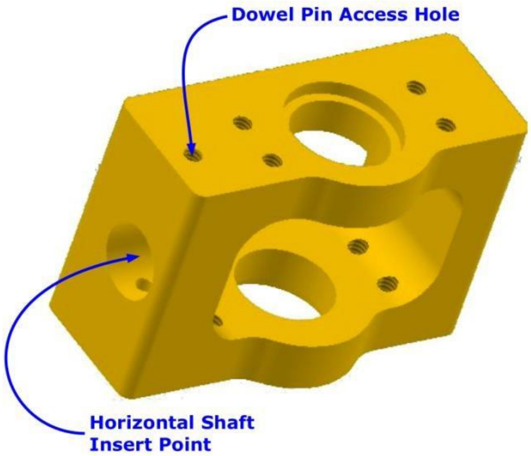


Figure 12: *Pivot Block 472-4743*

3.7.1.12 Insert the Horizontal Shaft and Mounting Block assembly into the Pivot Block.

3.7.1.13 Align the Ø1.5mm hole in the Horizontal Shaft with the M2 threaded holes on the Pivot Block and insert the Ø1.5mm dowel pin into the hole. This pin should slide into the hole in the Horizontal Shaft easily, do not force the pin into the hole.

3.7.1.14 Install a second M2 X 0.4 X 3 mm SHCS into the dowel pin access hole to secure the pin in place.

3.7.1.15 After assembly is complete, the 3D IR-TRACC assembly must be zeroed and have its initial position offset recorded. The procedure for accomplishing this is detailed in Section 5.

3.8 Wire Routing and Electrical Connections

3.8.1 Wire Routing

The wire routing for the 3D IR-TRACC units is described below.

Left side units: The wires are routed to the left side of the spine and are joined to the wire bundle at the base of the spine.

Right side units: The wires are routed to the right side of the spine and are joined to the wire bundle at the base of the spine.

3.8.2 Electrical Connection

Each sensor in the 3D IR-TRACC unit is wired during manufacturing with a multi-conductor instrumentation wire according to customer specifications as to connector type and pin out. The wire is fully shielded and the shield is passed through the connector.

Table 7: Potentiometer & IR-TRACC Wiring

Wire Color	Pin
Red	+Excitation
Green	+Signal
Orange	Channel ID
Shield	Ground
White	-Signal
Black	-Excitation

4 Sensor Calibration

4.1 Displacement Calibration

The IR-TRACC can be calibrated using conventional linear potentiometer calibration procedures. Humanetics offers an IR-TRACC bench top calibration fixture (TE-3700-IRKIT) designed to enable accurate determination of scale factors and linearity. This calibration device consists of a fixture to which both ends of the telescoping rod are attached, a mechanical gear drive and a digital caliper for accurate distance measurement.

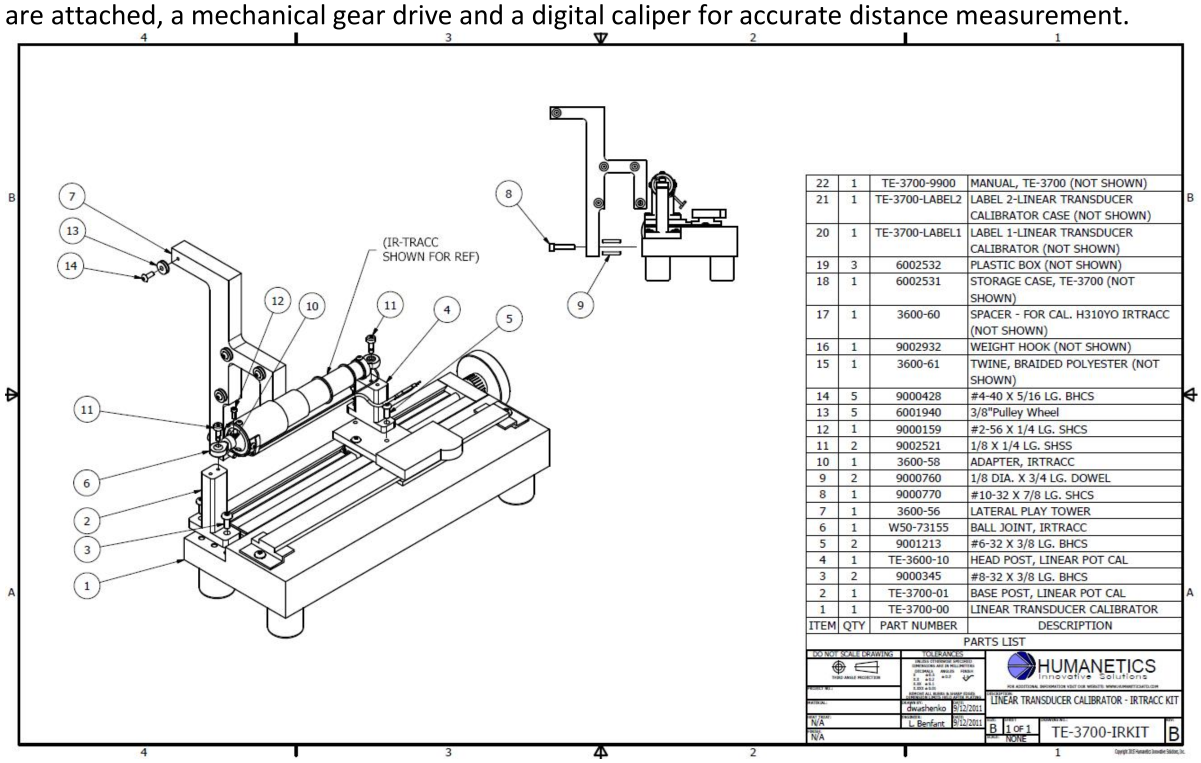


Figure 13: TE-3700-IRKIT, linear transducer calibrator

Calibration templates in MS-EXCEL and step by step procedures are available to collect and process calibration data. Apply Tubes In-Out Calibration Procedure EN-PR-00014C for revision R4 and higher IR-TRACCs and use Calibration Template EN-FO-00008C. These documents are available on a USB Flash Drive memory, part number 11428. The IR-TRACC revision number can be found in the model number. For revisions without 'R4' or 'R5' in the model number apply procedure EN-PR-00013C and use Calibration Template EN-FO-00007C. These documents are available on a USB Flash Drive memory, part number 11427. There is also a template for zero-position measurement, see section 5. An integrated 3D calibration-verification template in MS-EXCEL is also available. An overview of all calibration and verification documents is given in **Table 8**.

Table 8: Procedures and Templates available

Document Number	Part Number	Description	Application Model Number
EN-PR-00013C	11427	Harmonized Calibration Procedure	without “R4” or “R5”
EN-FO-00007C	11427	Harmonized Calibration Template	without “R4” or “R5”
EN-PR-00014C	11428	Tubes In-Out Calibration Procedure	R4 and R5
EN-FO-00008C	11428	Tubes In-Out Calibration Template	R4 and R5
EN-FO-00013C	11600	Stand-alone 3D IR-TRACC Zero-Position Verification Template for External Use	All models
EN-FO-00014C	11600	3D IR-TRACC Zero-Position Verification Integrated Harmonized Template for External Use	without “R4” or “R5”
EN-FO-00015C	11600	3D IR-TRACC Zero-Position Verification Integrated Tubes In-Out Template for External Use	R4 and R5

4.2 Angle Transducer Calibration

Calibrate the angle transducers using conventional methods and preferably use the Integrated Calibration Template EN-FO-00014C or EN-FO-00015C. Apply a calibration range of ± 75 degrees from the 0 volt output in the middle of the range.

5 Zero-Position Verification

5.1 Zero-Position Fixture TF-472-6000

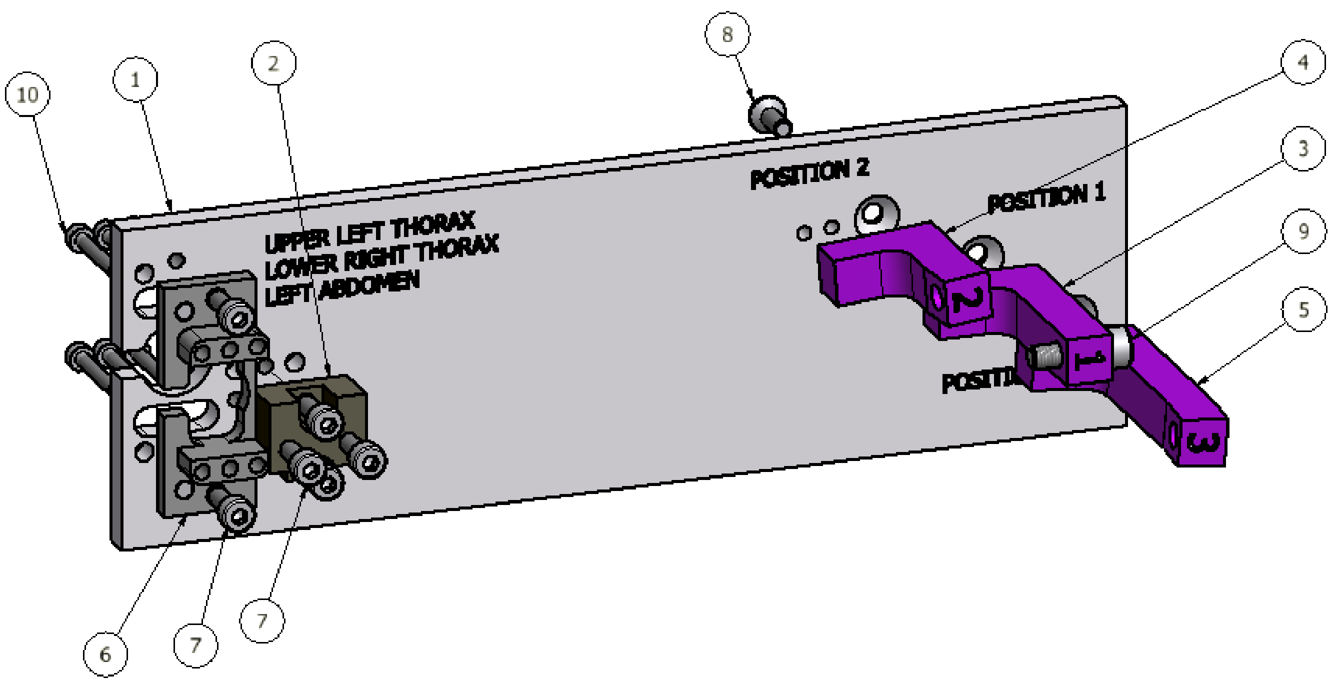


Figure 14: TF-472-6000

__Table 9:__ Zero-Position Fixture Parts list TF-472-6000

ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	TF-472-6001	BASE PLATE
2	1	TF-472-6002	SPACER BLOCK, UPPER THORAX
3	1	TF-472-6003	POST, POSITION 1
4	1	TF-472-6004	POST, POSITION 2
5	1	TF-472-6005	POST, POSITION 3
6	1	TF-472-6006	SPACER BLOCK, ABDOMEN
7	6	5000151	M4 X 0.7 X 10 LG. SHCS
8	3	5000023	M4 X 0.7 X 10 LG. FHCS
9	1	5000020	M5 X 0.8 X 16 LG. SHCS
10	6	5000312	M3 X 0.5 X 20 LG. SHCS

The Zero-Position fixture exploded view and parts list are shown in **Figure 14** and **Table 9**. The fixture serves 3 purposes:

- to set up 3D IR-TRACCs along their respective local coordinate systems to obtain zero-positions of the displacement and angle sensors in the local spine coordinate system;
- to obtain angle sensor polarities in local coordinate system;
- to verify if an entire measurement chain reproduces know positions on the fixture after calibration parameters and processing software have been implemented.

The zeroing fixture allows all six versions 3D IR-TRACCs to be set up in 3 positions. The spacer blocks are included to accommodate the following transducers:

- 472-3550 Upper Left and 472-3560 Upper Right: use spacer item 2;
- 472-4730-1 Left Abdomen and 472-4730-2 Right Abdomen: use spacer item 6;
- 472-3570 Lower Right and 472-3580 Lower Left: no spacer

The TF-472-6000 bench top inspection tool is designed to manipulate the THOR 3D IR-TRACCs through their range of motion. Each degree of freedom, φy, φz, & R, can be manipulated in both positive & negative directions in order to inspect the proper polarities of each sensor prior to installing into the dummy. This is critical as each sensor will have a component in the overall calculated deflection and if any polarity is incorrect it will have a significant effect on the deflection value but may not be initially obvious. Furthermore, the IR-TRACC assemblies are oriented differently in various locations of the dummy so verifying polarities can be confusing. For example, two similar IR-TRACCs placed side by side on the bench and moved in a similar fashion may have opposite expected polarities once installed in the dummy. Having a fixture and reference table of expected outputs removes any confusion. The fixture orients the 3D IR-TRACC assembly into the ZERO position (marked <u>POSITION 1(!)</u> on the fixture) where φy and φz are each set to zero relative to the local spine coordinate system. The radius (R) is also set to a known value, dependent on the type of 3D IR-TRACC installed.

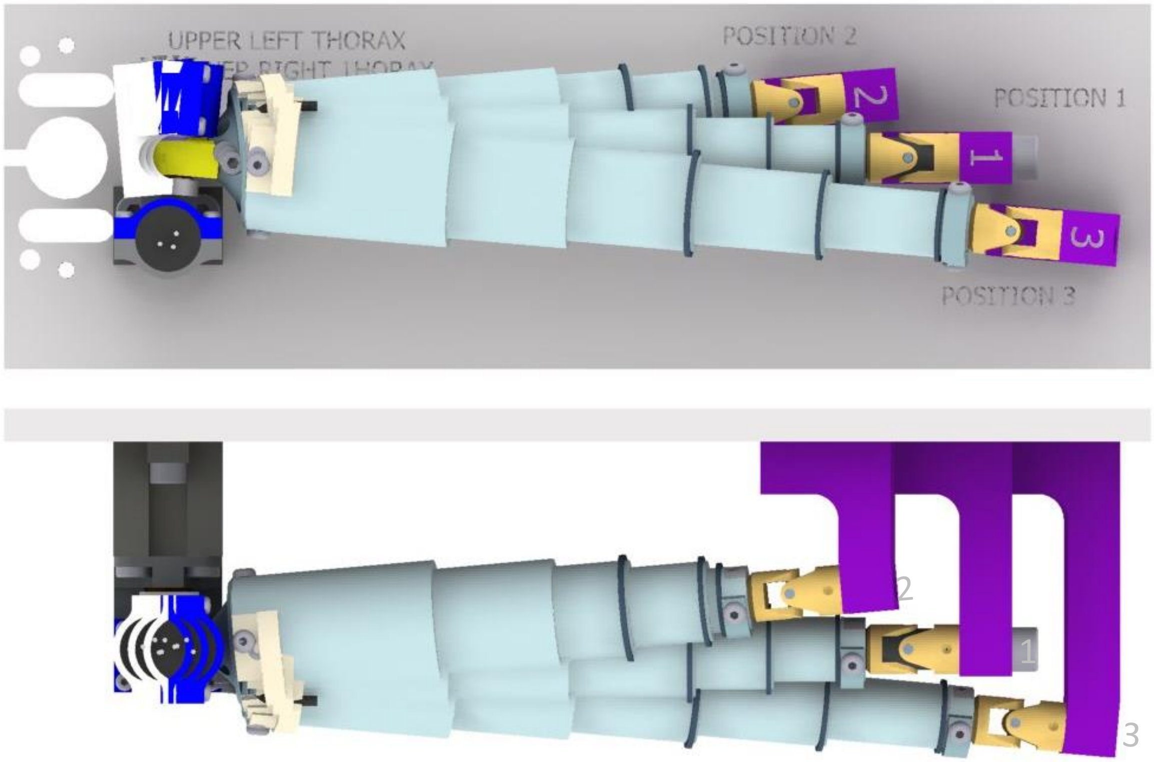


Figure 15: *Upper Left Thorax IR-TRACC overlay; shown assembled at positions 1, 2, & 3 (view -Y direction above; +Z-direction below)*

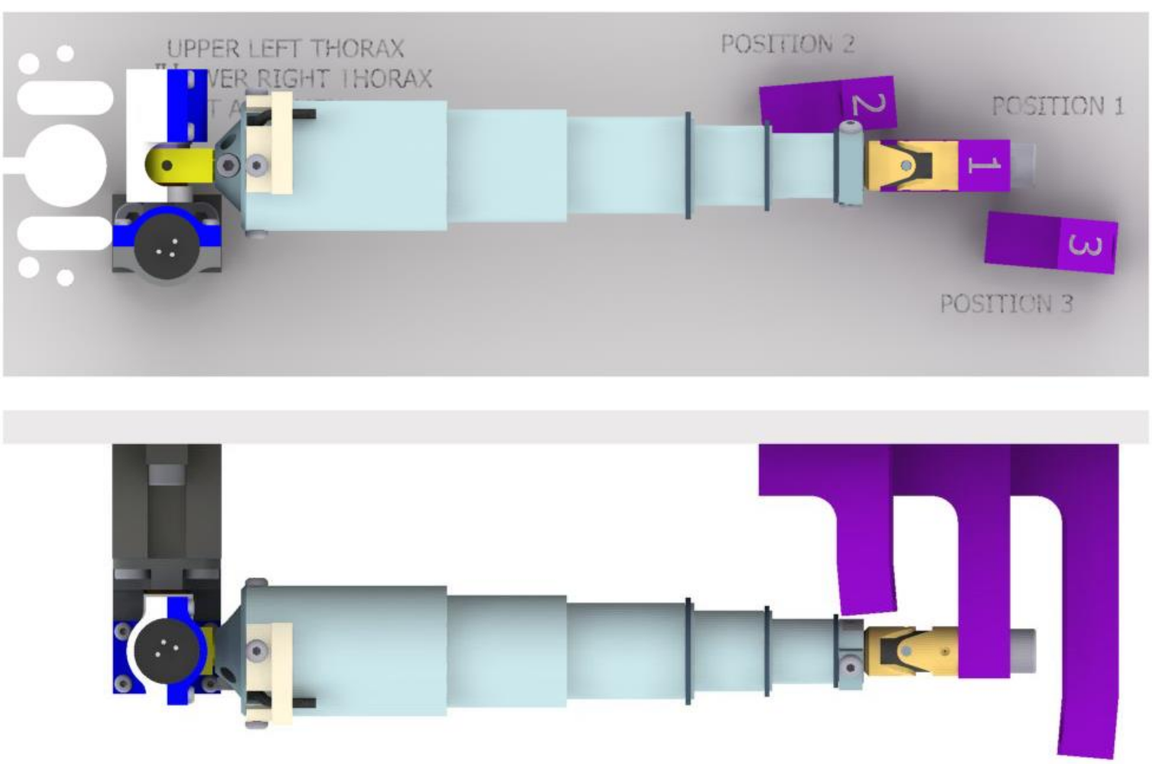


Figure 16: *Upper Left Thorax IR-TRACC at positions 1 (view Y direction above; Z-direction below)*

5.2 Zero-Position Verification Templates

The stand-alone zero-position verification template in MS-EXCEL (EN-FO-00013C) for data collection and processing creates a table with expected polarities and values per 3D IR-TRACC type and indicates if the values found correspond to expected outputs. The result of the procedure is a set of parameters of the 3D transducer for implementation in any Data Acquisition System (DAS) in a structured and traceable manner.

An integrated 3D calibration-verification template in MS-EXCEL is also available. These templates combine the zero-position verification template and displacement and angle calibration templates mentioned in paragraphs 4.1 and 4.2 and enables the collection of calibration data from displacement transducer, angle transducers and zero-position verification in one document. The relevant appropriate calibration parameters are copied over between various sheets in MS-EXCEL. The use of the integrated template is recommended as this reduces work load and it reduces the chance at making data-entry errors when numbers are copied by hand typing. The integrated 3D calibration-verification template is document EN-FO-00014C (without R4 or R5 in model number) and EN-FO-00015C (R4 and R5 models).

Calibration and verification templates are available on a USB Flash Drive memory, part number 11600, including this manual, document TF-472-6000-9900.

5.3 Assembly / Installing Transducers

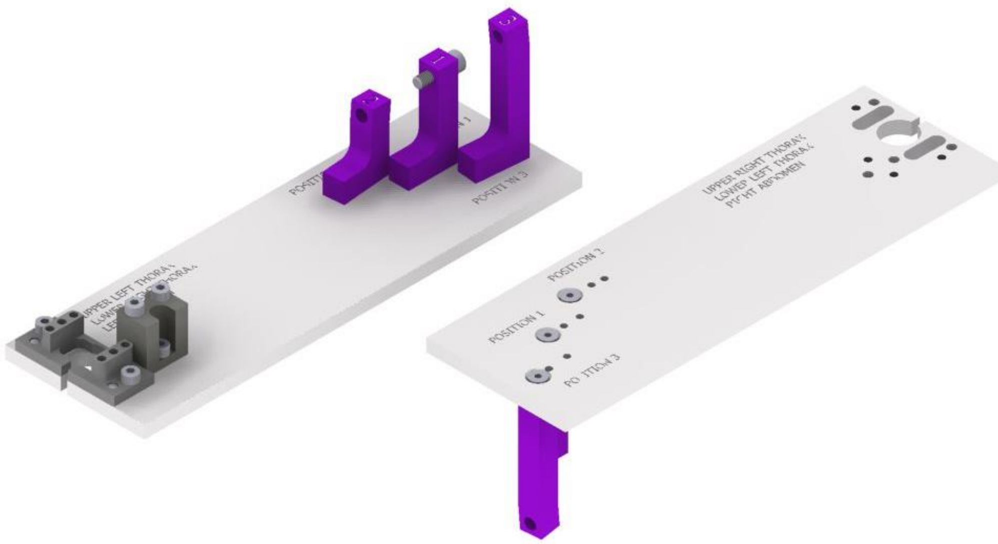


Figure 17: *Assembly Overview*

The set up fixture utilizes both sides of the base plate in order to accommodate left hand & right hand assemblies. All 3 posts & both spacers can be assembled on either side of the base plate. The base plate has been engraved to identify which assembly is mounted to which side. Upper thorax assemblies mount to the TF-472-6002 spacer block as shown below.

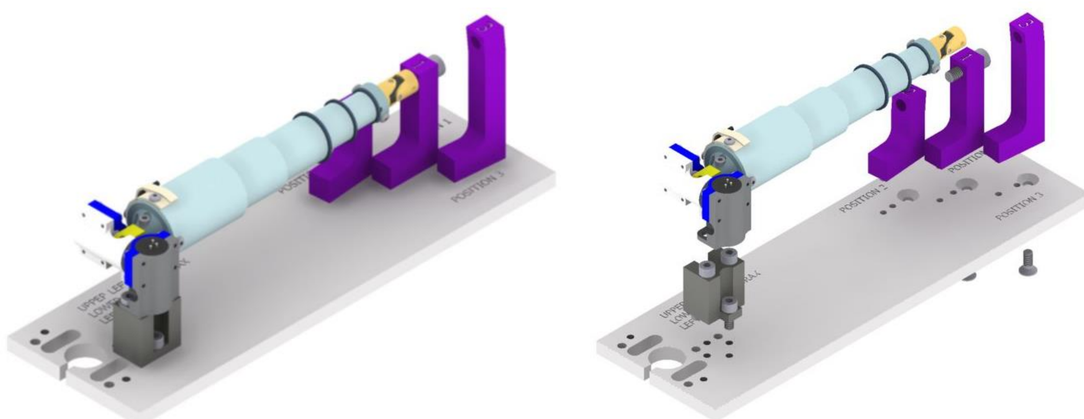


Figure 18: *Upper Left Thorax 3D IR-TRACC assembly shown installed (left) and exploded (right). (Upper right assembly mounts to the opposite side of the base plate).*

Lower thorax assemblies mount in the same position as upper thorax assemblies but without the spacer block.

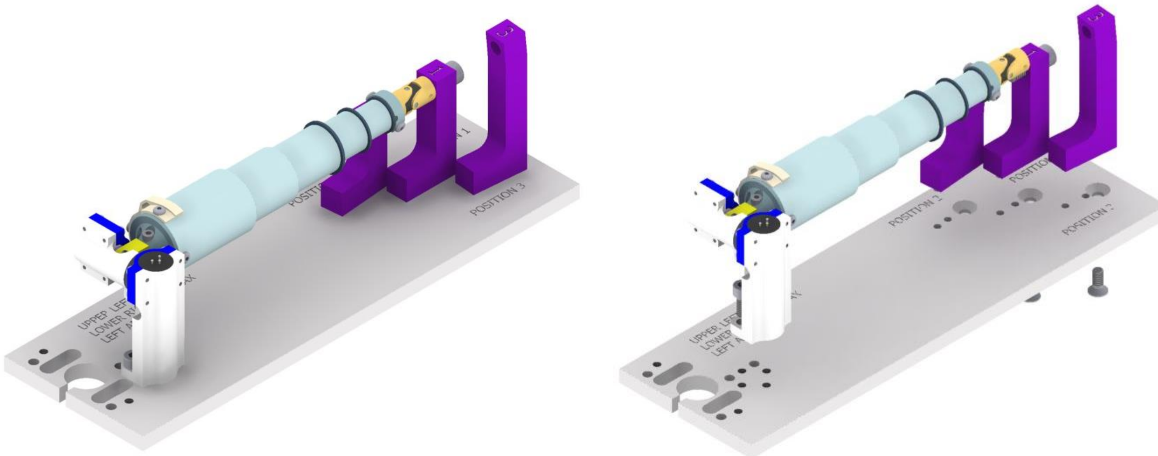


__Figure 19:__ Lower Right Thorax 3D IR-TRACC assembly shown installed (left) and exploded (right). (Lower left assembly mounts to the opposite side of the base plate).

Abdomen assemblies mount onto the TF-472-6006 spacer block at the rear-most edge of the base plate.

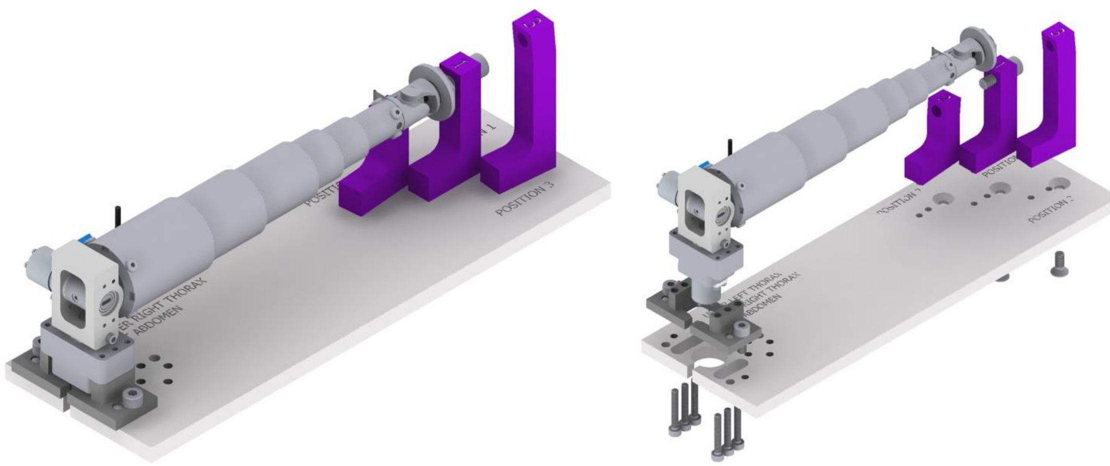


__Figure 20:__ Left Abdomen 3D IR-TRACC assembly shown installed (left) and exploded (right). (Right abdomen assembly mounts to the opposite side of the base plate.)

Dowel pins have been installed in all posts and spacers, each with a unique spacing. This ensures that the posts and spacers can be assembled in only one correct position, i.e. they cannot be accidentally swapped when changing from one side of the base plate to the other. Furthermore, using dowel pins increases the assembly position accuracy of the fixture.

5.4 Instructions and Use of the 3D IR-TRACC Verification Template

Equipment

- Zeroing Fixture part TF-472-6000 (**Figure 14**)
- A stable power supply with adjustable voltage up to at least 5V DC
- A calibrated digital voltmeter with resolution better than .00005V (.05mV)
- Computer
- 3D IR-TRACC Zero-Position Verification Template, document EN-FO-00013C. (Check your computer regional settings. It must be set to decimal point to have the template work properly. The EXCEL template includes instructions how to set your computer to decimal point. Go to tab 'INSTRUCTIONS' at the bottom left of the template.
- Calibration sheets of individual sensors in the assembly you are about to run zero-position verification.
- (Alternative: Integrated 3D calibration-verification template in MS-EXCEL (document EN-FO-00014C or EN-FO-00015C), which includes calibration sheets of the IR-TRACC and angle transducers. The relevant calibration parameters are copied over to the correct cells of the zero-position verification sheet).

Step 1

- Identify the 3D IR-TRACC Assembly you are about to run and prepare the zeroing fixture according to instructions (examples in the previous section).
- Install the 3D assembly with the spine mount on the fixture base (with or without spacer), tighten the screws securely.
- Fix the universal joint end to the position 1 post using an M5x16 SHCS screw, fasten screw until secure. (Please note: in position 1 the 3D IR-TRACC assembly is in its <u>zero</u> position). Slide all IR-TRACC tubes out to the small end for best reproducibility.

Step 2

- On the computer, open the 3D IR-TRACC Zero-Position Verification Template (EN-FO-00013C, Figure 21) and fill out the orange cells in the top section: date, technician name, assembly part number and measurement ID. (Note 1: cell colors may appear a different color depending individual computer settings or software versions). (Note 2: the technician name can be selected from a drop down list. Enter the names of your staff in cells O10-O18 to activate the drop down list).
- In cell L14 select Rev E or Rev D to identify Universal Joint (UJ) Revision, for Thorax IR-TRACC delete cell L14. Refer to the figures on the template to identify the revision of the universal joint on the abdomen IR-TRACC assembly. Rev E is common, Rev D is rare.
- Save the file according data base file naming conventions (e.g. the measurement ID-date-SN, etc.).
- Copy the serial numbers and calibration parameters from the calibration sheets of individual sensors in the orange cells. Make sure that you enter the correct calibration factors in degree/V/V unit for the angle sensors. The sensor polarity in cells J20 and N20 is default +1 and may need to be corrected in step 4.
- (Alternative: open the completed integrated 3D calibration-verification template (EN-FO-00014C or EN-FO-00015C, **Figure 22**) of the 3D IR-TRACC assembly with completed calibration of the angle and displacement transducers. Go to the tab *3D-DATA-Zero-Position.* Note that calibration parameters and serial numbers for IR-TRACC and angle transducers have already been filled out in the purple cells.) The sensor polarity in cells J20 and N20 is default +1 and may need to be corrected in step 4.
- Select from the drop down lists in row 14 the relevant 3D assembly identifiers for upper-lower, left-right, thorax-abdomen. Note that there are pop-up comments with additional instructions for some of these cells: in cell F14 delete 'Upper' or 'Lower' if you are running an abdomen IR-TRACC;
- In cell L14 select Rev E or Rev D to identify Universal Joint (UJ) Revision, for Thorax IR-TRACC delete cell L14. Refer to the figures on the template to identify the revision of the universal joint on the abdomen IR-TRACC assembly. Rev E is common, Rev D is rare.
- Hook up the power supply and voltmeter to measure excitation and adjust to 5.000V. Enter the excitation voltage in the template in cell J21. Note: the excitation during zero-position verification can be chosen independently from the original sensor calibration excitation. However, it is important to

enter the exact value here (if your excitation voltage was adjusted to for example 5.002 enter '5.002' in the cell).

- Save the file.

Date	12/02/2016	Technician	Helmut Loth	Measurement ID	

Dummy Installation Location							
Abdomen: DELETE; Thorax: select Upper or Lower	Lower	Select Left or Right:	Left	UJ Rev D or Rev E		Abdomen or Thorax	Thorax
Centerline Offset: δ [mm]	-15.65	$_{P1}$* = Distance from Coordinate System origin to end pivot center in position 1: D_{P1}* [mm]					141.8

Calibration Factors											
IR-TRACC Serial Number			DS0658	Y Angle Sensor Serial Number			DS3783	Z Angle Sensor Serial Number			DS3784
0.035032	Sensitivity [V_{LIN}/mm]	Cal. factor [mm/V_{LIN}]	28.5454	0.003035	Sensitivity [V/V/deg]	Cal. factor [deg/V/V]	329.47	0.003049	Sensitivity [V/V/deg]	Cal. factor [deg/V/V]	327.96
Displacement Intercept [mm]			115.46		Polarity		-1		Polarity		-1
EXPonent [-]			-0.48418	EXCITATION VOLTAGE U_{EX} [V]			5.000	(during 0 position measurements)			
1.47836	Radius Zero-Position Intercept [V_{LIN}]	[mm]	42.20	At Position 1: D_{P1} = Zero-position Intercept + Cal.Factor * (U_{IR1} ^ EXP); Zero-Position-Intercept = D_{P1} - Cal.Factor * (U_{IR1} ^ EXP) [mm]							

Zero Postion Measurements	IR-TRACC Radius R				Y Angle Sensor				Z Angle Sensor			
	Output U_{IR} [V]	Expected [mm]	Actual [mm]	Pass/Fail	Output U_{ANY} [V]	Expected [deg]	Actual [deg]	Pass/Fail	Output U_{ANZ} [V]	Expected [deg]	Actual [deg]	Pass/Fail
Zero Position 1	0.07570	141.8	141.8		-0.01739	0	1.1		-0.00290	0	0.2	
Position 2	0.12125	121.8	121.5	Pass	-0.09243	5	4.94	Pass	-0.07749	5	4.89	Pass
Position 3	0.05154	161.8	162.2	Pass	0.06177	-5	-5.22	Pass	0.07211	-5	-4.92	Pass

Figure 21: *Example 3D IR-TRACC Zero-position Verification Template. Polarities shown as -1, after correction in step 4.*

Date	12/02/2016	Technician	Helmut Loth	Measurement ID	

Dummy Installation Location							
Abdomen: DELETE; Thorax: select Upper or Lower	Lower	Select Left or Right:	Left	UJ Rev D or Rev E	REV E	Abdomen or Thorax	Thorax
Centerline Offset: δ [mm]	-15.65	* = Distance from Coordinate System origin to end pivot c	REV D / REV E			$_{P1}$* [mm]	141.8

Calibration Factors											
IR-TRACC Serial Number			DS0658	Y Angle Sensor Serial Number			DS3783	Z Angle Sensor Serial Number			DS3784
0.035032	Sensitivity [V_{LIN}/mm]	Cal. factor [mm/V_{LIN}]	28.5454	0.003035	Sensitivity [V/V/deg]	Cal. Factor [deg/V/V]	329.47	0.003049	Sensitivity [V/V/deg]	Cal. Factor [deg/V/V]	327.96
Displacement Intercept [mm]			115.46		Polarity		-1		Polarity		-1
EXPonent [-]			-0.48418	EXCITATION VOLTAGE U_{EX} [V]			5.000	(during 0 position measurements)			
1.47836	Radius Zero-Position Intercept [V_{LIN}]	[mm]	42.20	At Position 1: D_{P1} = Zero-position Intercept + Cal.Factor * (U_{IR1} ^ EXP); Zero-Position-Intercept = D_{P1} - Cal.Factor * (U_{IR1} ^ EXP) [mm]							

Zero Postion Measurements	IR-TRACC Radius R				Y Angle Sensor				Z Angle Sensor			
	Output U_{IR}	Expected	Actual		Output U_{ANY}	Expected	Actual		Output	Expected	Actual	

INSTRUCTIONS | DATA-3D-Zero Position | CL-FO-00103P | CL-FO-00066P-Y | CL-FO-00066P-Z | AY-FO-00013P | change log

Figure 22*: Example Integrated 3D calibration-verification template. Note tabs at the bottom of the sheet for displacement and angle transducer calibration. Polarities shown as -1, after correction in step 4. Drop down list cell L14 Rev D-Rev E shown.*

Step 3

- Hook up the power supply to the IR-TRACC and voltmeter to measure IR-TRACC output. Slide all IR-TRACC tubes out to the small end.
- Read the voltmeter and enter IR-TRACC output voltage in cell C27.
- Hook up the Y angle sensor and enter output voltage in cell G27; hook up the Z angle sensor and enter output voltage in cell K27. Please remember to enter the sign of the value, so if the voltage is negative, enter – value!
- Save the file.

Step 4

- Move the universal joint end to position 2 on the fixture using the M5x16 SHCS screw, fasten screw until secure. Slide all IR-TRACC tubes out to the small end.
- Hook up the IR-TRACC, enter IR-TRACC voltage in cell C28. Check pass-fail criteria. If there is a fail, check for a type error in the output voltage.

- Hook up the Y angle sensor and enter output voltage in cell G28; please remember to enter the correct sign of the value, so if the voltage is negative, enter –value! Check pass-fail criteria. If there is a fail, most likely the polarity is wrong. Go to cell J20 and select to opposite polarity from the drop down list (change from -1 to 1, or from 1 to -1). If the polarity flip did not solve the problem, recheck the excitation voltage on the sensor and if it is entered correctly in cell J21. If it still does not pass, there may a problem with the calibration factor in K19. Recheck the number with the calibration sheet and recheck the units or the unit conversion calculation.
- Hook up the Z angle sensor and enter output voltage in cell K28. Please remember to enter the sign of the value, so if the voltage is negative, enter –value! Check pass-fail criteria. If there is a fail, most likely the polarity is wrong. Go to cell N20 and select to opposite polarity from the drop down list (change from -1 to 1, or from 1 to -1). If the polarity flip did not solve the problem, recheck the calibration factor in N19. Recheck the number with the calibration sheet and recheck the units or the unit conversion calculation.
- Save the file.

Step 5

- Move the universal joint end to position 3 on the fixture using the M5x16 SHCS screw, fasten screw until secure. Slide all IR-TRACC tubes out to the small end.
- Hook up the IR-TRACC, enter IR-TRACC voltage in cell C29. The actual radius should be close the expected radius.
- Hook up the Y angle sensor and enter output voltage in cell G29; please remember to enter the correct sign of the value, so if the voltage is negative, enter –value! Check pass-fail criteria.
- Hook up the Z angle sensor and enter output voltage in cell K29. Please remember to enter the sign of the value, so if the voltage is negative, enter –value! Check pass-fail criteria.
- Save the file.
- The Zero-Position Verification is now completed, see **Figure 24**.

The zero-position verification sheets gives an overview of calibration factors of the three sensors of the assembly in the top section. Formulas and examples are provided to calculate the radius and angles based on the parameters found on the sheet. At the bottom of the sheet a table presents the known coordinates on the verification fixture and calculated coordinates based on the sensor outputs calculated with the mathematical functions described in paragraph 6. Note that deviations of z-angle sensor affect the x and mainly y coordinates and that deviations of the y-angle sensor affect the calculated x and mainly z coordinates.

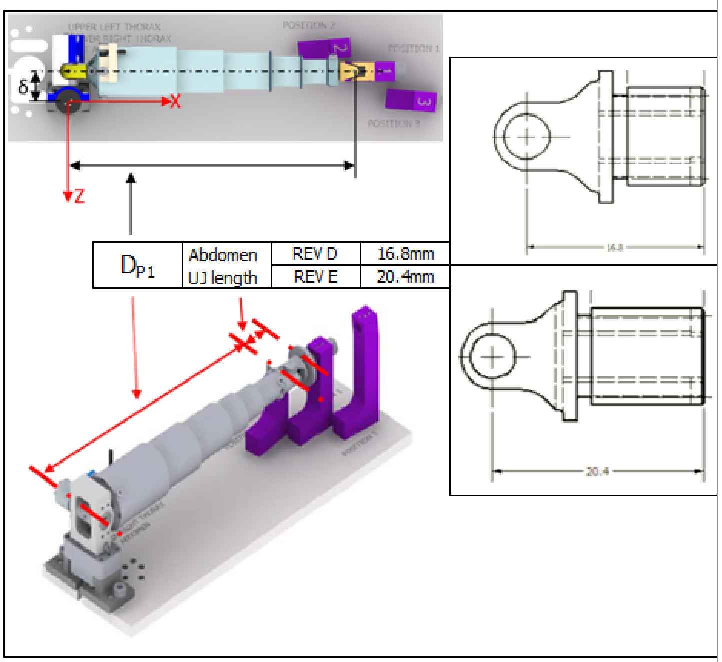
(An example of the integrated 3D calibration-verification template is shown in **Figure 24**. Additional to the items mentioned above, the integrated calibration-verification template gives calculated radius output per IR-TRACC raw voltage, based on the displacement calibration data. This can help identifying faults when setting up calibration parameters in your DA system).

Date	12/02/2016	Technician	Helmut Loth	Measurement ID	

Dummy Installation Location							
Abdomen: DELETE; Thorax: select Upper or Lower	Lower	Select Left or Right:	Left	UJ Rev D or Rev E		Abdomen or Thorax	Thorax
Centerline Offset: **δ [mm]**	-15.65	$_{P1}$* = Distance from Coordinate System origin to end pivot center in position 1: **D_{P1}* [mm]**					141.8

Calibration Factors											
IR-TRACC Serial Number			DS0658	Y Angle Sensor Serial Number			DS3783	Z Angle Sensor Serial Number			DS3784
0.035032	Sensitivity [V_{LIN}/mm]	Cal. factor [mm/V_{LIN}]	**28.5454**	0.003035	Sensitivity [V/V/deg]	Cal. factor [deg/V/V]]	**329.47**	0.003049	Sensitivity [V/V/deg]	Cal. factor [deg/V/V]]	**327.96**
Displacement Intercept [mm]			115.46	Polarity			-1	Polarity			-1
EXPonent [-]			**-0.48418**	**EXCITATION VOLTAGE U_{EX} [V]**			**5.000**	**(during 0 position measurements)**			
1.47836	Radius Zero-Position Intercept [V_{LIN}] [mm]		42.20	**At Position 1**: D_{P1} = Zero-position Intercept + Cal.Factor * (U_{IR1} ^ EXP); Zero-Position-Intercept = D_{P1} – Cal.Factor * (U_{IR1} ^ EXP) [mm]							

Zero Postion Measurements												
	IR-TRACC Radius R				Y Angle Sensor				Z Angle Sensor			
	Output U_{IR} [V]	Expected [mm]	Actual [mm]	Pass/Fail	Output U_{ANY} [V]	Expected [deg]	Actual [deg]	Pass/Fail	Output U_{ANZ} [V]	Expected [deg]	Actual [deg]	Pass/Fail
Zero **Position 1**	0.07570	141.8	141.8		-0.01739	0	1.1		-0.00290	0	0.2	
Position 2	0.12125	121.8	121.5	Pass	-0.09243	5	4.94	Pass	-0.07749	5	4.89	Pass
Position 3	0.05154	161.8	162.2	Pass	0.06177	-5	-5.22	Pass	0.07211	-5	-4.92	Pass
	1.47836	Radius Zero-Position Intercept [V_{LIN}] [mm]		42.20	0.01739	Y Angle Sensor Offset [V] [Deg]		1.14589	0.00290	Z Angle Sensor Offset [V] [Deg]		0.19021
	Radius [mm]= Zero-Int [mm] + Cal.Factor[mm/V_{lin}]*(U_{IR} ^ EXP) Radius [mm]= (U_{IR}^EXP + Zero-Int [V_{lin}])/Sensitivity [V_{lin}/mm]				Y Angle φ_Y = Cal.Factor*U_{ANY}/U_{EX} – φ_{OSY}. **At position1**: 0 = Cal.Factor*U_{ANY1}/U_{EX} – φ_{OSY}; Y Offset angle φ_{OSY} = + Cal.factor*U_{ANY1}/U_{EX} [deg]							
	Formula Radius = 42.2 + 28.5454 * (Uir ^ -0.4842) [mm] Formula Radius = (Uir ^ -0.4842 + 1.478) / 0.03503 [mm]				Calculate IR-TRACC Y Angle using the formula: Y Angle = 1.1459 + -329.47 * Uany / 5 [deg]				Calculate IR-TRACC Z Angle using the formula: Z Angle = 0.1902 + -327.96 * Uanz / 5 [deg]			



Position Verification	X position Expected	Calculated	Verification	Y position Expected	Calculated	Verification	Z Position Expected	Calculated	Verification
Position 1	141.8	141.8	Pass	0.0	0.0	Pass	-15.6	-15.7	Pass
Position 2	119.5	119.2	Pass	10.7	10.4	Pass	-26.1	-26.0	Pass
Position 3	161.7	162.3	Pass	-14.1	-13.9	Pass	-1.5	-0.9	Pass

Figure 23: *Completed 3D IR-TRACC Zero-Position Verification Sheet EN-FO-00013C*

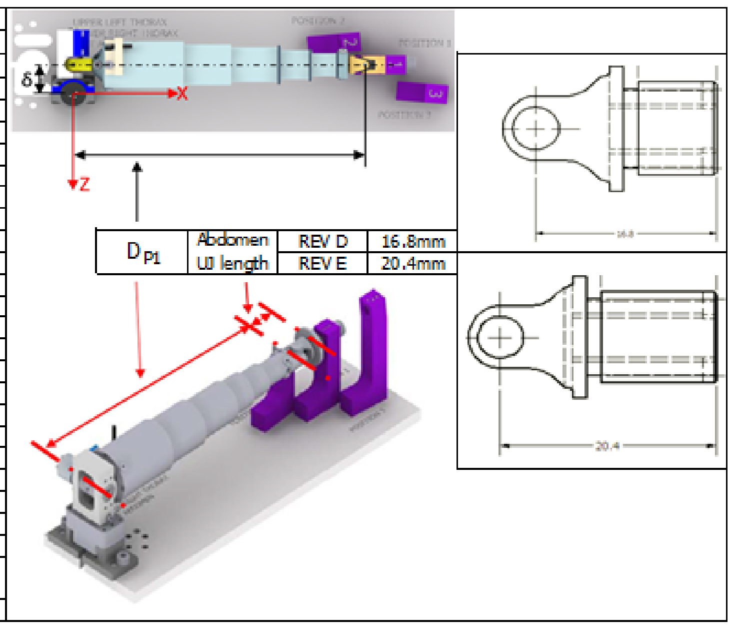
3D IR-TRACC Position Summary For use with TF-472-6000					
EN-FO-00013C				3D Assembly part nr	472-3580
Date	12/02/2016	Technician	Peter Peterson	Measurement ID	

Dummy Installation Location							
Abdomen: Delete Thorax: select Upper or Lower	Lower	Select Left or Right:	Right	UJ Rev D or Rev E		Abdomen or Thorax	Thorax
Centerline Offset: δ [mm]	-15.65	$_{P1}$ = Distance from Coordinate System origin to end pivot center in position 1: D_{P1} [mm]					141.8

Calibration Factors											
IR-TRACC Serial Number			DS0658	Y Angle Sensor Serial Number			DS3783	Z Angle Sensor Serial Number			DS3784
0.035032	Sensitivity [V_{LIN}/mm]	Cal. factor [mm/V_{LIN}]	28.5454	0.006070	Sensitivity [V/V/deg]	Cal. Factor [deg/V/V]	164.73	0.003049	Sensitivity [V/V/deg]	Cal. Factor [deg/V/V]	327.96
Displacement Intercept [mm]			115.46		Polarity		-1		Polarity		1
EXPonent [-]			-0.48418	EXCITATION VOLTAGE U_{EX} [V]			5.000	(during 0 position measurements)			
1.47836	Radius Zero-Position Intercept [V_{LIN}]	[mm]	42.20	At Position 1: D_{P1} = Zero-position Intercept + Cal.Factor * (U_{LR1} ^ EXP); Zero-Position-Intercept = D_{P1} - Cal.Factor * (U_{LR1} ^ EXP) [mm]							

Zero Postion Measurements	IR-TRACC Radius R				Y Angle Sensor				Z Angle Sensor			
	Output U_R [V]	Expected [mm]	Actual [mm]	Pass/Fail	Output U_{ANY} [V]	Expected [deg]	Actual [deg]	Pass/Fail	Output U_{ANZ} [V]	Expected [deg]	Actual [deg]	Pass/Fail
Zero Position 1	0.07570	141.8	141.8		-0.03478	0	1.1		-0.00290	0	-0.2	
Position 2	0.12125	121.8	121.5	Pass	-0.18486	5	4.94	Pass	-0.07749	-5	-4.89	Pass
Position 3	0.05154	161.8	162.2	Pass	0.12354	-5	-5.22	Pass	0.07211	5	4.92	Pass
	1.47836	Radius Zero-Position Intercept [V_{LIN}]	[mm]	42.20	0.03478	Y Angle Sensor Offset [V]	[Deg]	1.14589	-0.00290	Z Angle Sensor Offset [V]	[Deg]	-0.19021
	Radius [mm]= Zero-Int [mm] + Cal.Factor[mm/V_{lin}]*(U_R ^ EXP) Radius [mm]= (U_R^EXP + Zero-Int [V_{lin}])/Sensitivity [V_{lin}/mm]				Y Angle ϕ_Y = Cal.Factor*U_{ANY}/U_{EX} - ϕ_{OSY}. At position1: 0 = Cal.Factor*U_{ANY1}/U_{EX} - ϕ_{OSY} Y Offset angle ϕ_{OSY} = + Cal.factor*U_{ANY1}/U_{EX} [deg]							
	Formula Radius = 42.2 + 28.5454 * (Uir ^ -0.4842) [mm] Formula Radius = (Uir ^ -0.4842 + 1.478) / 0.03503 [mm]				Calculate IR-TRACC Y Angle using the formula: Y Angle = 1.1459 + -164.73 * Uany / 5 [deg]				Calculate IR-TRACC Z Angle using the formula: Z Angle = -0.1902 + 327.96 * Uanz / 5 [deg]			

Displacement Calibration		Radius Average output	
Displacement [mm]	Output U_R [V]	Ideal Radius [mm]	Calculated [mm]
0	0.0557	157.66	157.79
5.0	0.0614	152.66	152.43
10.0	0.0672	147.66	147.68
15.0	0.0741	142.66	142.83
20.0	0.0828	137.66	137.57
25.0	0.0923	132.66	132.68
30.0	0.1039	127.66	127.64
35.0	0.1174	122.66	122.72
40.0	0.1340	117.66	117.73
45.0	0.1548	112.66	112.65
50.0	0.1798	107.66	107.72
55.0	0.2125	102.66	102.62
60.0	0.2544	97.66	97.59
65.0	0.3100	92.66	92.53
70.0	0.3852	87.66	87.51
75.0	0.4899	82.66	82.53
80.0	0.6399	77.66	77.63
85.0	0.8679	72.66	72.77
87.0	0.9900	70.66	70.88
0.0	0.0000	0.00	0.00
0.0	0.0000	0.00	0.00
0.0	0.0000	0.00	0.00
0.0	0.0000	0.00	0.00
0.0	0.0000	0.00	0.00
0.0	0.0000	0.00	0.00



Position Verification	X position Expected	X position Calculated	X position Verification	Y position Expected	Y position Calculated	Y position Verification	Z Position Expected	Z Position Calculated	Z Position Verification
Position 1	141.8	141.8	Pass	0.0	0.0	Pass	-15.6	-15.7	Pass
Position 2	119.5	119.2	Pass	-10.7	-10.4	Pass	-26.1	-26.0	Pass
Position 3	161.7	162.3	Pass	14.1	13.9	Pass	-1.5	-0.9	Pass

Figure 24: *Completed Integrated 3D Zero-Position Verification Sheet EN-FO-00014C or EN-FO-00015C*

5.5 Parameter Implementation in Data Acquisition Systems

The Zero-Position Verification Sheet provides calibration parameters for all three sensors. Parameters are provided in multiple units to support various DAS system. The sensitivity is given in volt per engineering unit and the inverse value, the calibration factor in engineering unit per volt. It is important to apply fixed angle offsets in the DAS system, so the angle output of the sensors remains aligned with the local coordinate systems. For the

IR-TRACC transducer the exponent, calibration factor and zero-position intercept (mm offset to local coordinate system) must be implemented.

If the (DAS or software) system allows the centerline offset δ should be implemented at assembly level. Upper thorax, lower thorax and abdomen sensors all have a different centerline offset, which affects the post processing calculation, see Paragraph 6 and **Appendix B**.

For both the angle and displacement sensors, make sure that the data channels are not offset corrected at time zero. Zeroing the data at time zero will invalidate IR-TRACC data beyond recovery and the angle data will lose the connection to the local spine coordinate system.

Apply CFC180 filter class on all angle and displacement channels. Apply filtering of the IR-TRACC data <u>after</u> the linearization. Filtering raw IR-TRACC signal will invalidate the data.

The DAS system shall calculate the Y and Z-angles as follows:

$\phi_Y = U_{ANY} * C_{ANY} / U_{EX} - \phi_{OSY}$ [degrees] and $\phi_Z = U_{ANZ} * C_{ANZ} / U_{EX} - \phi_{OSZ}$ [degrees] (use if Data Acquisition System applies Calibration Factor)

$\phi_Y = (U_{ANY} - U_{ANY1}) / S_{ANY} / U_{EX}$ [degrees] and $\phi_Z = (U_{ANZ} - U_{ANZ1}) / S_{ANZ} / U_{EX}$ [degrees] (use if Data Acquisition System applies Sensitivity)

Apply the Radius Zero-Intercept I_R [mm] or Radius Zero-Intercept Voltage [V_{LIN}] as a fixed offset in the Data Acquisition System to obtain the IR-TRACC radius in [mm] as DAS output, for instance, in ISO MME code. The DAS system shall calculate the IR-TRACC Radius as follows:

R [mm] = $C_{IR} * (U_{IR}$^EXP$) + I_R$ (use if Data Acquisition System applies Calibration Factor)

R [mm] = $(U_{IR}$^EXP $+ I_{RV}) / S_{IR}$ (use if Data Acquisition System applies Sensitivity)

Examples how to implement parameters can be obtained for most data acquisition systems and/or automotive crash testing software.

In any case it is highly is recommended after sensor parameters have been implemented in the DAS to recheck the values on the zeroing fixture in the DAS online mode. If possible, do that immediately after step 5 from the previous chapter (5.4), leaving the 3D IR-TRACC on the fixture. Check if the 3D sensor replicates the expected radii and angles as shown in the verification sheet.

5.6 ISO Code Examples

ISO code examples are provided in **Appendix C**.

5.7 Expected Outputs on Fixture

After the data processing calculations have been implemented in software (see paragraph 6), the output of the 3D measurement system can be checked against the known 3D coordinates of the fixture in the **Table 10**. Please keep in mind that overall accuracy of the 3D IR-TRACC has its limitation due to the necessary system play to make the tubes collapsible. Deviations up to ±3% of the calibration range can be expected. Nevertheless, this step serves the purpose of an entire measurement chain check, including individual sensors, DAS parameter implementation and data processing software. **This final check is highly recommended as it closes the entire measurement chain loop.**

One example to proceed is to record a dynamic test on the fixture; move the IR-TRACC small end from position 1 to position 2 to position 3 and back; record the run in your final DAS test set-up; process the data with the software and check if the known positions on the fixture (**Table 10**) are replicated after post processing the data. If a large deviation is found, this is a good indication that there may be an error that needs correction.

Note that the zero-position verification sheet also provides expected calculated verification coordinates (**Figure 23** and **Figure 24**).

Table 10: *Position verification in 3 positions of the fixture per 3D IR-TRACC assembly type*

Position Verification	X Coordinate	Y Coordinate	Z Coordinate
Upper Thorax			
(Zero-) Position 1	141.8	0.0	15.6
Position 2	119.5	10.7	26.1
Position 3	161.7	-14.1	1.5
Lower Thorax			
(Zero-) Position 1	141.8	0.0	-15.6
Position 2	119.5	10.7	-26.1
Position 3	161.7	-14.1	-1.5
Abdomen Rev E			
(Zero-) Position 1	150.9	0.0	0.0
Position 2	128.7	9.7	9.6
Position 3	171.0	13.2	13.2
Abdomen Rev D			
(Zero-) Position 1	154.5	0.0	0.0
Position 2	132.3	10.0	9.9
Position 3	174.5	13.5	13.5

6 Data Processing Calculations

A list of definitions, parameters and symbols is given in **APPENDIX A**.
The mathematical background of the calculations is given in **APPENDIX B**.

Calculate the coordinates of the rib and abdomen joint center with respect to its local coordinate system with the following formulas:

$x_i = \delta * \sin(\varphi_{Yi}) + R_i * \cos(\varphi_{Yi}) * \cos(\varphi_{Zi})$ [mm]
$y_i = R_i * \sin(\varphi_{Zi})$ [mm]
$z_i = \delta * \cos(\varphi_{Yi}) - R_i * \sin(\varphi_{Yi}) * \cos(\varphi_{Zi})$ [mm]

Remember to apply the correct values for δ (also given in the zero-position verification sheet):

$\delta = +15.65$ Upper IR-TRACC [mm]
$\delta = -15.65$ Lower IR-TRACC [mm]
$\delta = 0$ Abdomen IR-TRACC [mm]

Calculate the x, y and z deflection of the rib and abdomen joint center with the following formulas:

$D_{xi} = x_i - x_0$ [mm]
$D_{yi} = y_i - y_0$ [mm]
$D_{zi} = z_i - z_0$ [mm]

Calculate the resultant deflection of the rib and abdomen joint center with the following formula:

$D_i = \sqrt{(D_{xi}^2 + D_{yi}^2 + D_{zi}^2)}$ [mm]

7 Installation, Inspection and Repairs

After a test series has been performed, several inspections may be performed to ensure the dummy's integrity has remained intact. Use good engineering judgment to determine the frequency of these inspections; however, it is recommended that a thorough inspection be conducted after every twenty tests have been performed. Inspection frequency should increase if the tests are particularly severe or if unusual data signals are being recorded. Both electrical and mechanical inspections are most easily carried out during a disassembly of the dummy. Disassembly of the 3D IR-TRACC units from the dummy can be performed by reversing the assembly procedure.

7.1.1 IR-TRACC Installation

1. The IR-TRACCs white wire is present on the upper and lower thoracic IR-TRACCs running from the large body to the front end. The white wire is a vulnerable part and it is recommended to pay attention to the cable routing. Keep it pointing up on upper IR-TRACCs away from the sternum mass, and keep the white wire pointing down on the lower thoracic IR-TRACCs away from the abdomen bag.
2. When assembling the IR-TRACC front end universal joint to the rib, make sure to hold the IR-TRACC smallest front tube against rotation while tightening the large 19mm hex screw in the bib. If not, the tube will rotate along and the little white wire will wind up on the tubes resulting in IR-TRACC failure.
3. Tie down the abdomen zipper tag in the area of the lower right IR-TRACC front end with cable tie to clear it away from the IR-TRACC white wire.
4. Be sure to keep clearance between the IR-TRACC tubes and spine. Make sure no cables are running in this area, as IR-TRACCs need as much range of motion as available.
5. It is recommended to assemble lower thoracic IR-TRACCs when the spine is adjusted at slouched position. When the spine is adjusted to erect position it can be hard to assemble the lower thoracic IR-TRACCs, as in this position these IR-TRACCs are fully extended. It may be necessary to push the number 6 rib ends slightly towards the back to ease assembly.

7.1.2 Electrical Inspections (Instrumentation Check)

Begin with a visual and tactile inspection of all instrument wires. The wires should be inspected for nicks, cuts, pinch points, and damaged electrical connections that would prevent the signals from being transferred properly to the data acquisition system. The instrument wire should be checked to ensure they are properly strain relieved.

7.1.3 Mechanical Inspection

The 3D IR-TRACC units need to be visually inspected to determine if they are still functioning properly. This mechanical inspection should also involve a quick check for any loose bolts in the main assembly. Each area of mechanical inspection is covered below.

1. Inspect the telescoping column of the IR-TRACC for physical damage.
2. Inspect the movement (extension and retraction) of the telescoping column of the IR-TRACC.
3. Inspect the rotary potentiometers and brackets for damage.
4. Inspect the wiring for physical damage including broken connectors, pinched wires, missing insulation, etc.

5. Inspect the set screws locking the rotary potentiometer shafts in place.
6. It is recommended to check the angle values of each of the 18 individual IR-TRACC sensors prior to each test (during dummy preps outside the vehicle) and compare the pre-test values with the ones from the previous test. If there is a large deviation there may be something wrong with the angle sensors. In such case repeat the zeroing procedure. Most DAS systems have built in functionality to check pre-test values.
7. It is recommended IR-TRACCs be checked inside the dummy for play. When IR-TRACCs are still inside the dummy you can easily check for play in the whole unit, by gripping the middle tube and try to move left-right, up-down. If there is excessive play, remove the IR-TRACC assembly for inspection and checking on the zeroing bracket. It is recommended to perform this play check prior to each test. It is simple and effective to find faulty IR-TRACCs.
8. Minimum frequency for IR-TRACC zero verification is once a year during sensor calibration, however it is recommended to do it more frequently. For instance, if an IR-TRACC is already removed from the dummy for another purpose, it is recommended to run the zero verification before assembly back into the dummy. Proposed checking frequency guide line for the zero-position is once every 10 tests.

8 APPENDIX A: Definitions, Parameters and Symbols

Table 11: *List of Parameters, symbols and definitions*

Number	Parameter	Symbol*	Unit	Definition/Description
	X-axis	X	-	Global dummy x-axis
	Y-axis	Y	-	Global dummy y-axis
	Z-axis	Z	-	Global dummy z-axis
	Origin of coordinate system	O_{UTS} O_{LTS} O_{LS} O_{IR}	-	Origin Upper thoracic Spine coordinate system Origin Lower thoracic Spine coordinate system Origin Lumbar Spine coordinate system Origin IR-TRACC coordinate system
		X_{UTS}	-	Local x-axis Upper Thoracic Spine (Figure 25)
		Y_{UTS}	-	Local y-axis Upper Thoracic Spine (Figure 25)
		Z_{UTS}	-	Local z-axis Upper Thoracic Spine (Figure 25)
		X_{IR}	-	IR-TRACC compression axis (Figure 25)
		Z_{IR}	-	IR-TRACC z-pivot axis (Figure 25)
		X_{LTS}	-	Local x-axis Lower Thoracic Spine (Figure 3)
		Y_{LTS}	-	Local y-axis Lower Thoracic Spine (Figure 3)
		Z_{LTS}	-	Local z-axis Lower Thoracic Spine (Figure 3)
		X_{LS}	-	Local x-axis Lumbar Spine
		Y_{LS}	-	Local y-axis Lumbar Spine
		Z_{LS}	-	Local z-axis Lumbar Spine
	Distance Position 1	D_{P1}	mm	Known distance origin of 3D sensor coordinate system to 3D sensor end pivot point in position-1 on Zero-position on fixture TH-472-6000
	Distance Position 2	D_{P2}	mm	Known distance at position-2 on TH-472-6000
	Distance Position 3	D_{P3}	mm	Known distance at position-3 on TH-472-6000
	Excitation	U_{EX}	V	Excitation voltage sensor
	IR-TRACC output	U_{IR}	V	IR-TRACC output voltage
	Optimized exponent	EXP	-	IR-TRACC linearization exponent
	Linearized voltage	U_{LIN}	V_{LIN}	IR-TRACC output voltage to power of exponent
	Calibration factor	C_{IR}	mm/V_{LIN}	IR-TRACC mm displacement per linearized voltage
	Sensitivity	S_{IR}	V_{LIN}/mm	IR-TRACC linearized voltage per 1mm displacement
	Displacement Intercept	I_D	mm	IR-TRACC Displacement at 0 V_{LIN}
	Displacement intercept voltage	I_{DV}	V_{LIN}	Linearized Voltage at 0mm displacement
	Radius Intercept	I_R	mm	IR-TRACC Radius at 0 V_{LIN}
	Radius Intercept voltage	I_{RV}	V_{LIN}	Linearized Voltage at 0mm radius

	Axis Offset	δ	mm	Mechanical offset distance between axis of radius measurement and sensor coordinate system (Figure 3, Figure 25)
	Angle Sensitivity	S_{ANY} S_{ANZ}	V/V/degrees	Angle Sensor Sensitivity. Output voltage per degree rotation at 1V excitation.
	Angle Calibration factor	C_{ANY} C_{ANZ}	degrees/V/V	Angle Sensor degrees rotation at 1V output per 1V excitation.
	IR-TRACC Pos1 output (tubes-out)	U_{IR1}	V	IR-TRACC Output voltage at position-1 (Zero-position on TH-472-6000)
	IR-TRACC Pos2 output (tubes-out)	U_{IR2}	V	IR-TRACC Output voltage at position-2 (tubes out)
	IR-TRACC Pos3 output (tubes-out)	U_{IR3}	V	IR-TRACC Output voltage at position-3 (tubes out)
	Y-angle sensor output	U_{ANY}	V	Y-axis angle sensor output voltage
	Y-Angle output 1	U_{ANY1}	V	Y-axis angle sensor output at position-1
	Y-Angle output 2	U_{ANY2}	V	Y-axis angle sensor output at position-2
	Y-Angle output 3	U_{ANY3}	V	Y-axis angle sensor output at position-2
	Z-angle sensor output	U_{ANZ}	V	Z-axis angle sensor output voltage
	Z-Angle output 1	U_{ANZ1}	V	Z-axis angle sensor output at position-1
	Z-Angle output 2	U_{ANZ2}	V	Z-axis angle sensor output at position-2
	Z-Angle output 3	U_{ANZ3}	V	Z-axis angle sensor output at position-2
	Angle sensor offset	φ_{OSY}	degrees	Y-angle sensor offset at Zero-Position
	Angle sensor offset	φ_{OSZ}	degrees	Z-angle sensor offset at Zero-Position
	Time	t, t_0, t_i	s	Time, time zero, time i
	Radius	R, R_0, R_i	mm	IR-TRACC Radius at t_0, at t_i (Figure 3, Figure 25) Distance from origin of sensor coordinate system to end pivot point
	IR-TRACC Y-angle	φ_Y, φ_{Y0}, φ_{Yi}	degrees	IR-TRACC angle along y-axis with respect to coordinate system, at t_0 and at t_i (Figure 3, Figure 25)
	IR-TRACC Z-angle	φ_Z , φ_{Z0}, φ_{Zi}	degrees	IR-TRACC angle along z-axis with respect to coordinate system, at t_0 and at t_i (Figure 25)
	x coordinate	x, x_0, x_i	mm	Rib or abdomen end pivot point x- coordinate, x at t_0, x at t_i (Figure 3, Figure 25)
	y coordinate	y, y_0, y_i	mm	Rib or abdomen end pivot point y- coordinate, y at t_0, y at t_i (Figure 3, Figure 25)
	z coordinate	z, z_0, z_i	mm	Rib or abdomen end pivot point z- coordinate, z at t_0, z at t_i (Figure 3, Figure 25)
	x deflection	Dx_i	mm	Rib or abdomen end pivot point deflection in x direction at t_i

y deflection	Dyi	mm	Rib or abdomen end pivot point deflection in y direction at t_i
z deflection	Dzi	mm	Rib or abdomen end pivot point deflection in z direction at t_i
Resultant Deflection	Di	mm	Resultant rib or end pivot point abdomen deflection in space at t_i

*Consolas Font was chosen to clearly distinguish between letters O, i and numeral characters zero 0, 1

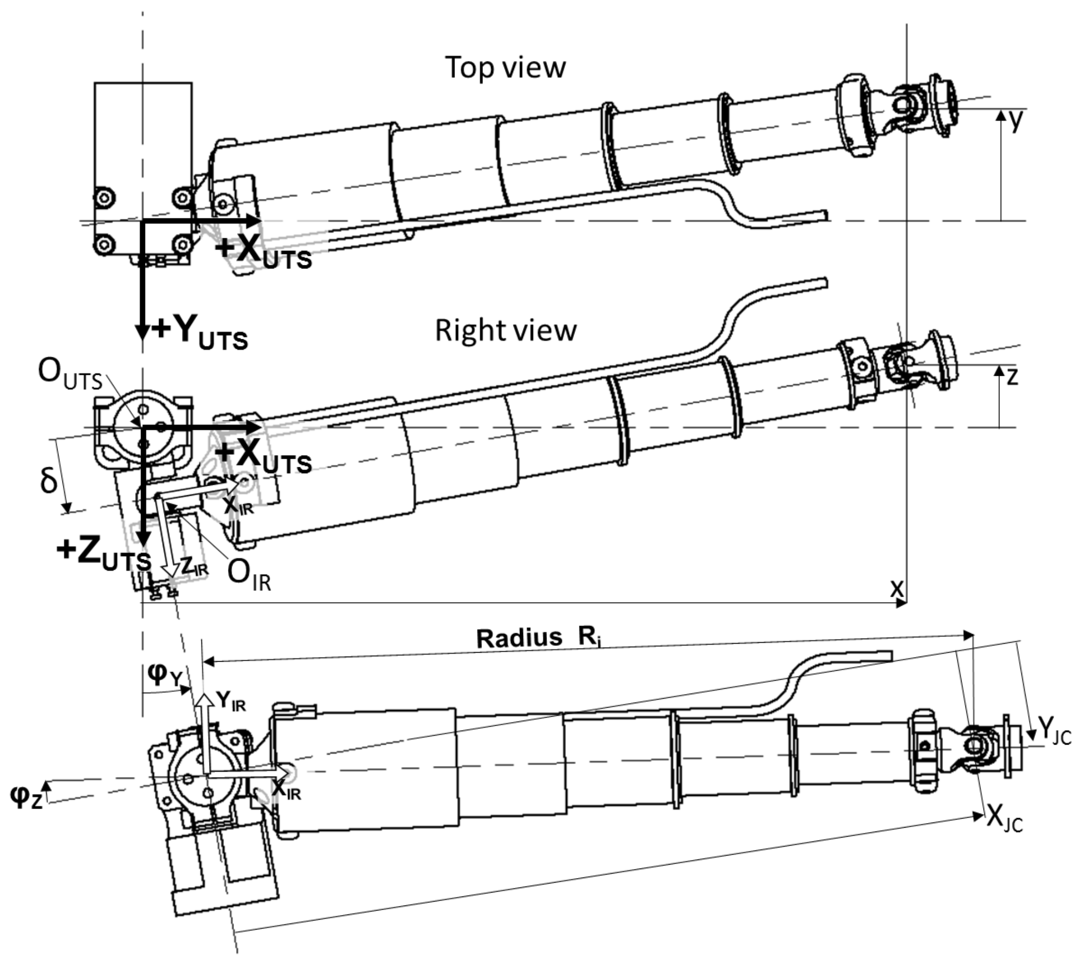


Figure 25: *Upper Right 3D IR-TRACC top view in +Z_{UTS} direction, right view in –Y_{UTS} direction and bottom view on Z-axis angle sensor -Z_{IR}. The orientation of the 3D IR-TRACC corresponds roughly to the assembly orientation inside the dummy. Note that the values for y, z and ϕ_z in this figure are negative.*

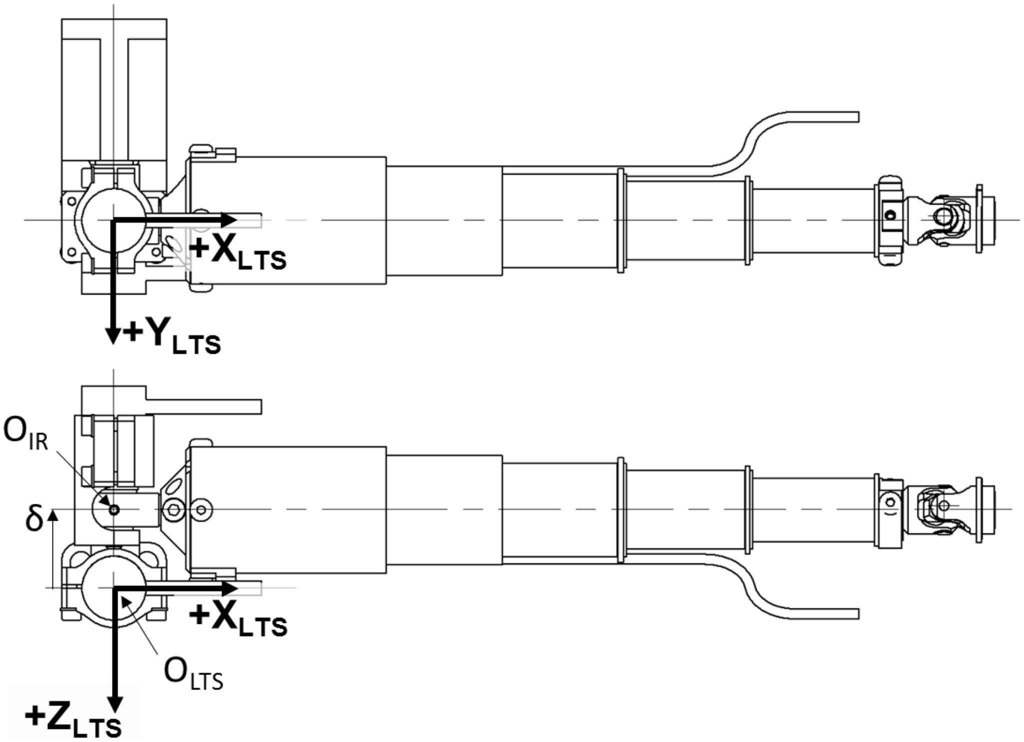


Figure 26: *Lower Right 3D IR-TRACC top view in +Z_{LTS} direction, right view in –Y_{LTS} direction. The orientation of the 3D IR-TRACC corresponds roughly to the assembly orientation inside the dummy.*

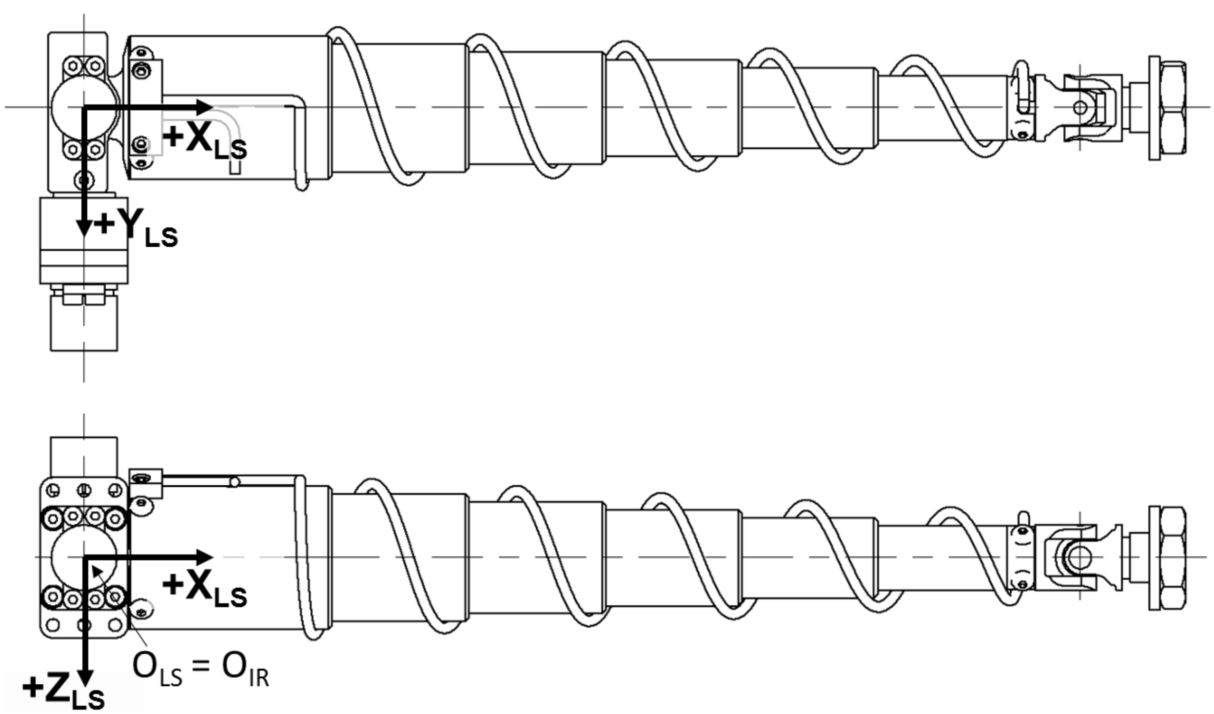


Figure 27: *Right Abdomen 3D IR-TRACC top view in +Z_{LS} direction, right view in –Y_{LS} direction.*

9 APPENDIX B: 3D IR-TRACC Data Processing Mathematical Background

For definitions see **Table 1**, **Table 11**, **Figure 2**, **Figure 3, Figure 25** and **Figure 26**.

IR-TRACC Calibration Parameters

The IR-TRACC is a nonlinear transducer. During transducer calibration, output voltage and displacement data are collected first (red line in **Figure 29**). Based on the nonlinear output the linearization exponent EXP is numerically determined by an optimization routine resulting in a linearized output (**Figure 28** blue line), then the Calibration factor C_{IR} is calculated. The IR-TRACC calibration processing procedure is part of the integrated calibration template for data collection and processing. The exponent and calibration factor can be found in the calibration sheet. Historically, this procedure is a displacement calibration resulting in 0mm fully extended and a negative calibration factor and descending calibration slope. Hence, the IR-TRACC displacement gets larger with decreasing length. This works well for a single dimensional chest compression injury parameter. Note that the coordinate system of the displacement calibration is not coincident with the 3D transducer local coordinate system LTS.

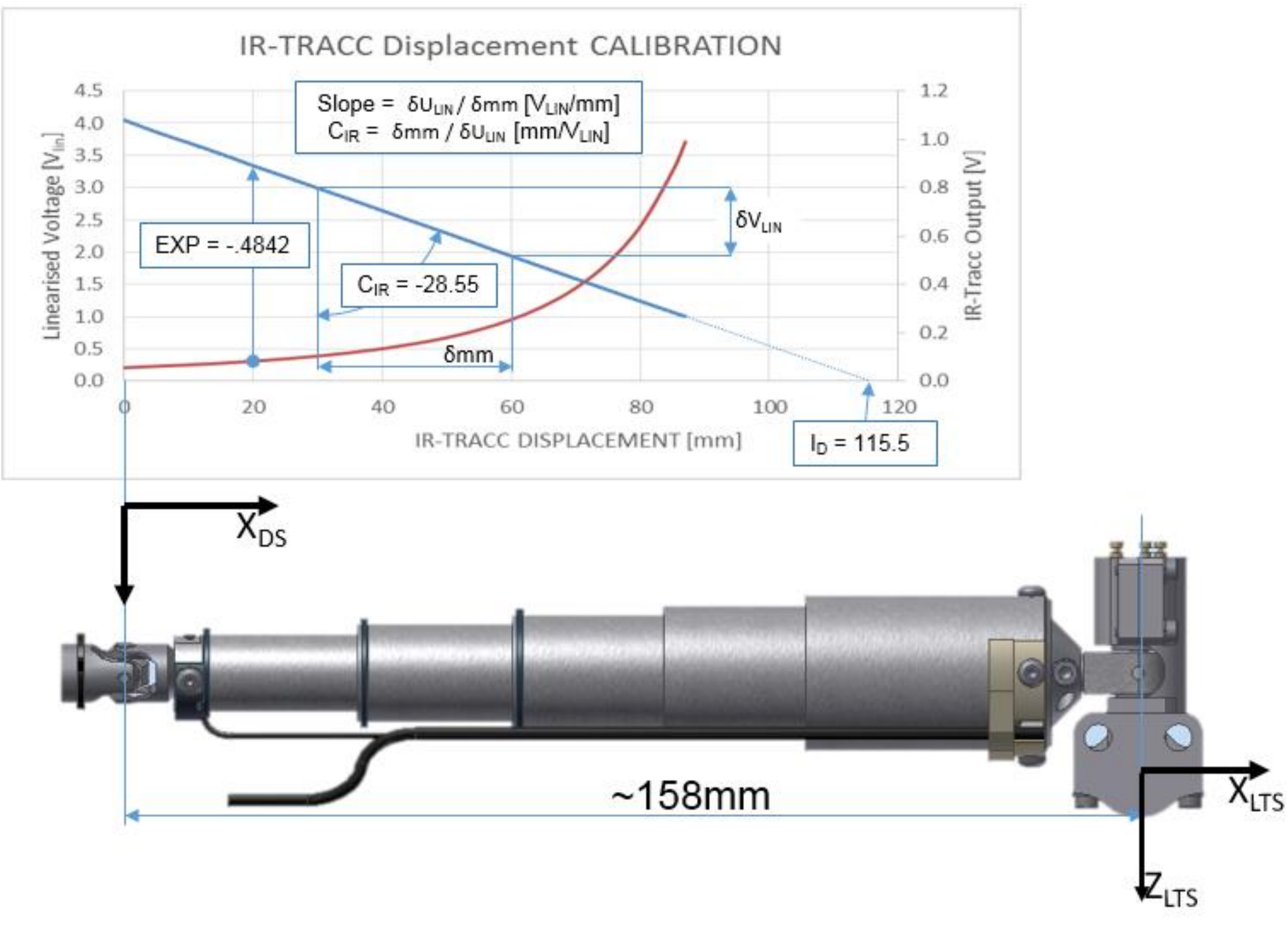


Figure 28: Displacement calibration example. Red line is nonlinear output of the IR-TRACC (scale right), blue line is the linearized output (scale left), including example parameters linearization exponent, calibration factor and displacement intercept. Note negative slope and mismatch of coordinate systems.

For 2D and 3D transducers however, IR-TRACC output needs to be expressed in the local coordinate system, and the IR-TRACC output shall be the distance between the coordinate system origin and the pivot point at the rib or abdomen connection, its radius, see **Figure 29**. We need a linear output increasing with extension, hence a positive calibration factor, hence the linearization exponent remains the same and the calibration factor from displacement calibration will get a positive sign. Further, the IR-TRACC radius should be zero mm at coordinate system origin. We can transform the displacement calibration parameter to radius calibration parameter by calculating the offset of the IR-TRACC output in a known distance on a fixture. The zero-position fixture (**Figure 14**) sets the IR-TRACC radius in a known distance D_{P1}, dependent of the IR-TRACC type and revision. The formula to calculate the Radius Intercept I_R (the radius offset to the coordinate system), with the distance on the fixture (141.8mm in example) and the output of the IR-TRACC in position 1 on the fixture (0.0757V in example). The IR-TRACC zero-position sheet is also part of the Integrated Calibration Template.

Radius Intercept: $I_R = D_{P1} - C_{IR} * U_{IR1}$ ^ EXP, see **Figure 29**.
Example:
Radius Intercept: I_R = 141.8 - 28.55*0.0757^-0.4842; Radius Intercept I_R = 42.2mm

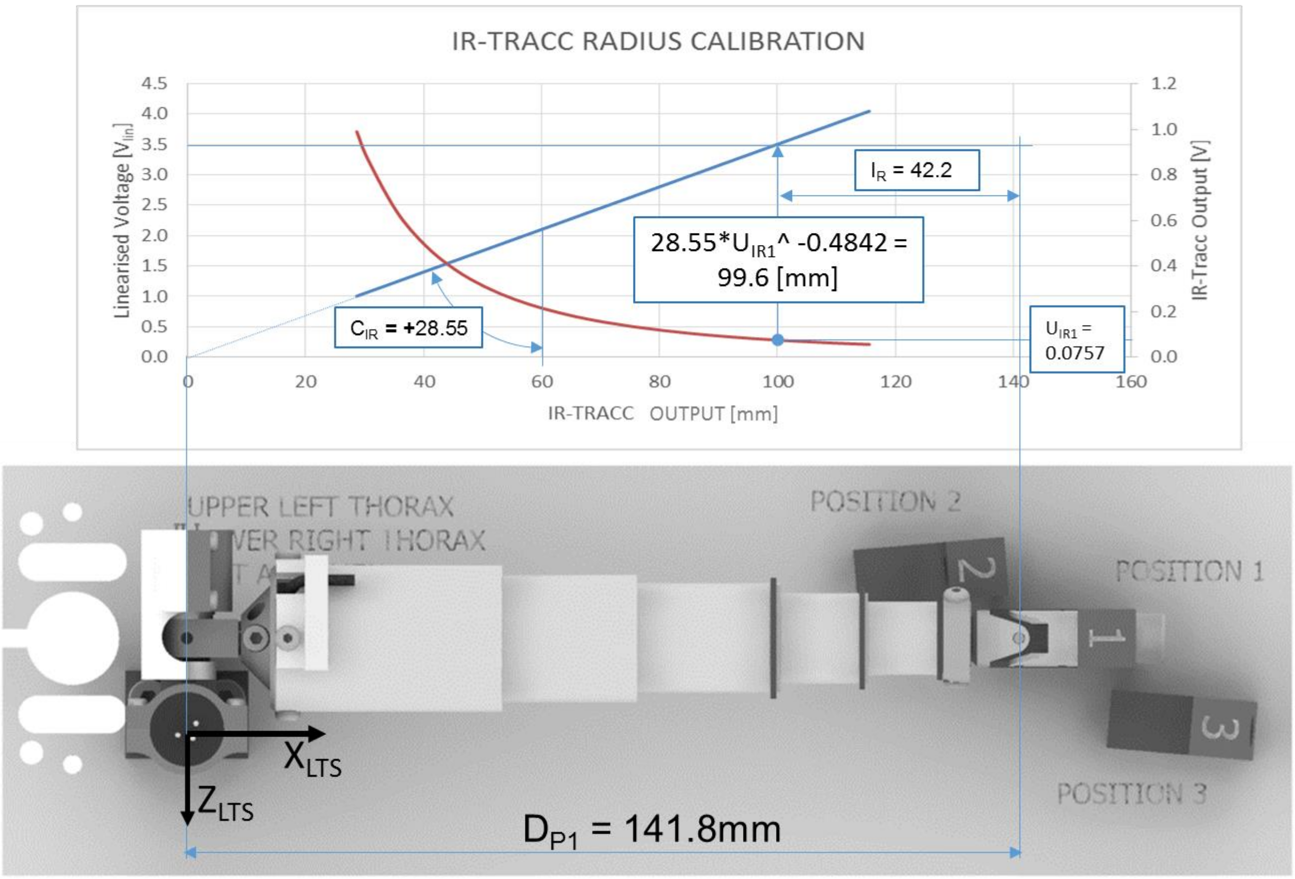


Figure 29: *Calculation of Radius Intercept I_R. Red line is nonlinear output of the IR-TRACC (scale right), blue line is the linearized output (scale left), including example parameters.*

Now that we found the three parameters, the IR-TRACC radius (origin to joint center distance) can be found by the following formula, see **Figure 30**:

Radius$_i$: $R_i = I_R + C_{IR} * U_{IRi}$ ^ EXP [mm]

Example:
Radius$_i$ = 42.20 + 28.55 * U_{IRi} ^-0.4842 [mm]

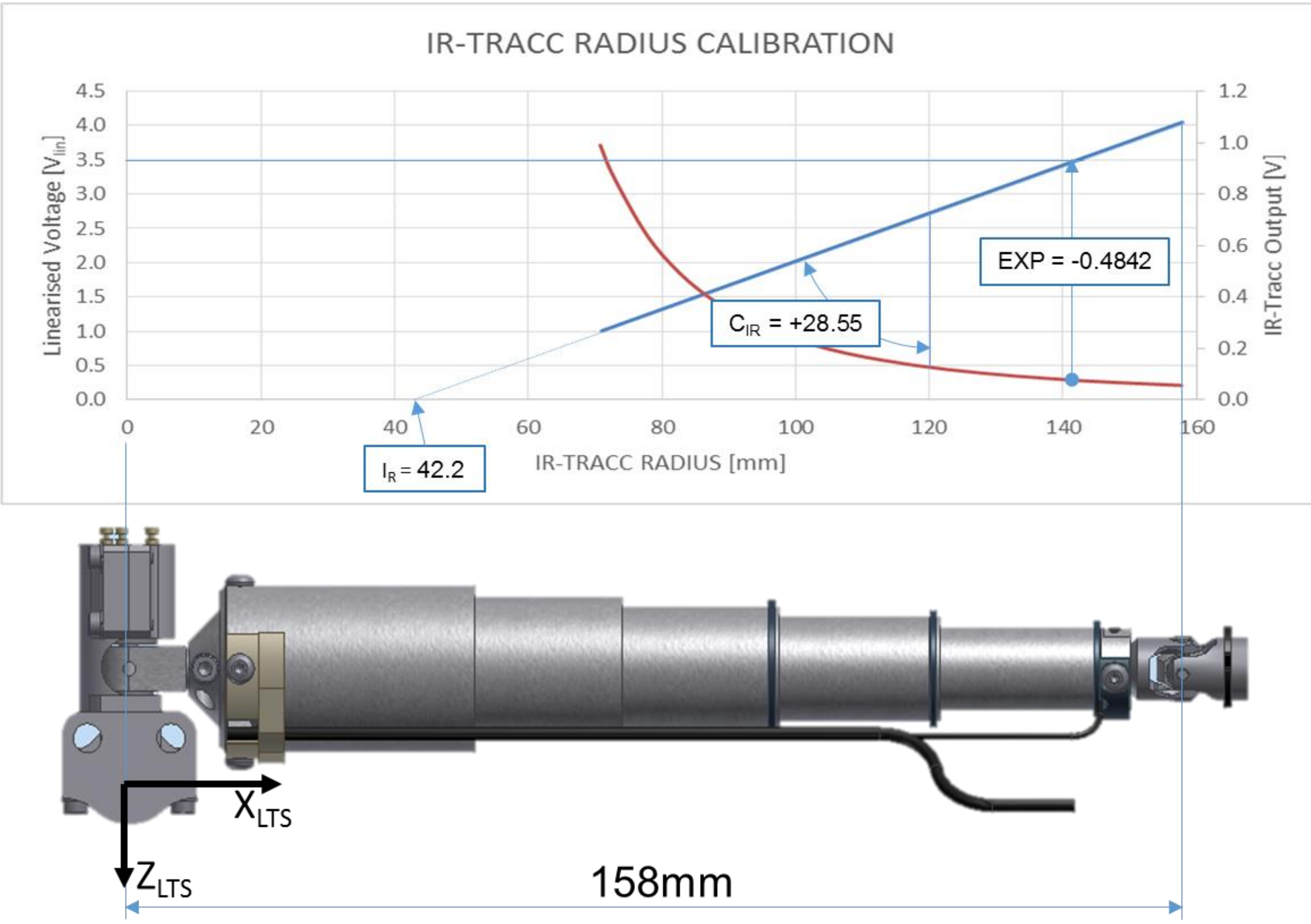


***Figure 30**: Calculation of IR-TRACC Radius from calibration parameters, including example parameters.*

Some data acquisition system implement the calibration parameters in (linearized) voltage units. The sensitivity is the inverse of the calibration factor:

$S_{IR} = 1/ C_{IR}$; $[V_{LIN}/mm]$

The Radius Intercept Voltage: $I_{RV} = S_{IR} * I_R$ $[V_{LIN}]$

Calculate the radius with linearized voltage parameters as follows, see **Figure 31**:

$Radius_i = (U_{IRi}$ ^ $EXP + I_{RV}) / C_{IR}$ [mm]

Example:

$Radius_i = (U_{IRi}$^$(-0.4842) +1.482)/0.03505$ [mm]

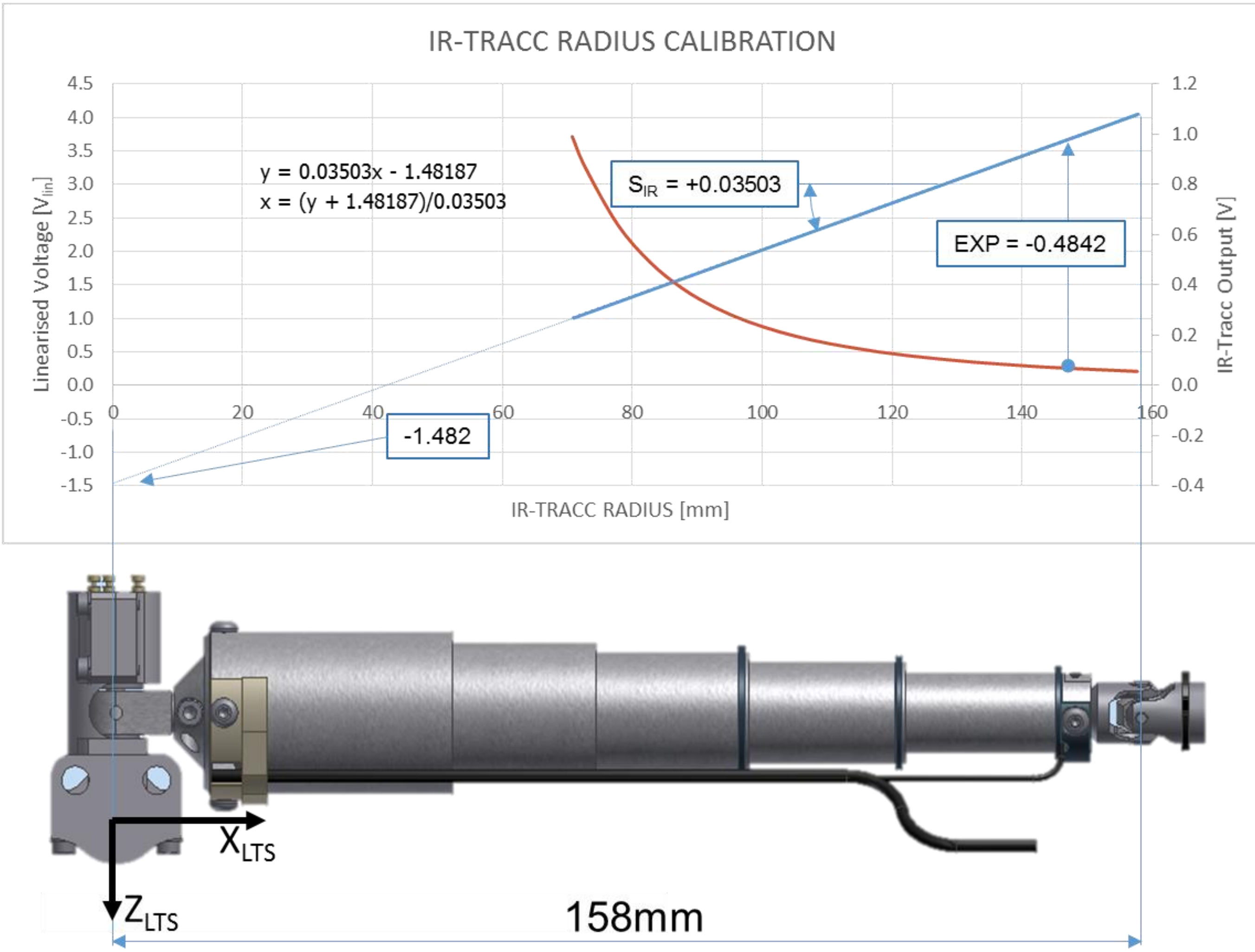


Figure 31: *Calibration parameters expressed in Linearized Volts, same example IR-TRACC*

Angle Transducers

Calculate the Y and Z angles with the following formulae:

Y Angle: $\varphi_{Yi} = C_{ANY} * U_{ANYi} / U_{EX} - \varphi_{OSY}$. [degrees]

Z Angle: $\varphi_{Zi} = C_{ANZ} * U_{ANZi} / U_{EX} - \varphi_{OSZ}$. [degrees]

Calculate the Y and Z Offset angles with the following formulae:

Output in position 1 on zeroing fixture:

$0 = C_{ANY} * U_{ANY1} / U_{EX} - \varphi_{OSY}$.

Y Offset angle: $\varphi_{OSY} = C_{ANY} * U_{ANY1} / U_{EX}$ [deg] (U_{ANY1} is the Y angle sensor output at position 1 on the fixture).

Z Offset angle: $\varphi_{OSZ} = C_{ANZ} * U_{ANZ1} / U_{EX}$ [deg] (U_{ANZ1} is the Z angle sensor output at position 1 on the fixture).

Calculate IR-TRACC Joint Center Position in Local Coordinate System

Starting point of these calculations are the offset corrected angles and IR-TRACC radius. Make sure your data acquisition system outputs the IR-TRACC radius and Y and Z angles in the local coordinate system, according previous sections.

1. <u>Deflection of O_{IR} (IR-TRACC Origin) Local Coordinate system</u>

UPPER THORACIC IR-TRACCs

Note that the mechanical link on the Upper 3D IR-TRACCs creates an offset δ between axis of radius measurement X_{IR} and local **UTS** coordinate system and in the Upper IR-TRACC it is pointing **downward in positive Z-direction.** This results in a **positive** term in the formulae, +δ.

Deflection of O_{IR} (IR-TRACC Origin) in **Upper** Thoracic Spine coordinate system, see **Figure 25**:

$X_{IR} = \mathbf{+}\delta * \sin(\varphi_Y)$

$Y_{IR} = 0$

$Z_{IR} = \mathbf{+}\delta * \cos(\varphi_Y)$

LOWER THORACIC IR-TRACCs

Note that the mechanical link between axis of radius measurement X_{IR} and local **LTS** coordinate system is pointing **upward in negative Z direction** (in contradiction to Upper 3D IR-TRACCs where the link is pointing downward). This results in a **negative** term in the formulae, -δ.

Deflection of O_{IR} (IR-TRACC Origin in in **Lower** Thoracic Spine coordinate system, see **Figure 26**:

$x_{IR} = \delta * \sin(\mathbf{180°} + \varphi_Y) = \mathbf{-}\ \delta * \sin(\varphi_Y)$

$y_{IR} = 0$

$z_{IR} = \delta * \cos(\mathbf{180°} + \varphi_Y) = \mathbf{-}\ \delta * \cos(\varphi_Y)$

ABDOMEN IR-TRACCs

The **abdomen** 3D IR-TRACCs have **no offset** and all axis of the transducers are intersecting. The offset on Abdomen IR-TRACCs δ = **0 mm**. This results in a **zero** term in the formulae.

The value and sign of the offset δ is the only difference to process 3D IR-TRACC assembly varieties. All other processing formulae are identical between IR-TRACC varieties. The recommended practice is to give the δ parameter a value and sign dependent on the type of IR-TRACC which is being processed, see below.

Upper IR-TRACC δ = **+**15.65 [mm]

Lower IR-TRACC δ = **-**15.65 [mm]

Abdomen IR-TRACC δ = 0 [mm]

The correct δ values are also given in **Table 1** and on the zero-position verification sheet.

2. <u>Deflection of Joint Center in $X_{IR}Y_{IR}Z_{IR}$ Coordinate System</u>

$x_{JC} = R * \cos(\varphi_Z)$

$y_{JC} = R * \sin(\varphi_Z)$

$z_{JC} = 0$

Project the above result to the UTS coordinate system (rotate $X_{IR}Y_{IR}Z_{IR}$ by φ_Y to $X_{JC}Y_{JC}Z_{JC}$ along Y_{UTS} axis)

3. <u>Apply the coordinate system transformation to result 2, the deflection X_1,$Y_1$$Z_1$ of Joint Center at O_{IR} projected in UTS coordinate system</u>

$X_1 = R * \cos(\varphi_Z) * \cos(\varphi_Y)$

$Y_1 = R * \sin(\varphi_Z)$

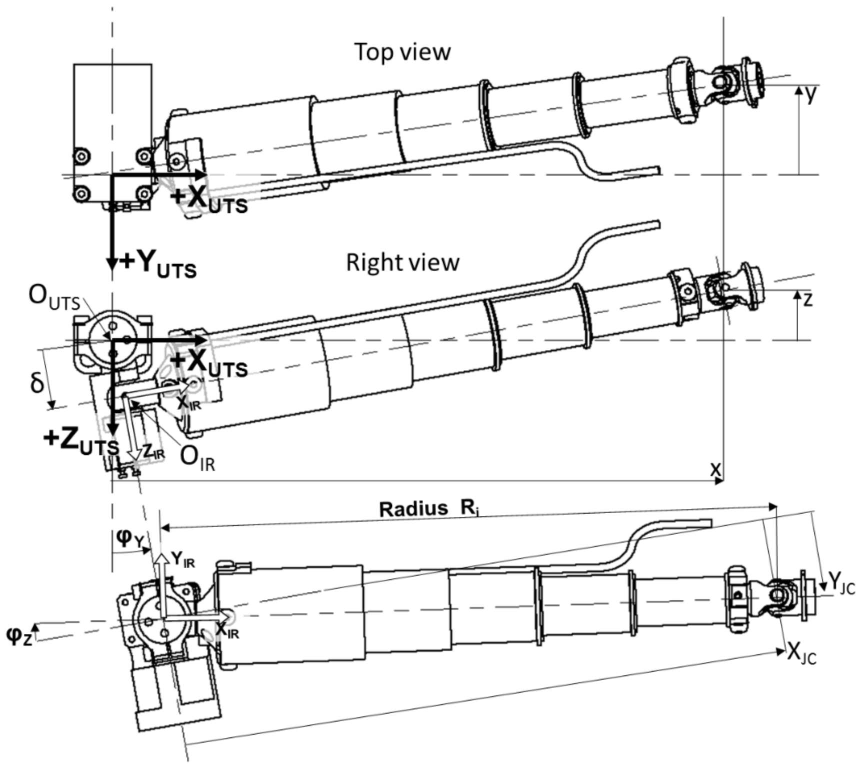
$Z_1 = -\ R * \cos(\varphi_Z) * \sin(\varphi_Y)$

4. Deflection of Joint Center in UTS Coordinate System (superpose the result 1 and 3 together)

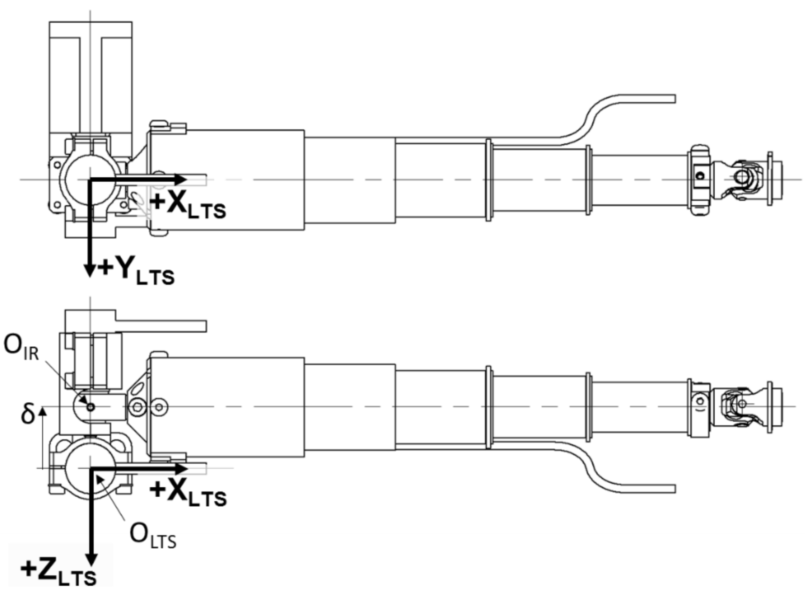
$x = X_{IR} + X_1 = \delta * \sin(\varphi_Y) + R * \cos(\varphi_Z) * \cos(\varphi_Y)$

$y = Y_{IR} + Y_1 = R * \sin(\varphi_Z)$

$z = Z_{IR} + Z_1 = \delta * \cos(\varphi_Y) - R * \cos(\varphi_Z) * \sin(\varphi_Y)$



Upper Right Thoracic IR-TRACC



Lower Right Thoracic IR-TRACC

10 APPENDIX C: Proposed ISO MME Codes

ISO codes for 3D IR-TRACC data channels are provided in **Table 12**. One complete example is given for Left Upper Thorax in the top rows of table. For the other 3D IR-TRACCs only examples of the calculated deflection channel are given.

***Table 12:** Proposed ISO codes for data channels and calculated channels*

CHANNEL DESCRIPTION	PARAMETER*	ISO MME CODE *
Thorax IR-TRACC Output Left Upper	U_{IR}	??CHSTLEUPTHVO0P
Thorax IR-TRACC Radius Left Upper	R, R_0, R_i	??CHSTLEUPTHDC0P
Thorax IR-TRACC Rotation Left Upper Y	φ_Y, φ_{Y0}, φ_{Yi}	??CHSTLEUPTHANYP
Thorax IR-TRACC Rotation Left Upper Z	φ_Z , φ_{Z0}, φ_{Zi}	??CHSTLEUPTHANZP
Thorax Left Upper X Coordinate	x, x_0, x_i	??CHSTLEUPTHDCXP
Thorax Left Upper Y Coordinate	y, y_0, y_i	??CHSTLEUPTHDCYP
Thorax Left Upper Z Coordinate	z, z_0, z_i	??CHSTLEUPTHDCZP
Thorax Deflection Left Upper X	Dx_i	??CHSTLEUPTHDSXP
Thorax Deflection Left Upper Y	Dy_i	??CHSTLEUPTHDSYP
Thorax Deflection Left Upper Z	Dz_i	??CHSTLEUPTHDSZP
Thorax Deflection Left Upper	D_i	??CHSTLEUPTHDS0P
Thorax Deflection Right Upper	D_i	??CHSTRIUPTHDS0P
Thorax Deflection Left Lower	D_i	??CHSTLELOTHDS0P
Thorax Deflection Right Lower	D_i	??CHSTRILOTHDS0P
Abdomen Deflection Left Lower	D_i	??ABDORILOTHDS0P
Abdomen Deflection Right Lower	D_i	??ABDORILOTHDS0P

*Consolas Font was chosen to clearly distinguish between letters O, i and numeral characters zero 0, 1

IR-TRACC transfer functions and descriptors are given in **Table 13**.

***Table 13:** IR-TRACC Channel Descriptors*

APPENDIX A Table 11 Parameter	APPENDIX A Table 11 Symbol*	ISO MME Symbol*	ISO MME Descriptor*
IR-TRACC output	U_{IR}	S	??CHST????THVO0P
Optimized exponent	EXP	α	.Power func exponent
Calibration factor	C_{IR}	C	.Power func sensitivity
Radius Intercept	I_R	M	.Power func eng offset**
Radius Intercept voltage	I_{RV}	S_0	.Power func electr offset**
Lines of code in the channel file header			
.Transfer function used		:Power function	
.Direction polarity		:+	
Offset post test		:0	

*Consolas Font was chosen to clearly distinguish between letters O, i and numeral character zero 0, 1

Angle Sensor transfer functions and descriptors are given in **Table 14.**

Table 14: *Angle sensor Channel Descriptors*

APPENDIX A Table 11 Parameter	APPENDIX A Table 11 Symbol*	ISO MME Symbol*	ISO MME Descriptor*
Angle Calibration factor	C_{ANY} C_{ANZ}	C	Inverse polynom coeff C
Angle sensor offset	φ_{OSY} φ_{OSZ}	M	Inverse polynom coeff M
Lines of code in the channel file header			
.Transfer function used	:Linear regression with offset		
.Direction polarity	:		
Offset post test	:0		

*Consolas Font was chosen to clearly distinguish between letter O and numeral character zero 0

Source: ISO/TS 13499 – RED A : 2016(E) version 1.6, ISO TC 22/SC 36/WG 3, Road vehicles — Multimedia data exchange format for impact tests.
http://www.iso-mme.org/forum/viewtopic.php?f=38&t=443

11 LEGAL DISCLAIMER AND NOTICES

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Humanetics Innovative Solutions Inc. is a global company whose strategy is to harness the best of today's technologies for the creation of high-quality products which play an important role in improving safety, comfort, and protection of people and their environment. Humanetics is the world's leading supplier in the design and manufacture of sophisticated crash test dummies, associated technical support, and laboratory services and load cell crash wall systems. Furthermore, Humanetics develops and supplies finite element software-based dummy models for computerized crash test simulations, and specializes in static and dynamic strain measurements.

For additional information on Humanetics and its products and services, please refer to www.humaneticsatd.com or contact:

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User Manual Update Log

Revision Level	Revision Date	Revision Author	Revision Description
A	September 06, 2016	B.W. Been	Initial release
B	12 Sept 2016	B.W. Been	Correct deflection formula
C	7 Oct 2016	B.W.Been/ G.Forgue	Additional instructions for zero-position templates in Paragraph 5.4, updated captions for Figures 21 and 22