IOR_Foot_Model_2007

This tutorial describes the 2007 publication. For the updated 2014 IOR foot model see here.

Sample Data

Sample data can be downloaded here.

Once the zip file has been downloaded, you can find a static C3D and three dynamic trials in the SampleFiles folder. These files will be used to complete the tutorial.

The model, planar angles and joint angles for the right side were defined and plotted in the Leardini_2007_Angles.cmo. Once the left side angles have been defined, the report template will graph both the left and right angles.

Introduction

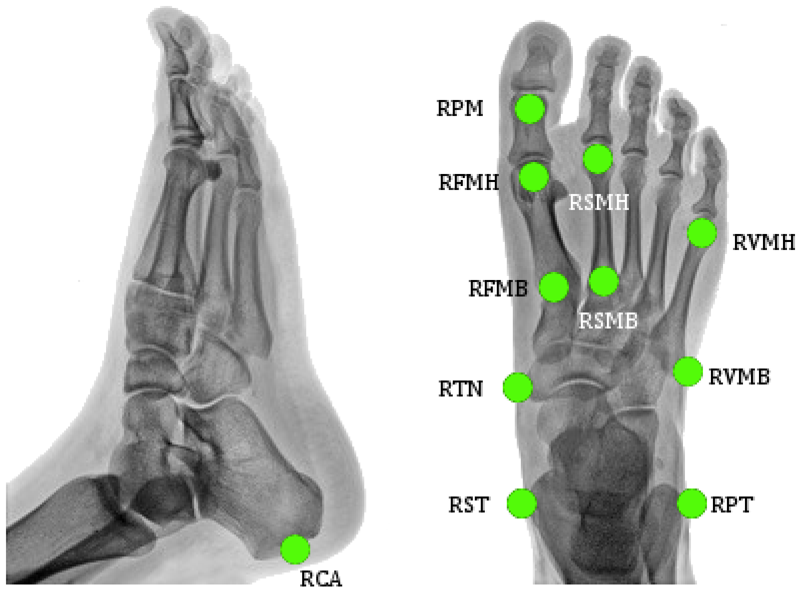
Visual3D is a general tool capable of implementing many different foot models.

This tutorial describes the IOR Foot analysis as it was published in the ORIGINAL paper (shown below):

Leardini, A., M.G. Benedetti, L. Berti, D. Bettinelli, R. Nativo, and S. Giannini. "Rear-foot, Mid-foot and Fore-foot Motion during the Stance Phase of Gait." Gait & Posture 25 (2007): 453-55
Modifications were made to the original IOR Foot analysis (published in the paper below). **The modified tutorial can be found here**.

Portinaro, N., A. Leardini, A. Panou, V. Monzani, and P. Caravaggi. "Modifying the Rizzoli foot model to improve the diagnosis of pes-planus: application to kinematics of feet in teenagers." Journal of Foot and Ankle Research (2014) Below is a tutorial demonstrating how to implement the ORIGINAL analysis in Visual3D. If you would rather see a fully completed model you can simply download the following file [blank] and open it in Visual3D.

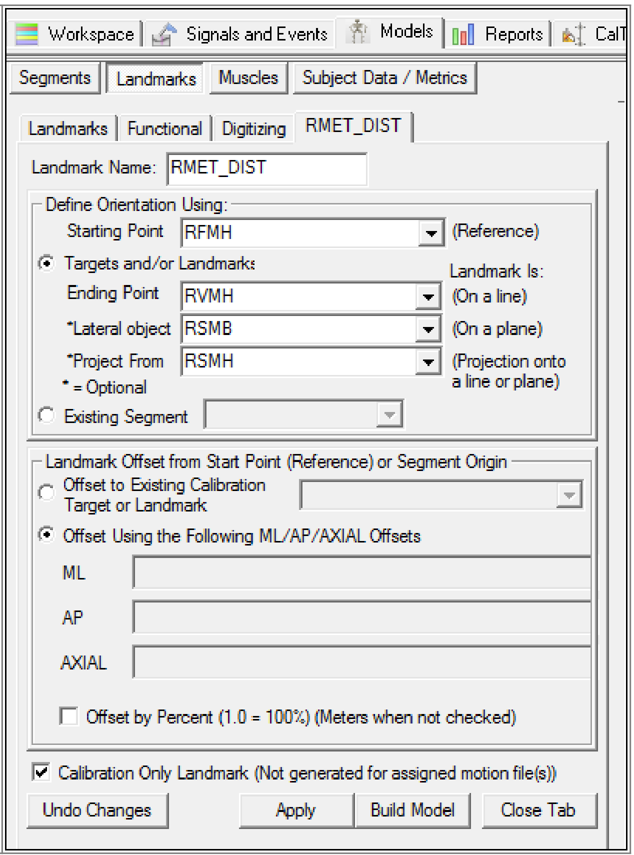
Multi-Segment Foot Marker Set



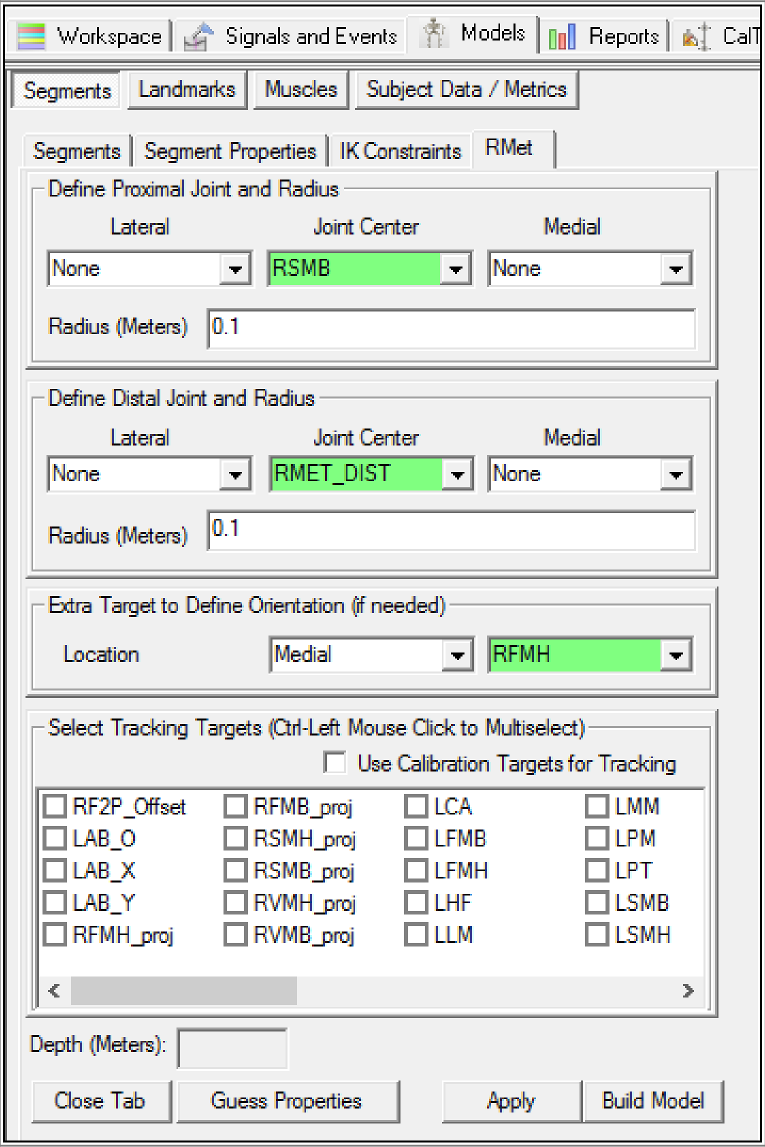
CA[1](FCC) [2]:p. 160 = Posterior Surface of Calcaneus ST[1](FST)[2] = Sustentaculum Tali of Calcaneus PT[1](FPT)[2] = Lateral apex of the peroneal tubercle TN[1](FNT)[2] = Medial apex of the tuberosity navicular FMH[1](FM1)[2] = Head of 1st Metatarsus SMH[1](FM2)[2] = Head of 2nd Metatarsus VMH[1](FM5)[2] = Head of 5th Metatarsus VMB[1](FMT)[2] = Tuberosity of 5th Metatarsal PM[1](PM6)[2] = Proximal Medial Phalanx FMB[1] = Base of First Metatarsal SMB[1] = Base of Second Metatarsal

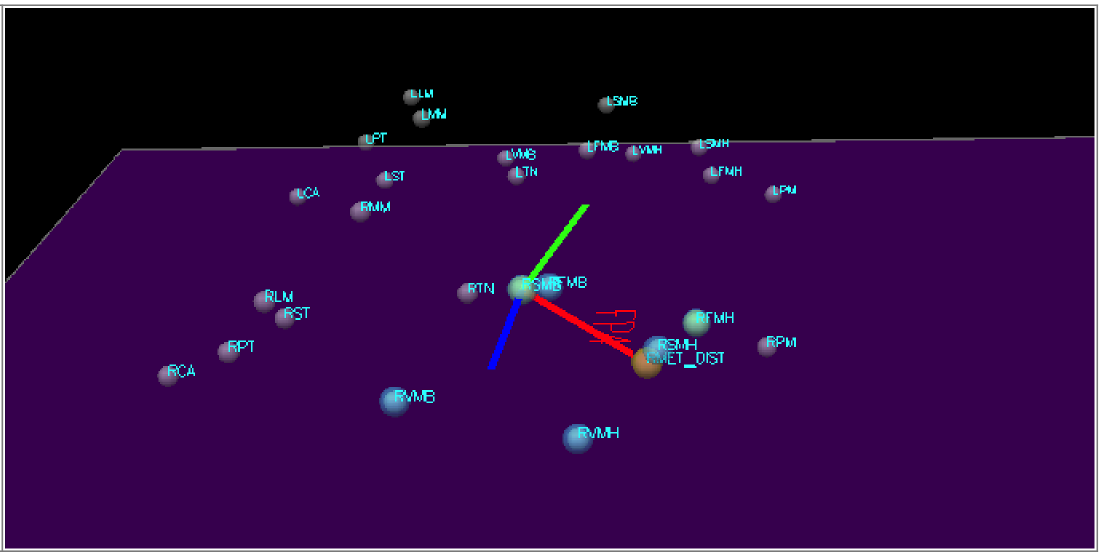
Metatarsus (Met)

Landmarks

1. Create RMET_DIST: • Click **Landmarks** button • Click **Add New Landmark** button • Create Landmark: *RMET_DIST*	**Landmark Name:** *RMET_DIST* **Define Orientation Using:** **Starting Point:** *RFMH* **Ending Point:** *RVMH* **Lateral Object:** *RSMB* **Project From:** *RSMH*	• **Do NOT Check:** *Offset by Percent (1.0 = 100%)* • **Check:** *Calibration Only Landmark*	

Segment Definition

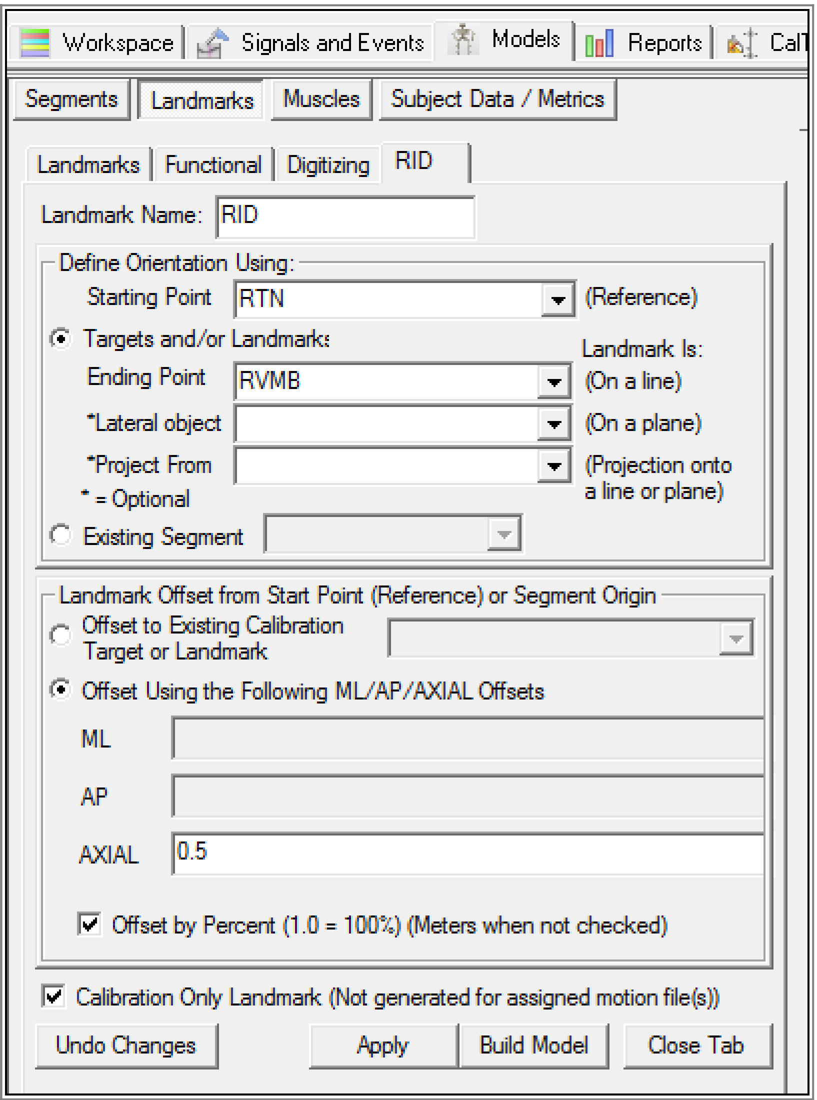
1. Create RMet Segment: • In the **Segments** tab, select *RMet* in the Segment Name box. • Select **Kinematic Only** • Click on the **Create Segment** button. • In the **RMet** tab, enter these values:	**Define Proximal Joint and Radius** **Lateral:** *None* **Joint:** *RSMB* **Medial:** *None* **Radius:** *0.1* **Define Distal Joint and Radius** **Lateral:** *None* **Joint:** *RMET_DIST* **Medial:** *None* **Radius:** *0.1* **Extra Target to Define Orientation** **Location:** *Medial* *RFMH* **Select Tracking Targets:** *RFMB*, *RFMH*, *RSMB*, *RSMH*, *RVMB*, *RVMH*	• Click on **Build Model.** • Click on **Close Tab** before proceeding.	

2. Modify the Segment Coordinate System: • Define the Segment Orientation as:	**A/P Axis:** *+Y* **Distal to Proximal:** *-X*	

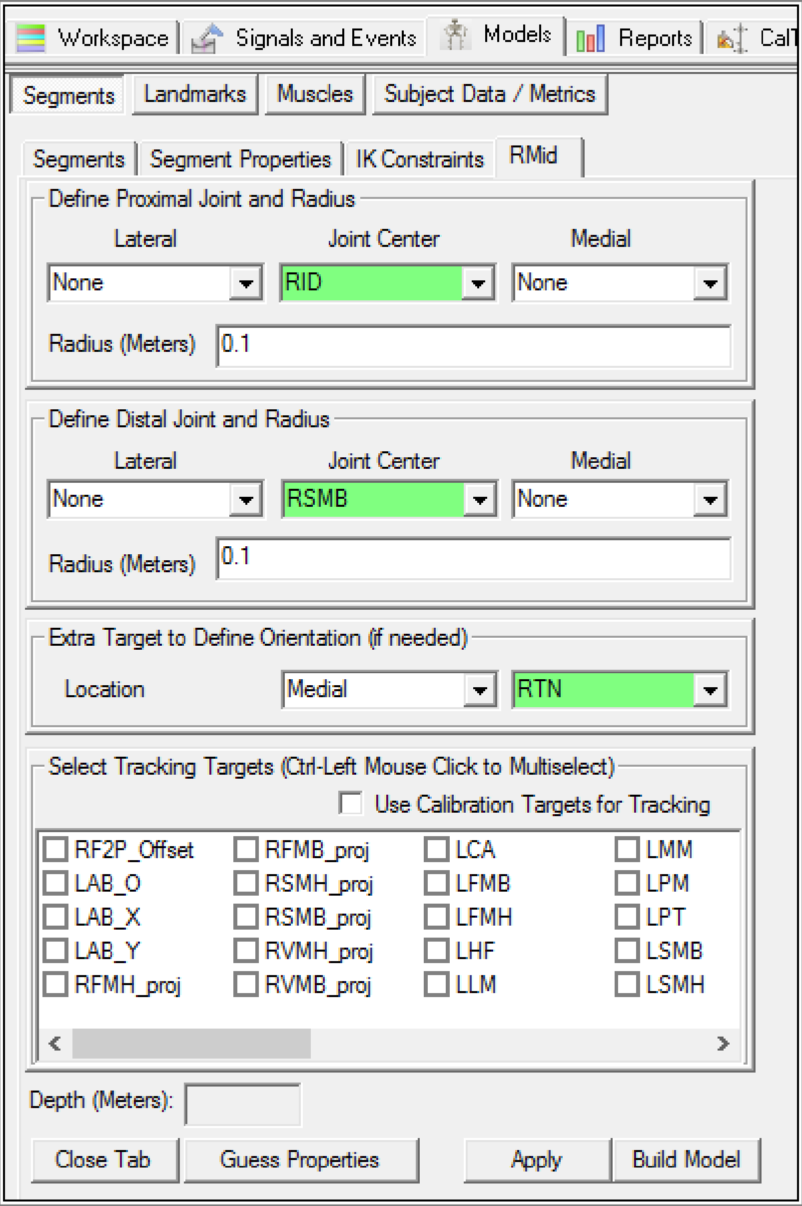
The image to the right (and all other images in this tutorial) show a mediolateral view of the segment coordinate system after it has been modified.

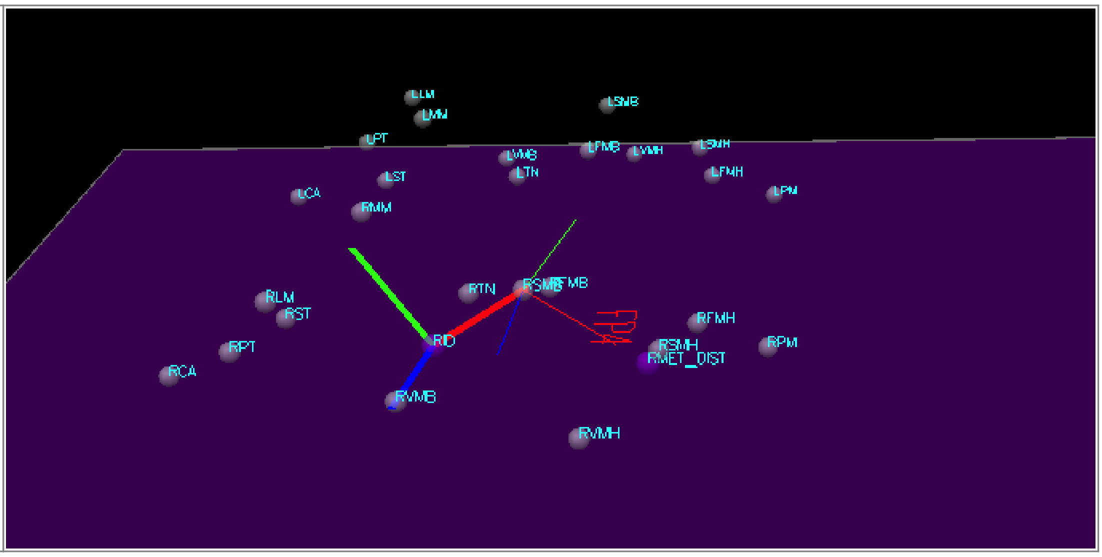
Mid-foot (Mid)

Landmarks

1. Create RID Joint Center: • Click **Landmarks** button • Click **Add New Landmark** button • Create Landmark: *RID*	**Landmark Name:** *RID* **Define Orientation Using:** **Starting Point:** *RTN* **Ending Point:** *RVMB*	• Offset Using the Following **AXIAL** Offset: *0.5* • **Check:** *Offset by Percent (1.0 = 100%)* • **Check:** *Calibration Only Landmark*	

Segment Definition

1. Create RMid Segment: • In the **Segments** tab, select *RMid* in the Segment Name box. • Select **Kinematic Only**. • Click on the **Create Segment** button. • In the **RMid** tab, enter these values:	**Define Proximal Joint and Radius** **Lateral:** *None* **Joint:** *RID* **Medial:** *None* **Radius:** *0.1* **Define Distal Joint and Radius** **Lateral:** *None* **Joint:** *RSMB* **Medial:** *None* **Radius:** *0.1* **Extra Target to Define Orientation** **Location:** *Medial* *RTN* **Select Tracking Targets:** *RSMB*, *RTN*, *RVMB*	• Click on **Build Model.** • Click on **Close Tab** before proceeding.	

2. Modify the Segment Coordinate System: • Define the Segment Orientation as:	**A/P Axis:** *+Y* **Distal to Proximal:** *-X*	

Calcaneus (Cal)

Landmarks

<table>
<tr>
<td>1. Create RIC Joint Center:

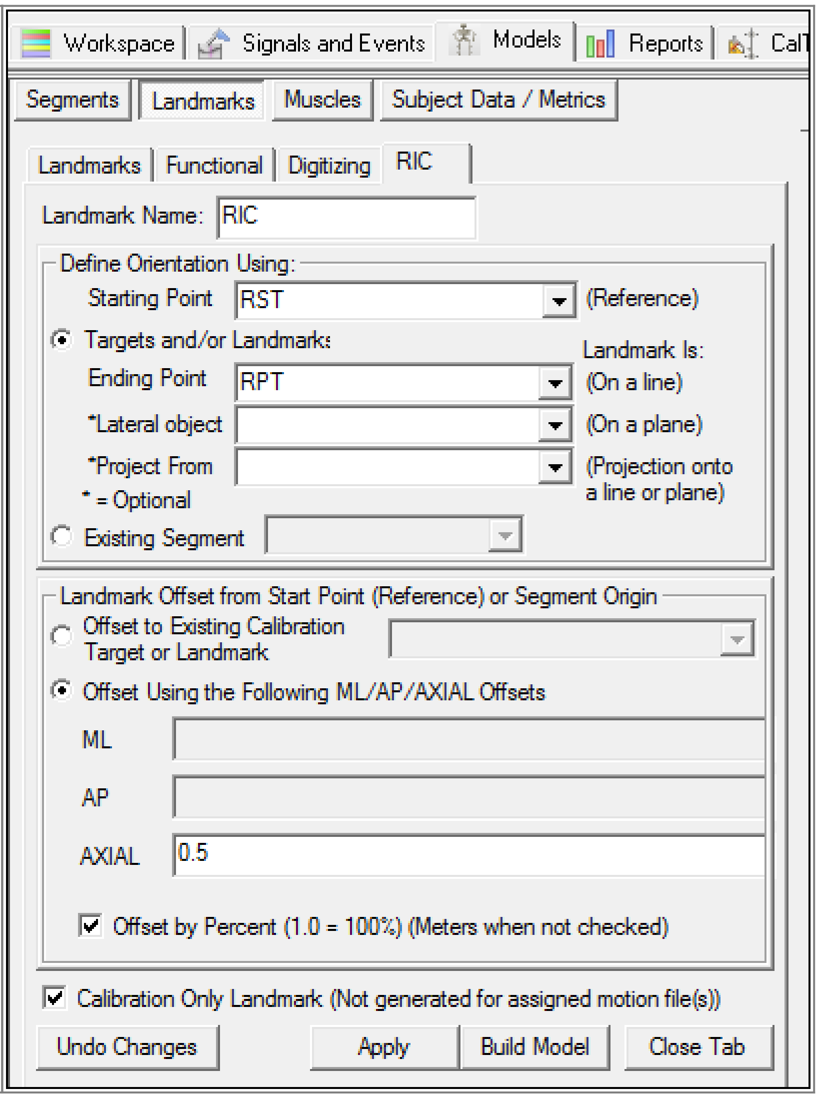
• Click Landmarks button

• Click Add New Landmark button

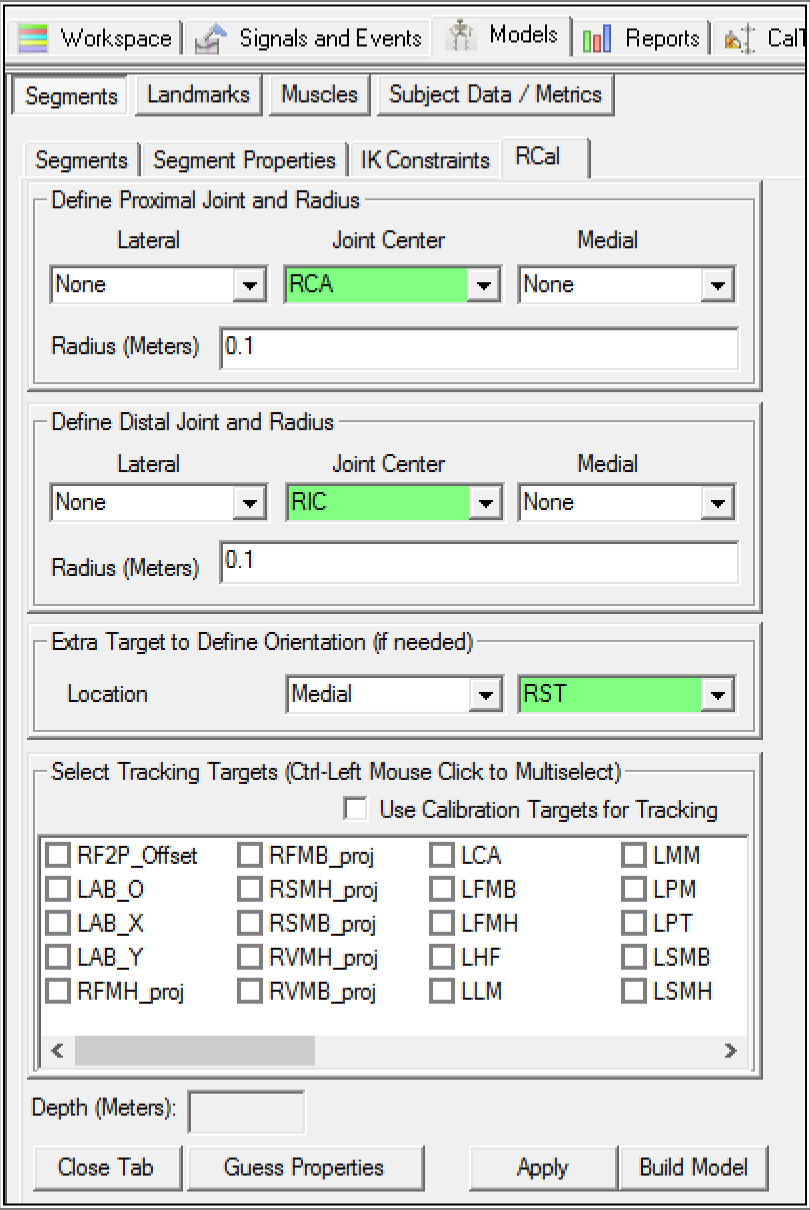
• Create Landmark: RIC</td>
<td>Landmark Name: RIC

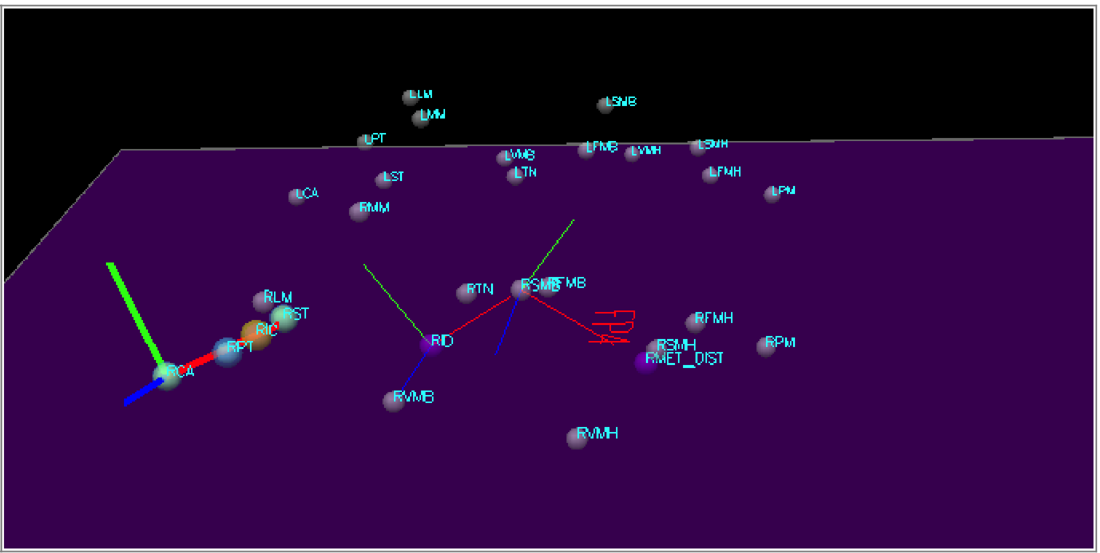
Define Orientation Using:
Starting Point: RST
Ending Point: RPT</td>
<td>• Offset Using the Following AXIAL Offset: 0.5

• Check: Offset by Percent (1.0 = 100%)

• Check: Calibration Only Landmark</td>
<td>
</td>
</tr>
</table>

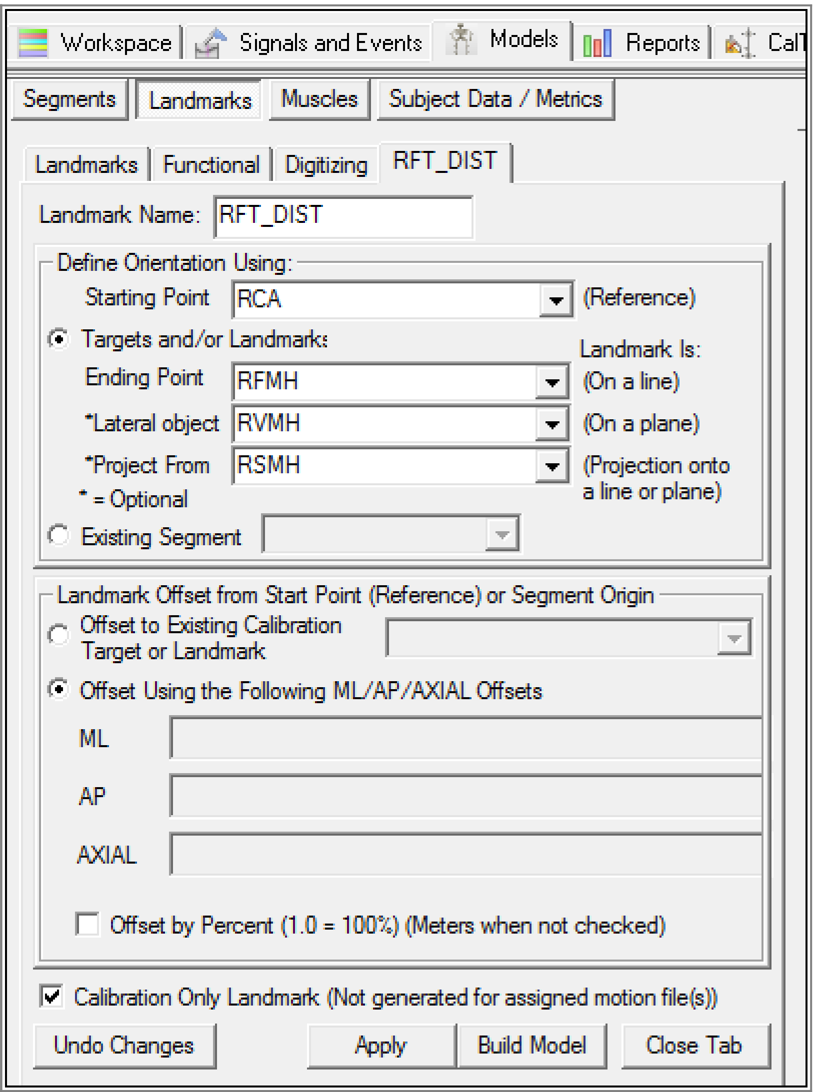
Segment Definition

1. Create RCal Segment: • In the **Segments** tab, select *RCal* in the Segment Name box. • Click on the **Create Segment** button. • In the **RCal** tab, enter these values:	**Define Proximal Joint and Radius** **Lateral:** *None* **Joint:** *RCA* **Medial:** *None* **Radius:** *0.1* **Define Distal Joint and Radius** **Lateral:** *None* **Joint:** *RIC* **Medial:** *None* **Radius:** *0.1* **Extra Target to Define Orientation** **Location:** *Medial* *RST* **Select Tracking Targets:** *RCA*, *RPT*, *RST*	• Click on **Build Model.** • Click on **Close Tab** before proceeding.	

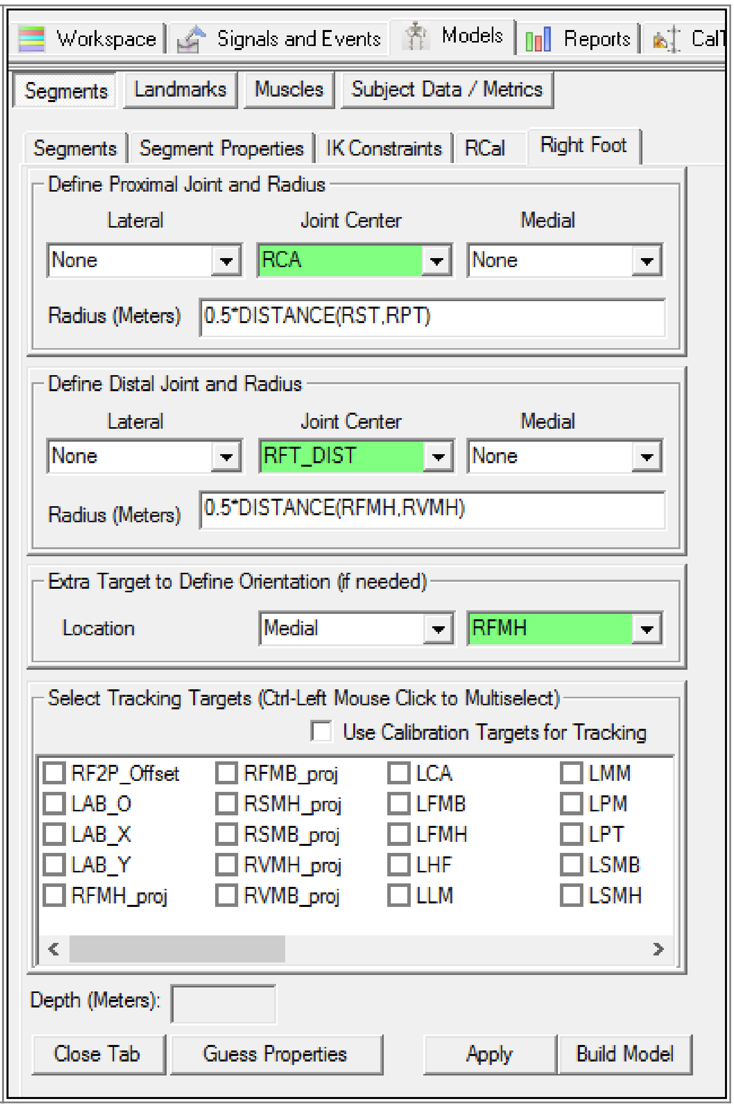
2. Modify the Segment Coordinate System: • Define the Segment Orientation as:	**A/P Axis:** *+Y* **Distal to Proximal:** *-X*	

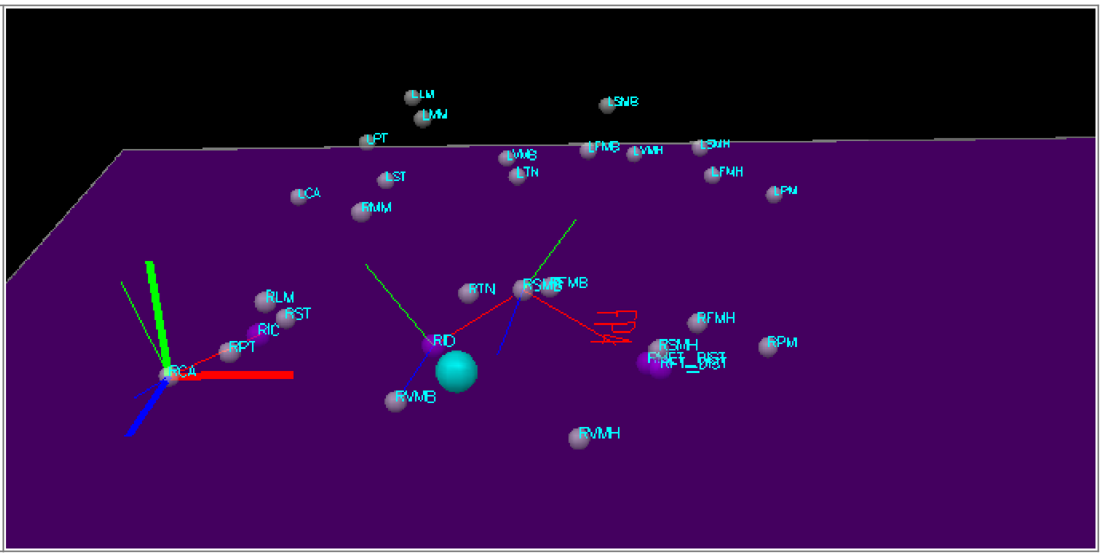
Foot (Foo)

Landmarks

1. Create RFT_DIST: • Click **Landmarks** button • Click **Add New Landmark** button • Create Landmark: *RFT_DIST*	**Landmark Name:** *RFT_DIST* **Define Orientation Using:** **Starting Point:** *RCA* **Ending Point:** *RFMH* **Lateral Object:** *RVMH* **Project From:** *RSMH*	• **Do NOT Check:** *Offset by Percent (1.0 = 100%)* • **Check:** *Calibration Only Landmark*	

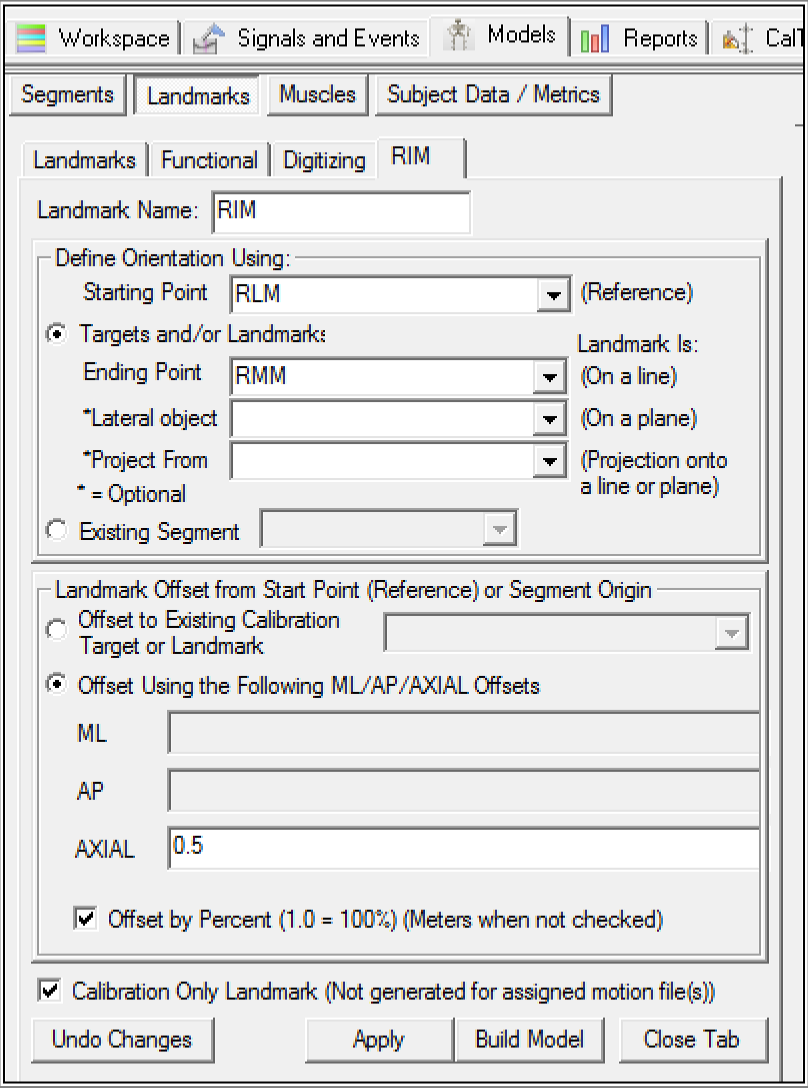
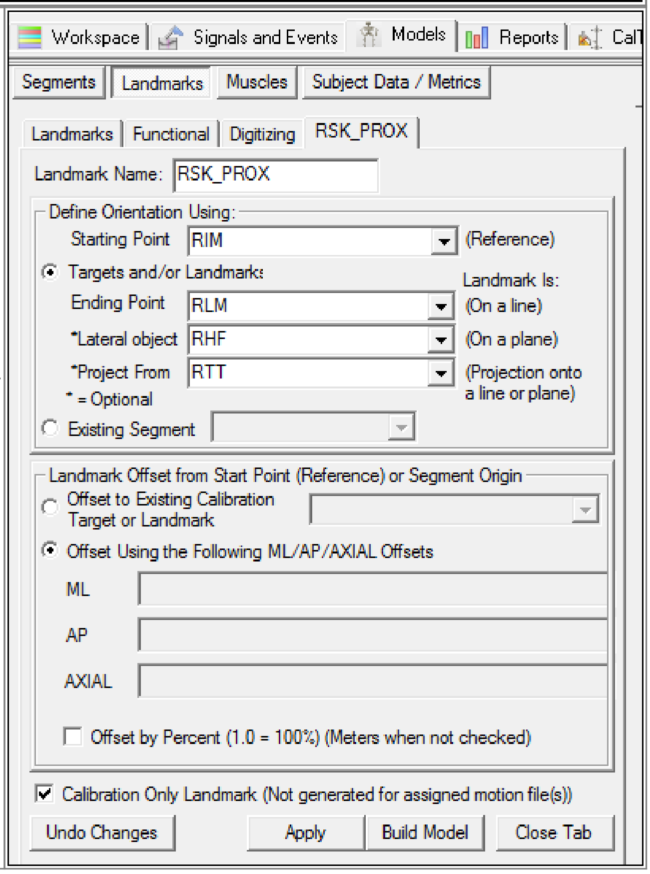
Segment Definition

1. Create Right Foot Segment: • In the **Segments** tab, select *Right Foot* in the Segment Name box. • Click on the **Create Segment** button. • In the **Right Foot** tab, enter these values:	**Define Proximal Joint and Radius** **Lateral:** *None* **Joint:** *RCA* **Medial:** *None* **Radius:** *0.5*DISTANCE(RST,RPT)* **Define Distal Joint and Radius** **Lateral:** *None* **Joint:** *RFT_DIST* **Medial:** *None* **Radius:** *0.5*DISTANCE(RFMH,RVMH)* **Extra Target to Define Orientation** **Location:** *Medial* *RFMH* **Select Tracking Targets:** *RCA, RFMH, RVMH*	• Click on **Build Model.** • Click on **Close Tab** before proceeding.	

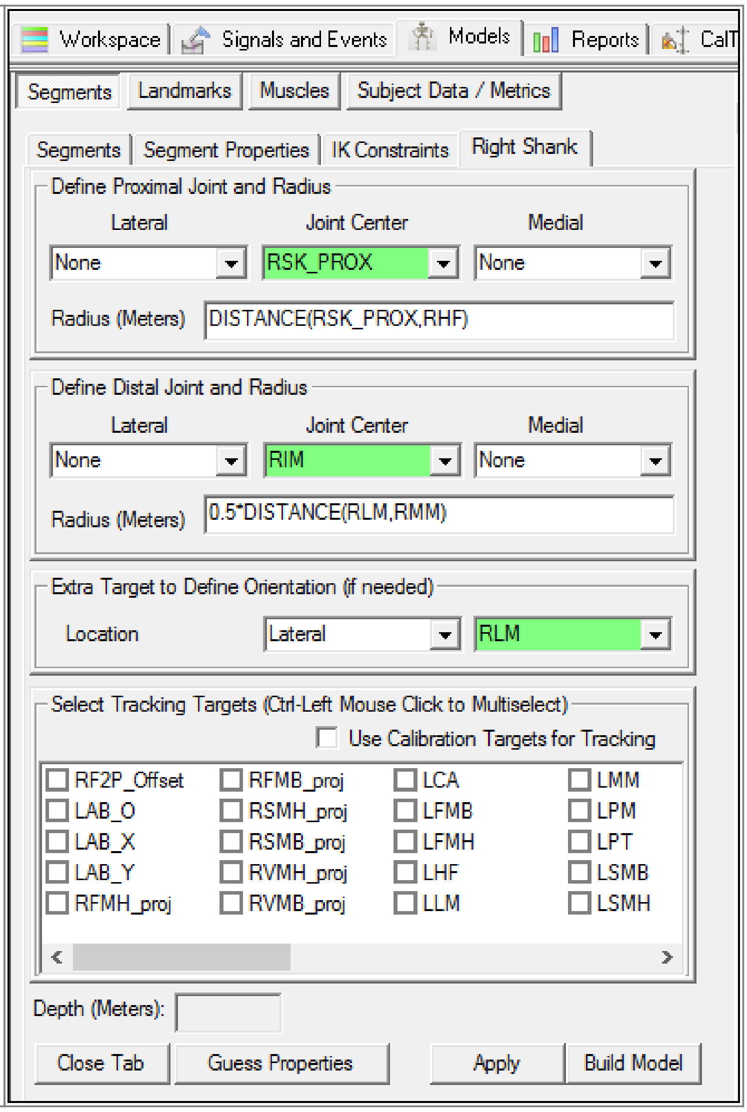
2. Modify the Segment Coordinate System: • Define the Segment Orientation as:	**A/P Axis:** *+Y* **Distal to Proximal:** *-X*	

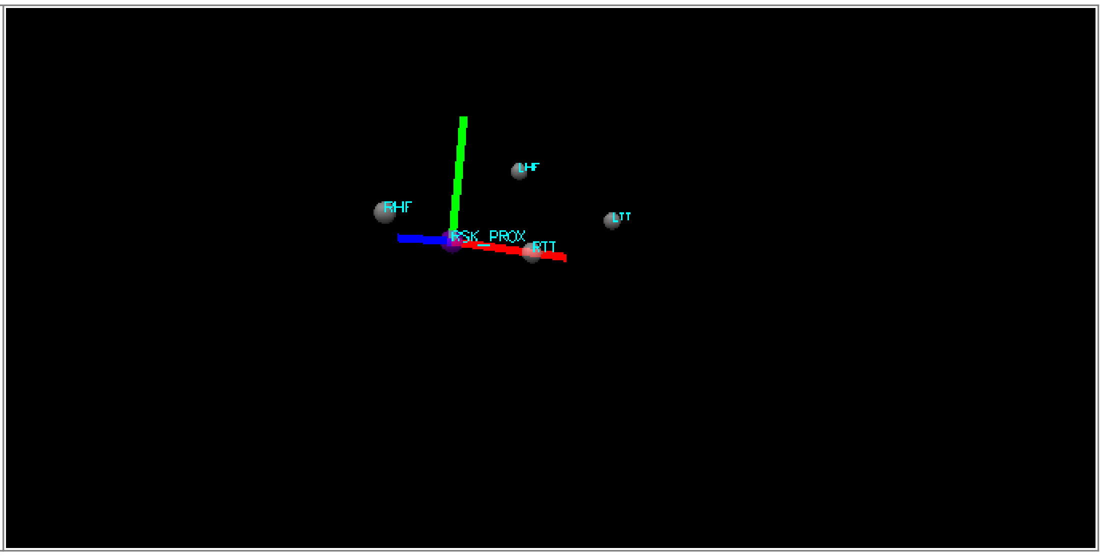
Shank (Sha)

Landmarks

1. Create RIM: • Click **Landmarks** button • Click **Add New Landmark** button • Create Landmark: *RIM*	**Landmark Name:** *RIM* **Define Orientation Using:** **Starting Point:** *RLM* **Ending Point:** *RMM*	• Offset Using the Following **AXIAL** Offset: *0.5* • **Check:** *Offset by Percent (1.0 = 100%)* • **Check:** *Calibration Only Landmark*	
2. Create RSK_PROX: • Click **Landmarks** button • Click **Add New Landmark** button • Create Landmark: *RSK_PROX*	**Landmark Name:** *RSK_PROX* **Define Orientation Using:** **Starting Point:** *RIM* **Ending Point:** *RLM* **Lateral Object:** *RHF* **Project From:** *RTT*	• **Do NOT Check:** *Offset by Percent (1.0 = 100%)* • **Check:** *Calibration Only Landmark*	

Segment Definition

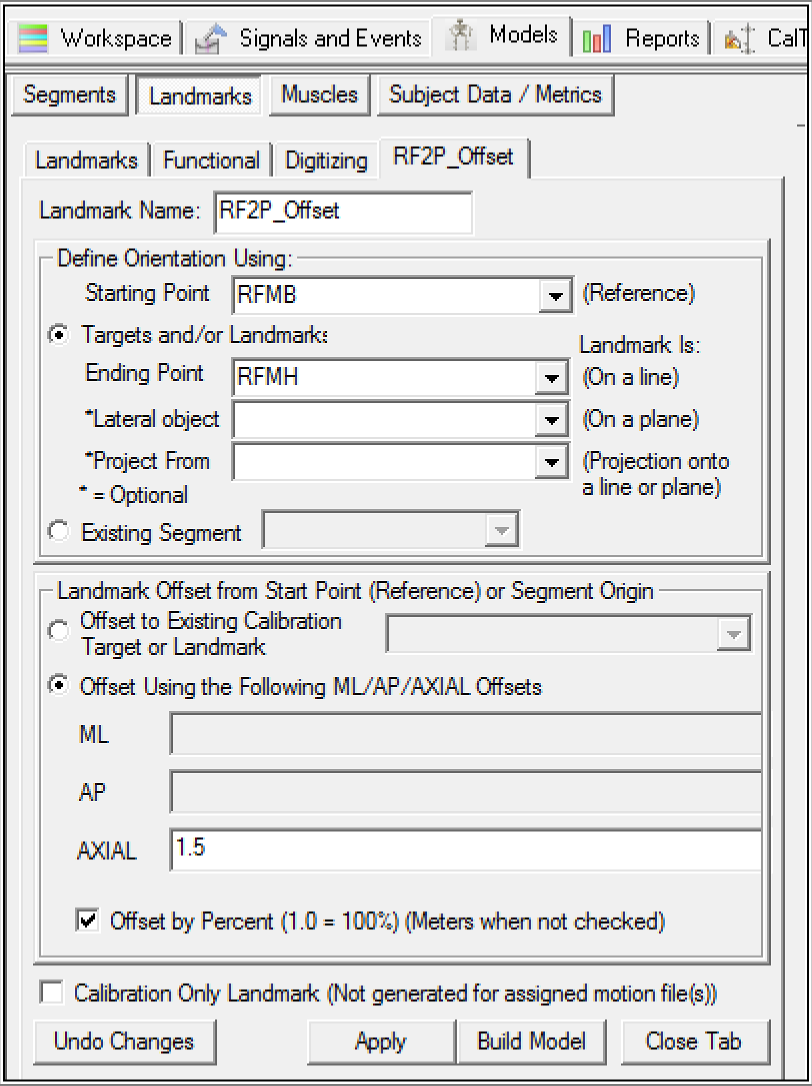
1. Create Right Shank Segment: • In the **Segments** tab, select *Right Shank* in the Segment Name box. • Click on the **Create Segment** button. • In the **Right Shank** tab, enter these values:	**Define Proximal Joint and Radius** **Lateral:** *None* **Joint:** *RSK_PROX* **Medial:** *None* **Radius:** *DISTANCE(RSK_PROX,RHF)* **Define Distal Joint and Radius** **Lateral:** *None* **Joint:** *RIM* **Medial:** *None* **Radius:** *0.5*DISTANCE(RLM,RMM)* **Extra Target to Define Orientation** **Location:** *Lateral* *RLM* **Select Tracking Targets:** *RHF*, *RLM*, *RMM*, *RTT*	• Click on **Build Model.** • Click on **Close Tab** before proceeding.	

2. Modify the Segment Coordinate System: • Define the Segment Orientation as:	**A/P Axis:** *+X* **Distal to Proximal:** *+Y*	

Angles

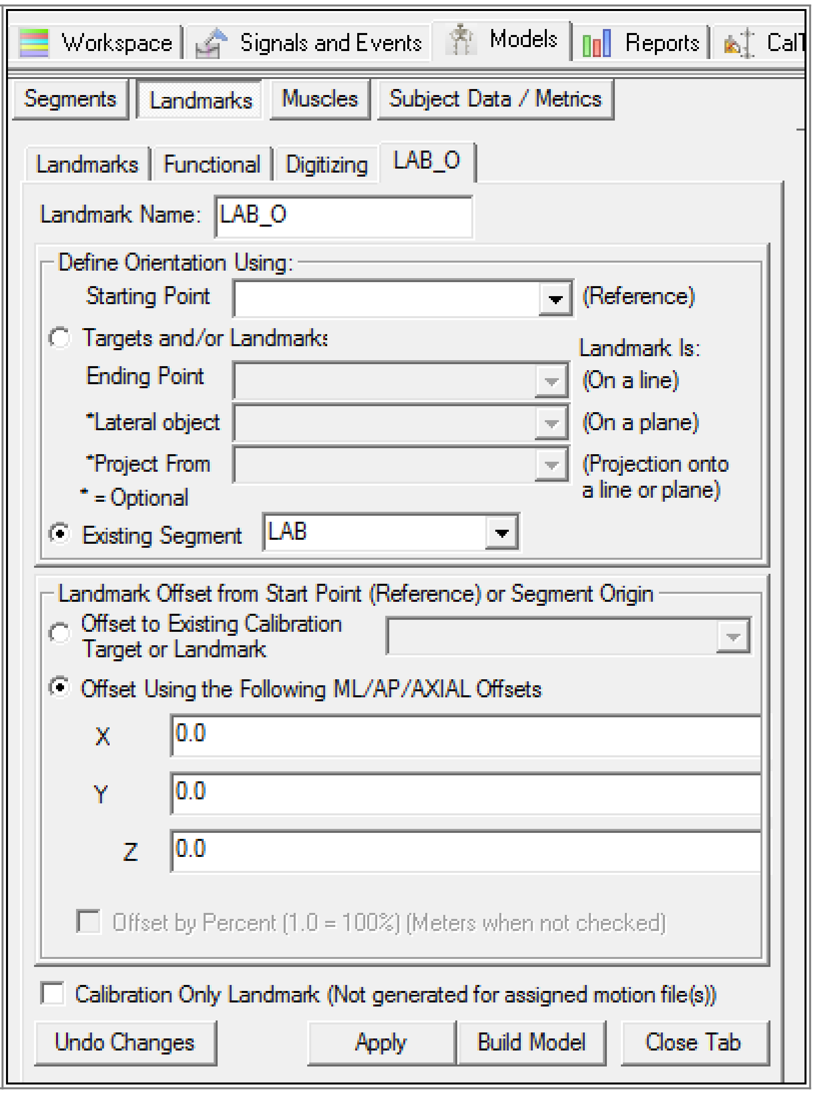
Landmarks

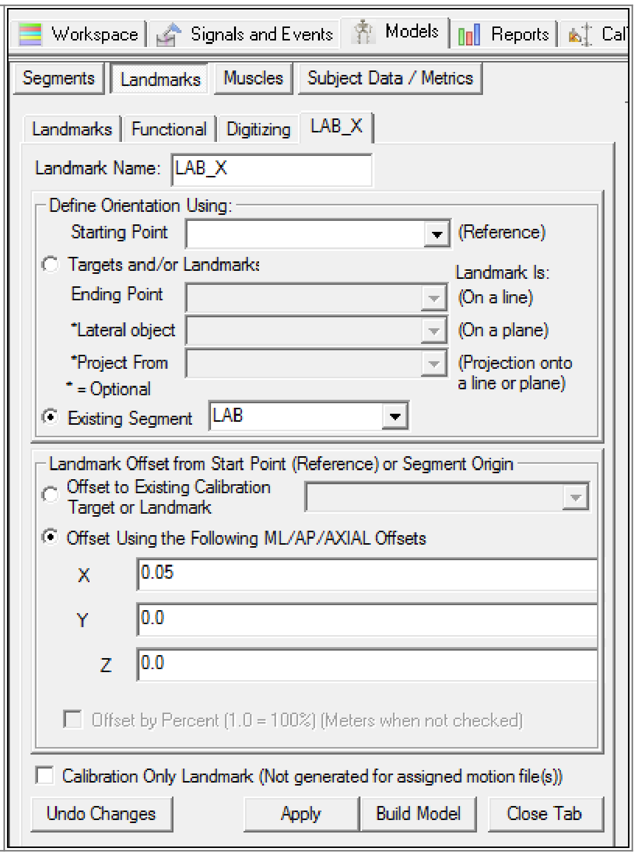
The F2Pt and F2Ps planar angles are calculated as the angle between the lines created by the targets FMB-FMH and FMH-PM. To calculate this angle using the Compute Planar Angle command, an offset along the line between FMB and FMH is created to define the 3 point angle.

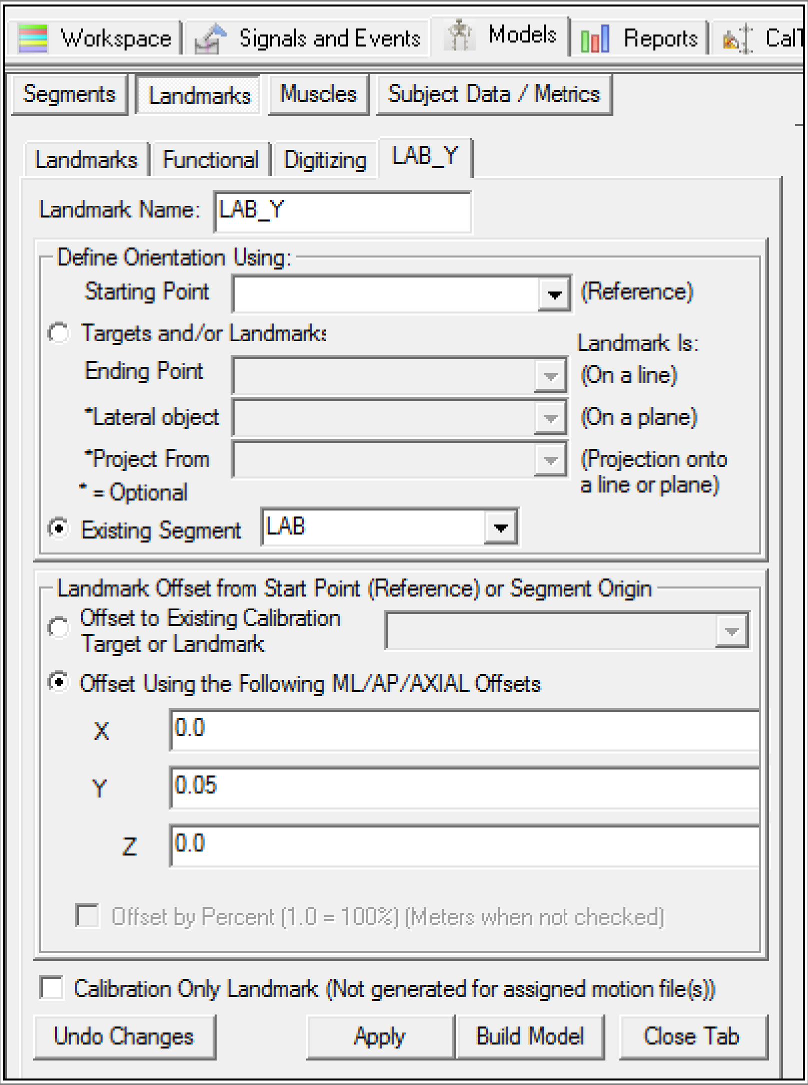
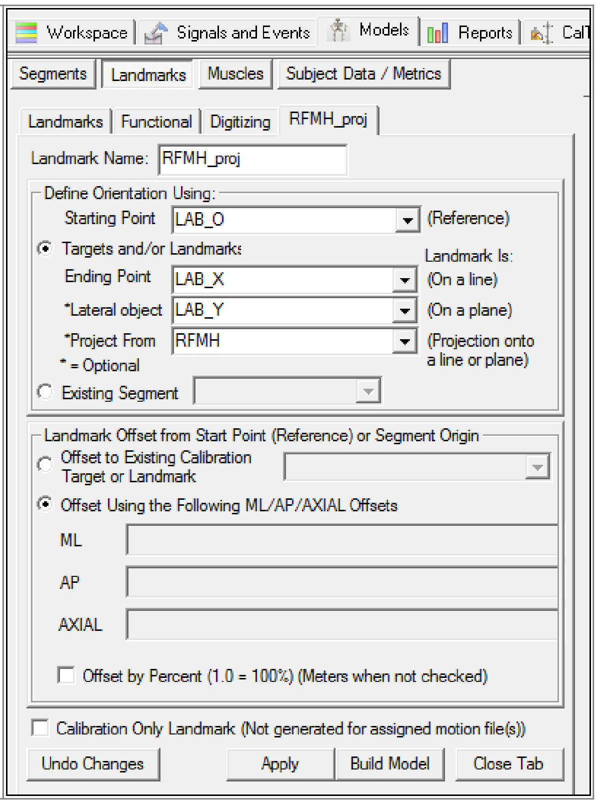
1. Create RF2P_Offset: • Click **Landmarks** button • Click **Add New Landmark** button • Create Landmark: *RF2P_Offset*	**Landmark Name:** *RF2P_Offset* **Define Orientation Using:** **Starting Point:** *RFMB* **Ending Point:** *RFMH*	• Offset Using the Following **AXIAL** Offset: *1.5* • **Check:** *Offset by Percent (1.0 = 100%)* • **Do NOT Check:** *Calibration Only Landmark*	

2. Create LF2P_Offset: • When defining the left signal, use same definitions as for the *RF2P_Offset* landmark

The F2G, S2G and V2G angles are calculated in the plane orthogonal to the ground. These landmarks will need to be projected onto the ground. To project landmarks onto the ground, the Lab_O, Lab_X and Lab_Y landmarks will need to be created to identify the plane of the ground.

3. Create Lab_O: • Click **Landmarks** button • Click **Add New Landmark** button • Create Landmark: *Lab_O*	**Landmark Name:** *Lab_O*	• Offset Using the Following **ML/AP/AXIAL** Offsets: **X:** *0.0* **Y:** *0.0* **Z:** *0.0* • **Do NOT Check:** *Offset by Percent (1.0 = 100%) (Meters when not checked)* • **Do NOT Check:** *Calibration Only Landmark (Not generated for assigned motion file(s))*	

4. Create Lab_X: • Click **Landmarks** button • Click **Add New Landmark** button • Create Landmark: *Lab_X*	**Landmark Name:** *Lab_X*	• Offset Using the Following **ML/AP/AXIAL** Offsets: **X:** *0.05* **Y:** *0.0* **Z:** *0.0* • **Do NOT Check:** *Offset by Percent (1.0 = 100%) (Meters when not checked)* • **Do NOT Check:** *Calibration Only Landmark (Not generated for assigned motion file(s))*	

5. Create Lab_Y: • Click **Landmarks** button • Click **Add New Landmark** button • Create Landmark: *Lab_Y*	**Landmark Name:** *Lab_Y*	• Offset Using the Following **ML/AP/AXIAL** Offsets: **X:** *0.0* **Y:** *0.05* **Z:** *0.0* • **Do NOT Check:** *Offset by Percent (1.0 = 100%) (Meters when not checked)* • **Do NOT Check:** *Calibration Only Landmark (Not generated for assigned motion file(s))*	
6. Create RFMH_proj: • Click **Landmarks** button • Click **Add New Landmark** button • Create Landmark: *RFMH_proj*	**Landmark Name:** *RFMH_proj* **Define Orientation Using:** **Starting Point:** *LAB_O* **Ending Point:** *LAB_X* **Lateral Object:** *LAB_Y* **Project From:** *RFMH*	• **Do NOT Check:** *Offset by Percent (1.0 = 100%)* • **Do NOT Check:** *Calibration Only Landmark*	

Create landmarks 7-17 by following the same format as the RFMH_proj landmark for: ****

****

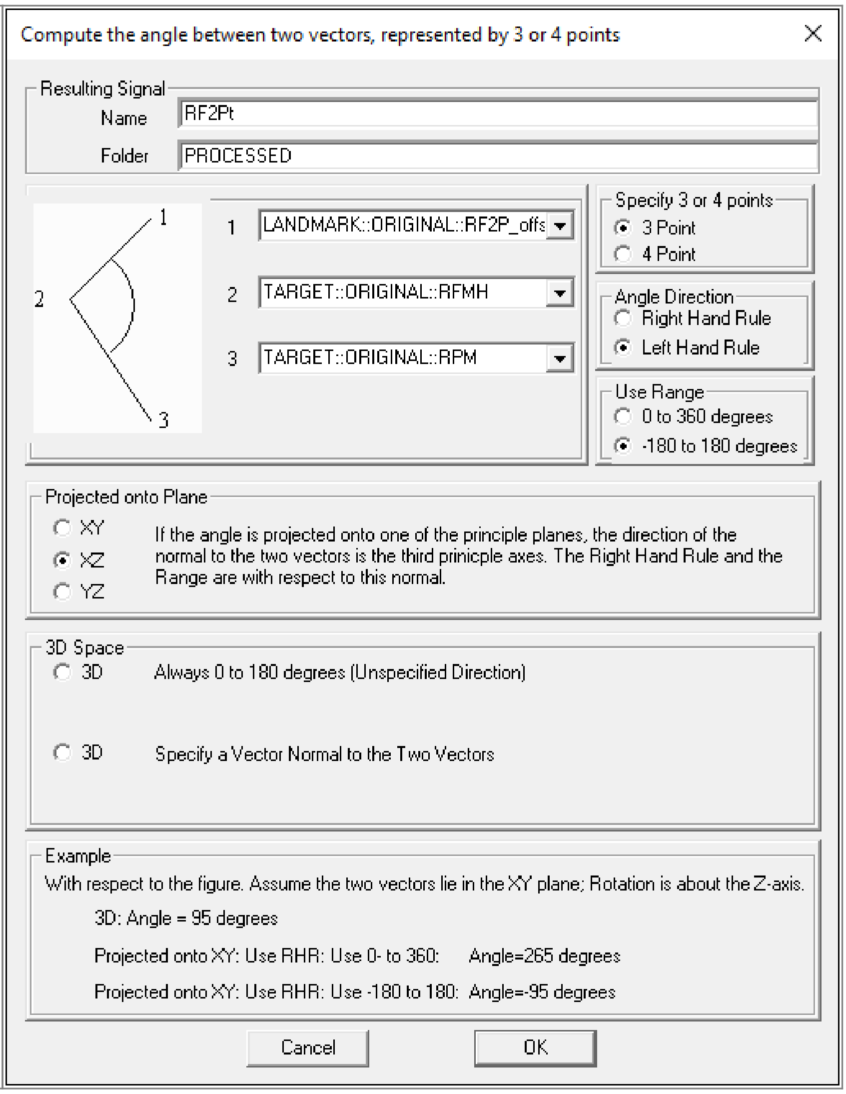
	12. LFMH
7. RFMB	13. LFMB
8. RSMH	14. LSMH
9. RSMB	15. LSMB
10. RVMH	16. LVMH
11. RVMB	17. LVMB

**** ****

Planar Angles

F2Pt

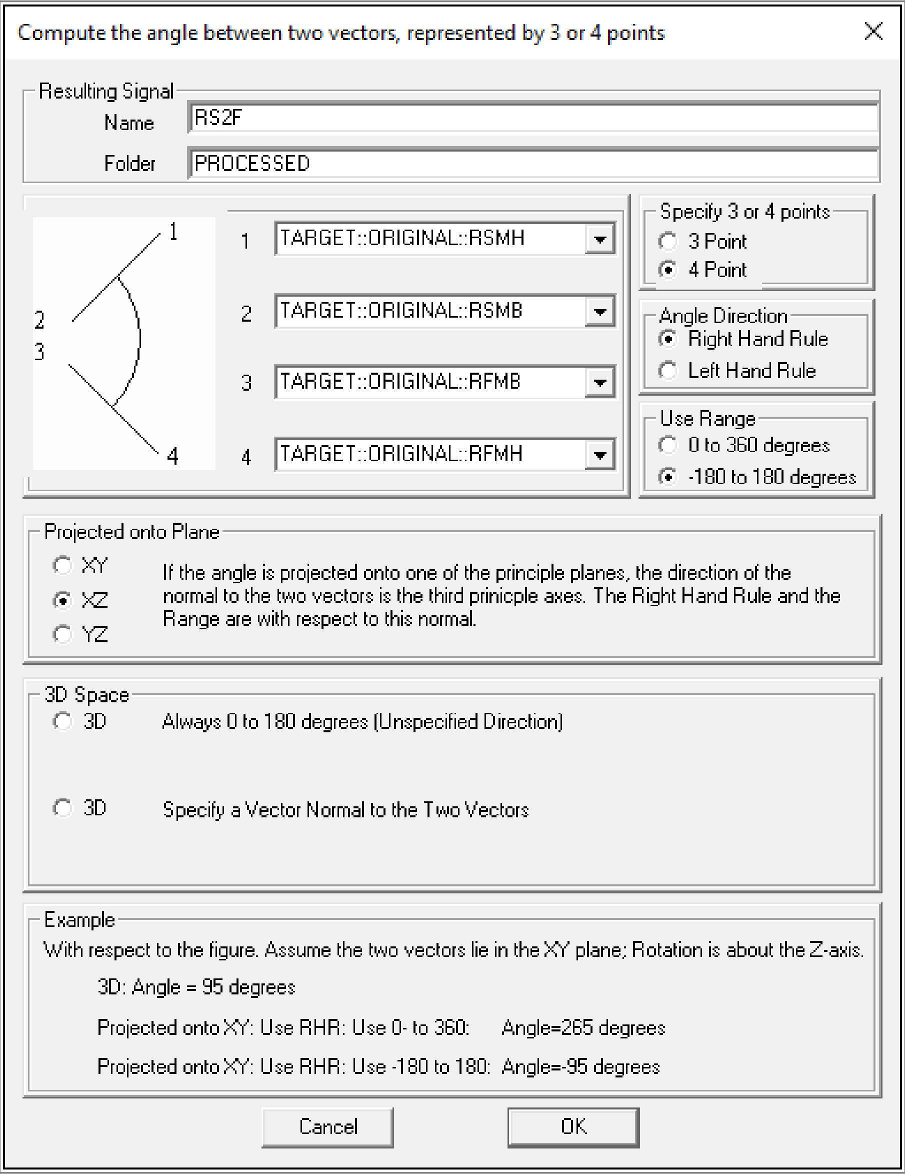
F2Pt - the angle between the lines FMH-PM and FMB-FMH projected onto the transverse plane of the metatarsus
Represents - valgus of the first metatarsophalangeal joint

1. Create RF2Pt planar angle: • Define **Resulting Signal** Name: *RF2Pt* • Calculate a **3 point angle** between the following targets:	1 - *LANDMARK::ORIGINAL::RF2P_offset* 2 - *TARGET::ORIGINAL::RFMH* 3 - *TARGET::ORIGINAL::RPM* **Angle Direction:** *Left Hand Rule* **Use Range:** *-180 to 180 degrees* **Projected onto Plane:** *XZ* **Note: The reference segment will need to be changed to *RMet* within the text option.**	

2. Create LF2Pt planar angle: • When defining the left signal, use same definitions **except** set:	**Angle Direction:** *Right Hand Rule* **Note: The reference segment will need to be changed to *LMet* within the text option.**

S2F

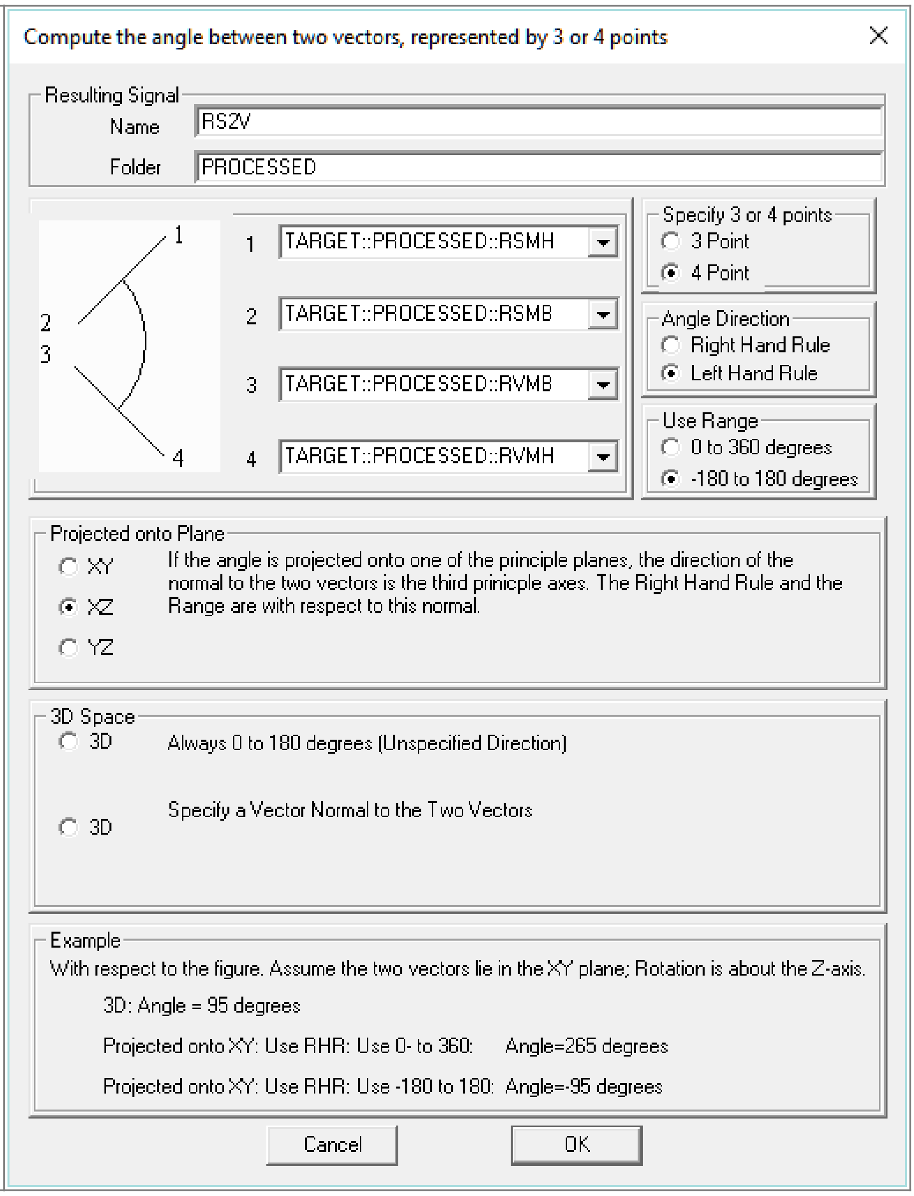
S2F - the angle between the lines FMB-FMH and SMB-SMH projected onto the transverse plane of the metatarsus

1. Create RS2F planar angle: • Define **Resulting Signal** Name: *RS2F* • Calculate a **4 point angle** between the following targets:	1 - *TARGET::ORIGINAL::RSMH* 2 - *TARGET::ORIGINAL::RSMB* 3 - *TARGET::ORIGINAL::RFMB* 4 - *TARGET::ORIGINAL::RFMH* **Angle Direction:** *Right Hand Rule* **Use Range:** *-180 to 180 degrees* **Projected onto Plane:** *XZ* **Note: The reference segment will need to be changed to *RMet* within the text option.**	

2. Create LS2F planar angle: • When defining the left signal, use same definitions **except** set:	**Angle Direction:** *Left Hand Rule* **Note: The reference segment will need to be changed to *LMet* within the text option.**

S2V

S2V - the angle between the lines VMB-VMH and SMB-SMH projected onto the transverse plane of the metatarsus

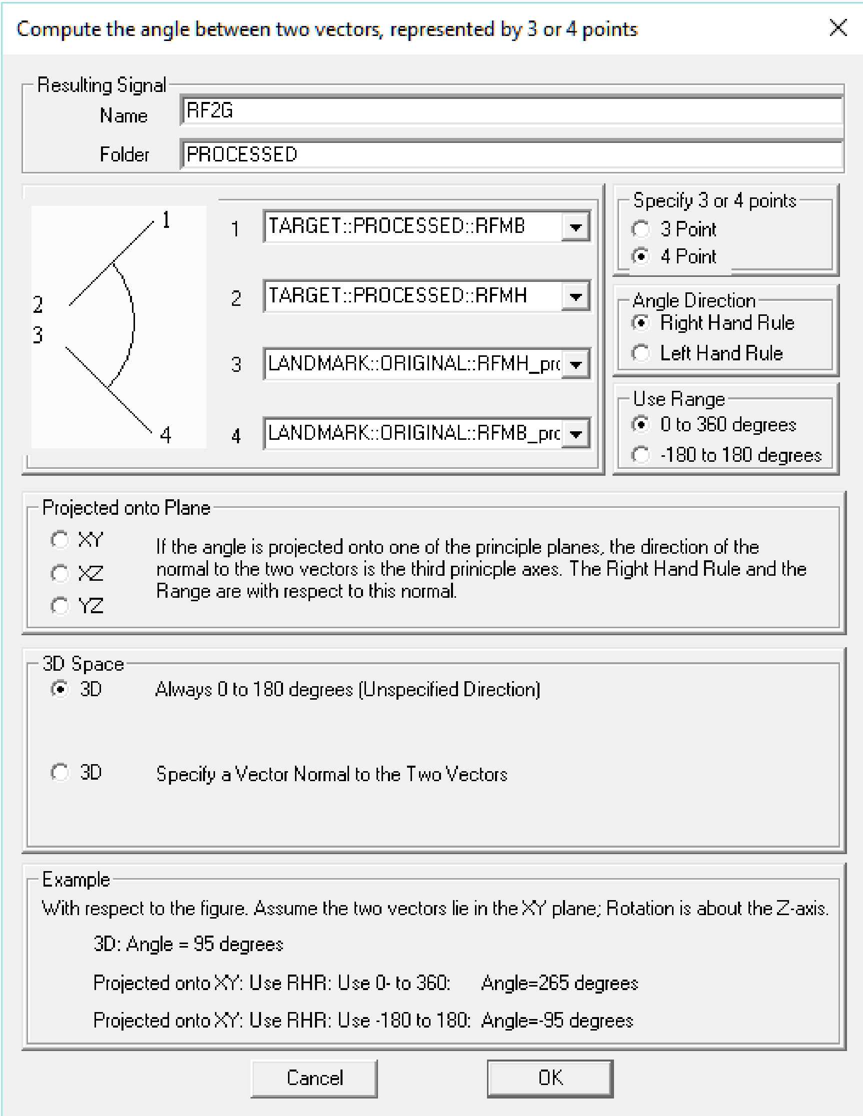
1. Create RS2V planar angle: • Define **Resulting Signal** Name: *RS2V* • Calculate a **4 point angle** between the following targets:	1 - *TARGET::ORIGINAL::RSMH* 2 - *TARGET::ORIGINAL::RSMB* 3 - *TARGET::ORIGINAL::RVMB* 4 - *TARGET::ORIGINAL::RVMH* **Angle Direction:** *Right Hand Rule* **Use Range:** *-180 to 180 degrees* **Projected onto Plane:** *XZ* **Note: The reference segment will need to be changed to *RMet* within the text option.**	

2. Create LS2V planar angle: • When defining the left signal, use same definitions **except** set:	**Angle Direction:** *Left Hand Rule* **Note: The reference segment will need to be changed to *LMet* within the text option.**

F2G

F2G - the angle between the lines FMB-FMH and the ground, plane orthogonal to the ground (3D angle relative to the ground)

The **FMH_proj** and **FMB_proj** landmarks will be used to calculate the **F2G** planar angle which are described in the landmarks section.

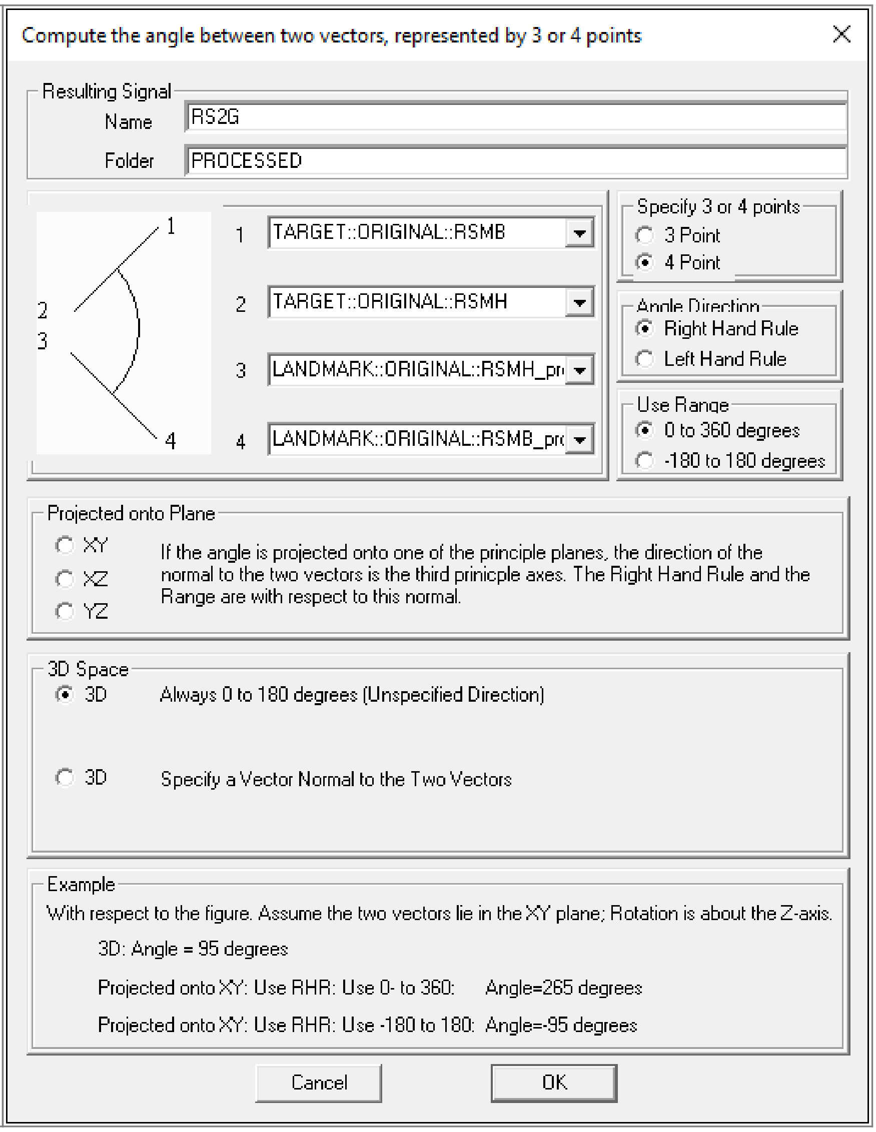
1. Create RF2G planar angle: • Define **Resulting Signal** Name: *RF2G* • Calculate a **4 point angle** between the following targets:	1 - *TARGET::ORIGINAL::RFMB* 2 - *TARGET::ORIGINAL::RFMH* 3 - *TARGET::ORIGINAL::RFMH_proj* 4 - *TARGET::ORIGINAL::RFMB_proj* **Angle Direction:** *Right Hand Rule* **3D Space:** *Always 0 to 180 degrees*	

2. Create LF2G planar angle: • When defining the left signal, use same definitions as for the right angle

S2G

S2G - the angle between the lines SMB-SMH and the ground, plane orthogonal to the ground (3D angle relative to the ground)

The **SMH_proj** and **SMB_proj** landmarks will be used to calculate the **S2G** planar angle which are described in the landmarks section.

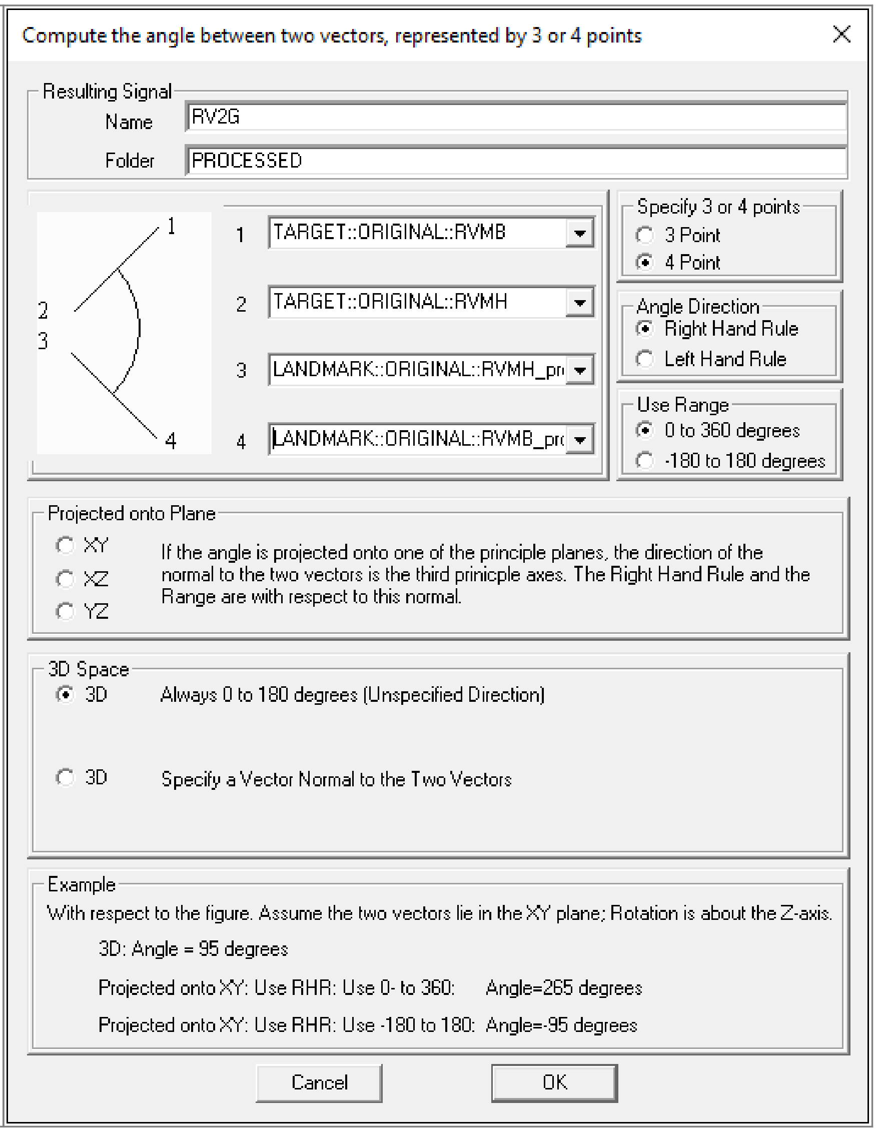
1. Create RS2G planar angle: • Define **Resulting Signal** Name: *RS2G* • Calculate a **4 point angle** between the following targets:	1 - *TARGET::ORIGINAL::RSMB* 2 - *TARGET::ORIGINAL::RSMH* 3 - *TARGET::ORIGINAL::RSMH_proj* 4 - *TARGET::ORIGINAL::RSMB_proj* **Angle Direction:** *Right Hand Rule* **3D Space:** *Always 0 to 180 degrees*	

2. Create LS2G planar angle: • When defining the left signal, use same definitions as for the right angle

V2G

V2G - the angle between the lines VMB-VMH and the ground, plane orthogonal to the ground (3D angle relative to the ground)

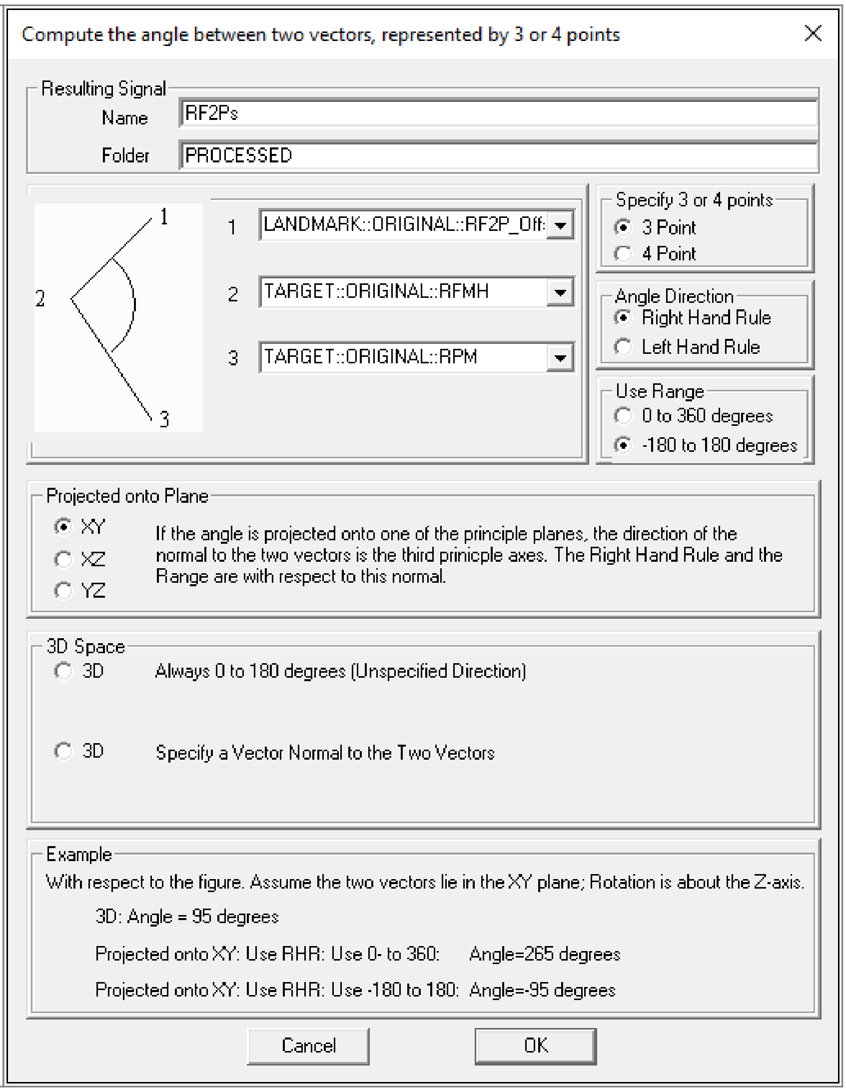
The **VMH_proj** and **VMB_proj** landmarks will be used to calculate the **V2G** planar angle which are described in the landmarks section.

1. Create RV2G planar angle: • Define **Resulting Signal** Name: *RV2G* • Calculate a **4 point angle** between the following targets:	1 - *TARGET::ORIGINAL::RVMB* 2 - *TARGET::ORIGINAL::RVMH* 3 - *TARGET::ORIGINAL::RVMH_proj* 4 - *TARGET::ORIGINAL::RVMB_proj* **Angle Direction:** *Right Hand Rule* **3D Space:** *Always 0 to 180 degrees*	

2. Create LV2G planar angle: • When defining the left signal, use same definitions as for the right angle

F2Ps

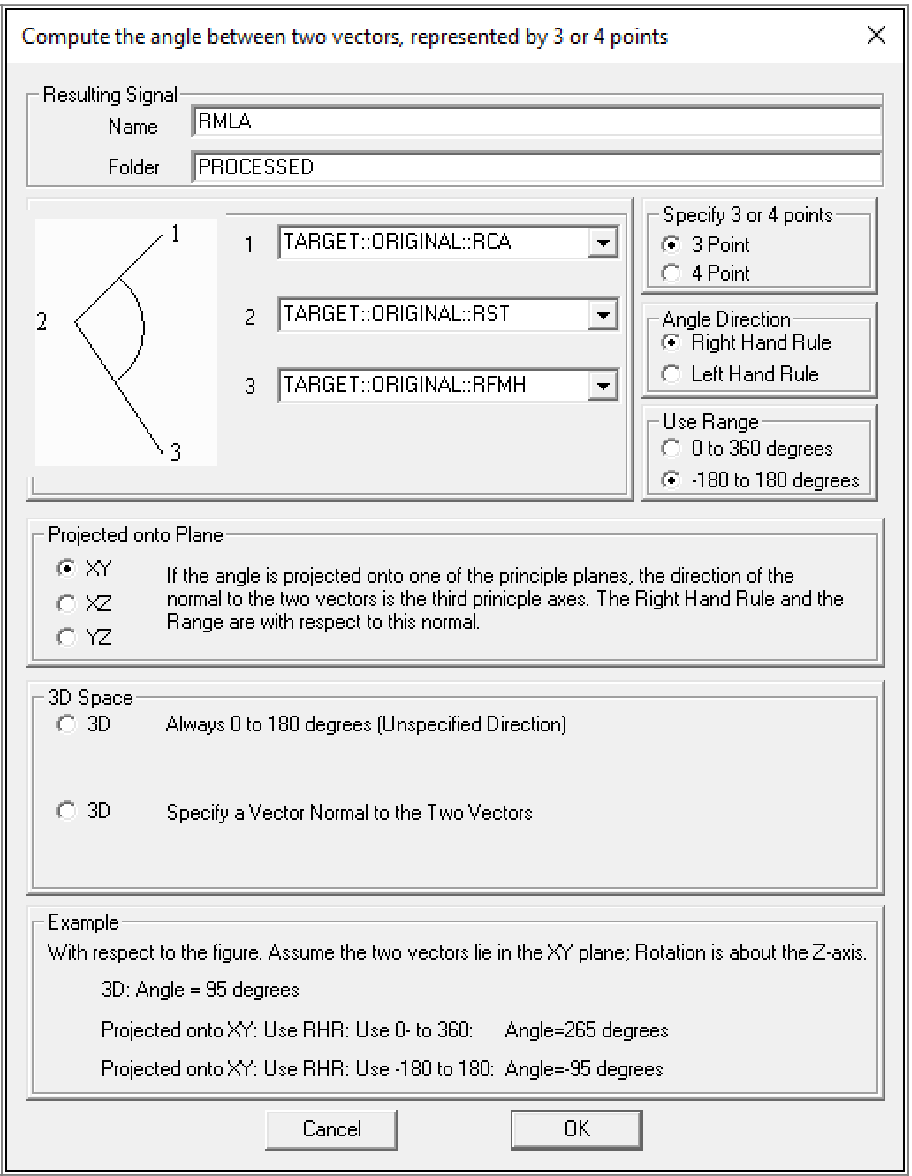
F2Ps - the angle between the lines FMH-PM and FMB-FMH projected onto the sagittal plane of the metatarsus
Represents - dorsiflexion of the first metatarso-phalangeal joint

1. Create RF2Ps planar angle: • Define **Resulting Signal** Name: *RF2Ps* • Calculate a **3 point angle** between the following targets:	1 - *LANDMARK::ORIGINAL::RF2P_offset* 2 - *TARGET::ORIGINAL::RFMH* 3 - *TARGET::ORIGINAL::RPM* **Angle Direction:** *Right Hand Rule* **Use Range:** *-180 to 180 degrees* **Projected onto Plane:** *XY* **Note: The reference segment will need to be changed to *RMet* within the text option.**	

2. Create LF2Ps planar angle: • When defining the left signal, use same definitions as for the right angle	**Note: The reference segment will need to be changed to *LMet* within the text option.**

MLA

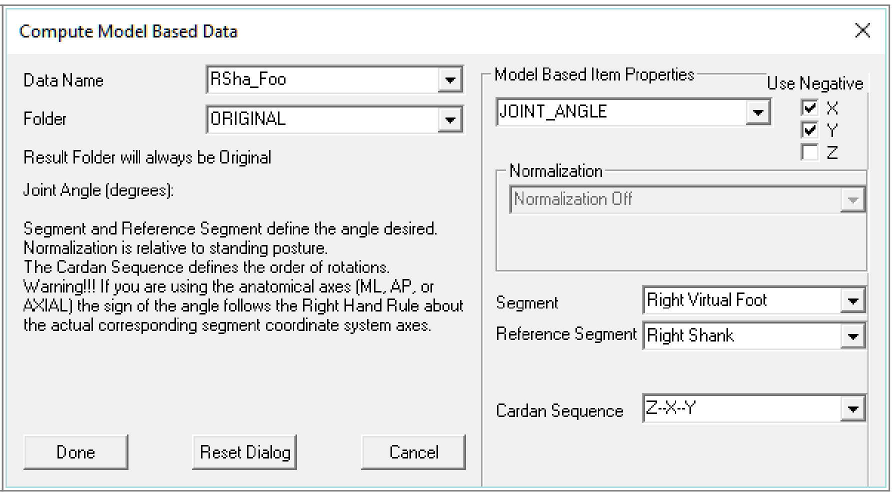
MLA - the angle between the lines CA-ST and ST-FMH projected onto the sagittal plane of the foot
Represents - navicular drop

1. Create RMLA planar angle: • Define **Resulting Signal** Name: *RMLA* • Calculate a **3 point angle** between the following targets:	1 - *TARGET::ORIGINAL::RCA* 2 - *TARGET::ORIGINAL::RST* 3 - *TARGET::ORIGINAL::RFMH* **Angle Direction:** *Right Hand Rule* **Use Range:** *-180 to 180 degrees* **Projected onto Plane:** *XY* **Note: The reference segment will need to be changed to *RMet* within the text option.**	

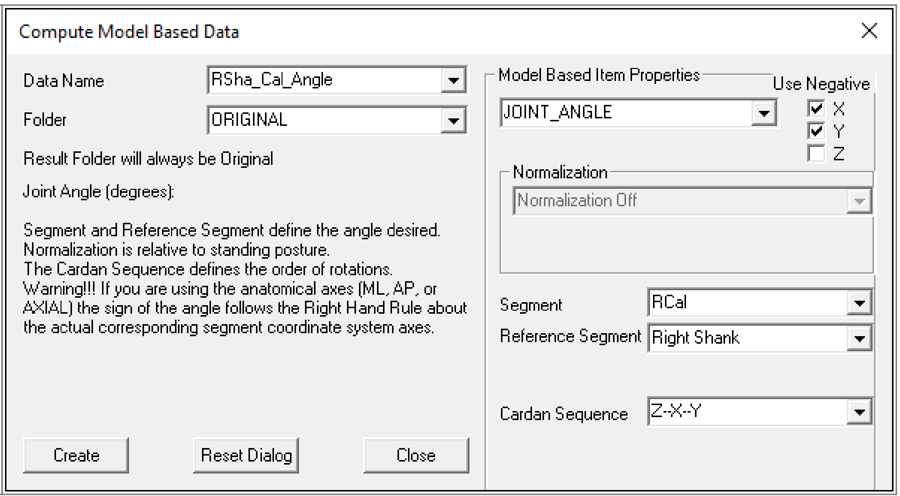
2. Create LMLA planar angle: • When defining the left signal, use same definitions as for the right angle	**Note: The reference segment will need to be changed to *LMet* within the text option.**

Joint Angles

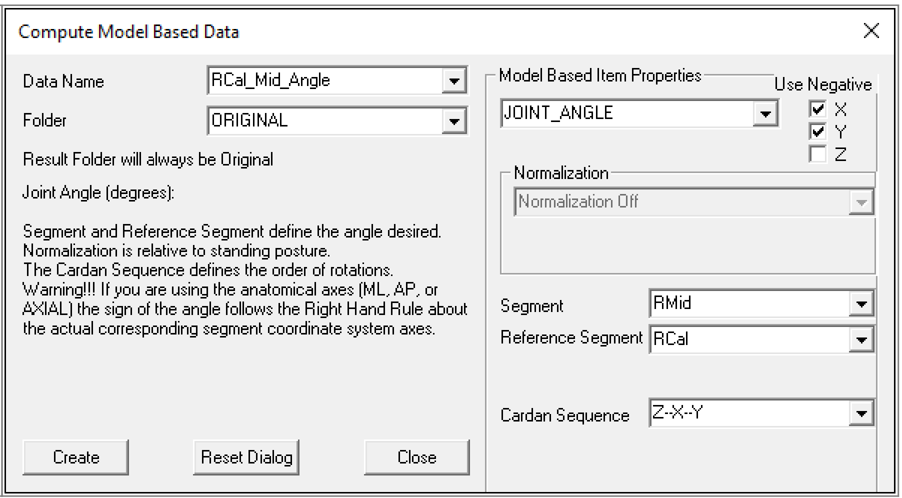
Sha_Foo_Angle

1. Define the RSha_Foo_Angle: • Open the **Compute Model Based** dialog • Select **JOINT_ANGLE** from drop down list	**Data Name:** *RSha_Foo_Angle* **Segment:** *Right Foot* **Reference Segment:** *Right Shank* **Cardan Sequence:** *Z-X-Y*	• **Use Negative**: **X:** *TRUE* **Y:** *TRUE* **Z:** *FALSE*	

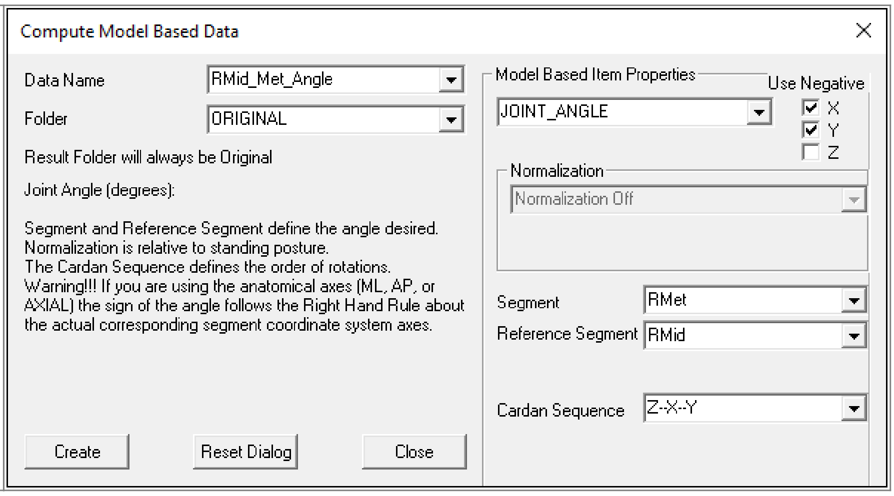
Sha_Cal_Angle

1. Define the RSha_Cal_Angle: • Open the **Compute Model Based** dialog • Select **JOINT_ANGLE** from drop down list	**Data Name:** *RSha_Cal_Angle* **Segment:** *RCal* **Reference Segment:** *Right Shank* **Cardan Sequence:** *Z-X-Y*	• **Use Negative**: **X:** *TRUE* **Y:** *TRUE* **Z:** *FALSE*	

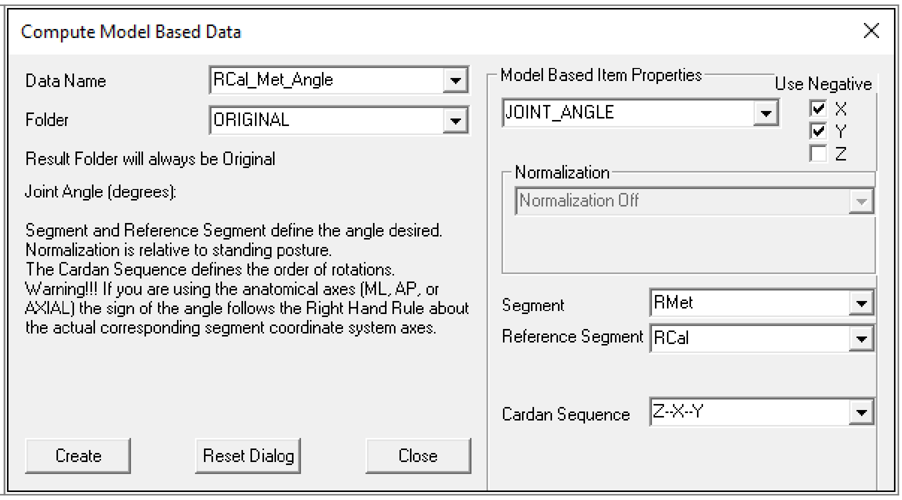
Cal_Mid_Angle

1. Define the RCal_Mid_Angle: • Open the **Compute Model Based** dialog • Select **JOINT_ANGLE** from drop down list	**Data Name:** *RCal_Mid_Angle* **Segment:** *RMid* **Reference Segment:** *RCal* **Cardan Sequence:** *Z-X-Y*	• **Use Negative**: **X:** *TRUE* **Y:** *TRUE* **Z:** *FALSE*	

Mid_Met_Angle

1. Define the RMid_Met_Angle: • Open the **Compute Model Based** dialog • Select **JOINT_ANGLE** from drop down list	**Data Name:** *RMid_Met_Angle* **Segment:** *RMet* **Reference Segment:** *RMid* **Cardan Sequence:** *Z-X-Y*	• **Use Negative:** **X:** *TRUE* **Y:** *TRUE* **Z:** *FALSE*	

Cal_Met_Angle

1. Define the RCal_Met_Angle: • Open the **Compute Model Based** dialog • Select **JOINT_ANGLE** from drop down list	**Data Name:** *RCal_Met_Angle* **Segment:** *RMet* **Reference Segment:** *RCal* **Cardan Sequence:** *Z-X-Y*	• **Use Negative:** **X:** *TRUE* **Y:** *TRUE* **Z:** *FALSE*	

References

1. ↑ 1.00 1.01 1.02 1.03 1.04 1.05 1.06 1.07 1.08 1.09 1.10 Leardini, A., M.G. Benedetti, L. Berti, D. Bettinelli, R. Nativo, and S. Giannini. “Rear-foot, Mid-foot and Fore-foot Motion during the Stance Phase of Gait.” Gait & Posture 25 (2007): 453-55
2. ↑ 2.0 2.1 2.2 2.3 2.4 2.5 2.6 2.7 2.8 Serge van Sint Jan “Color Atlas of Skeletal Landmark Definitions: Guidelines for Reproducible Manual and Virtual Palpations” 2007 - Churchill Livingstone