Landmark Types

Landmarks provide a powerful method of representing significant locations within space or locations defined by the model.

There are several landmark types or ways to create landmarks. Landmarks can be created:

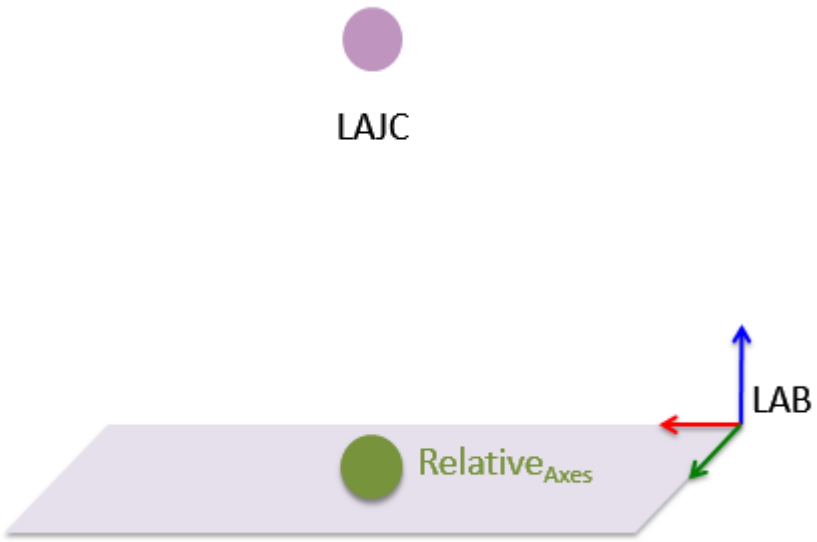
1. as a point relative to one marker/landmark
2. as a point on a Line
3. as a point in a Plane
4. as a point Projected on a Line
5. as a point Projected on a Plane
6. as offsets (using regression equations or relative to a segment)
7. relative to three points
8. digitized with a pointer
9. as a functional point

Type 1: In a Reference Coordinate System

The simplest landmark is a landmark which is defined in a segment coordinate system. There are many variations of this but a landmark can be defined in lab space, in a segment coordinate system, or by a 4x4Rotation Signal. The definition's offsets define where the landmark is created relative to the coordinate system.

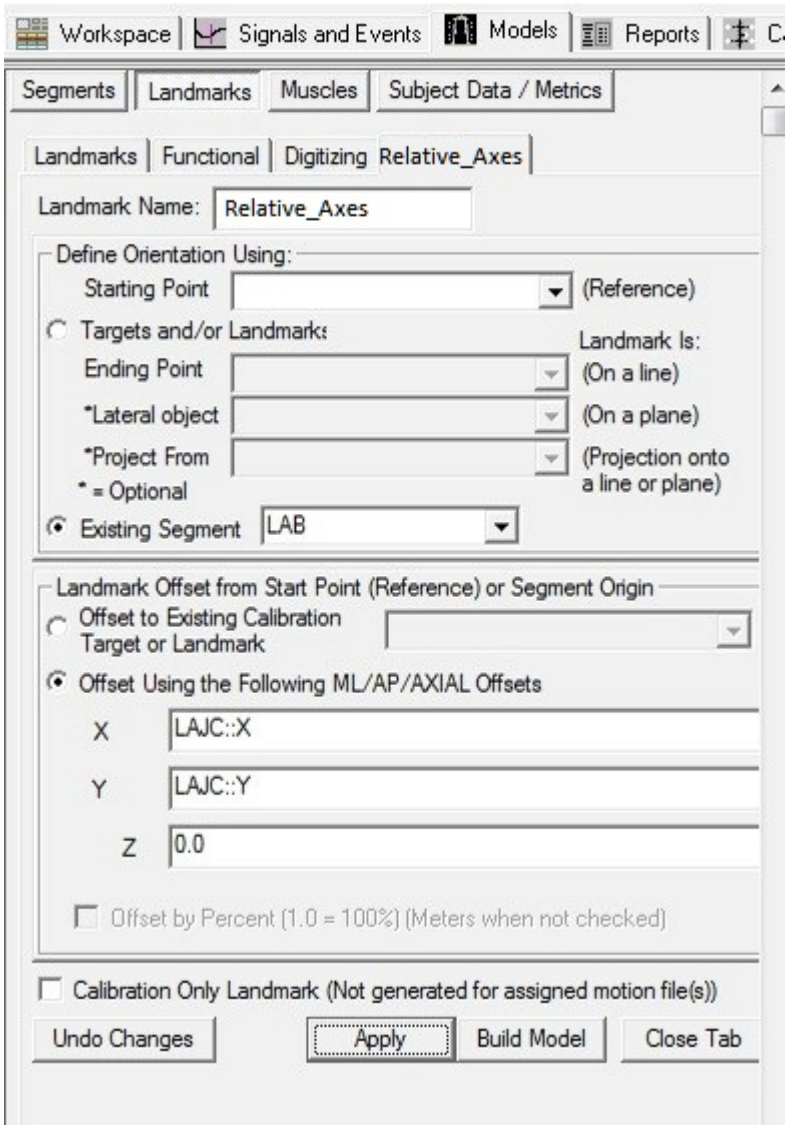
In Lab Space

This landmark is defined in Lab space, or the laboratory coordinate system.

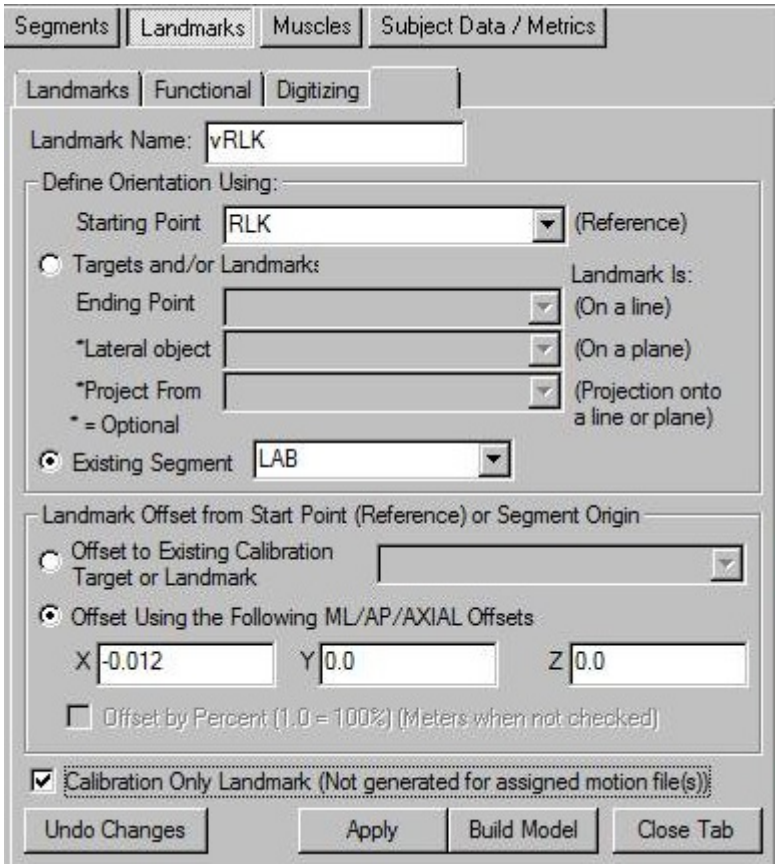


As an example definition of a landmark relative to specific axes in the laboratory coordinate system:

1. Click **Landmarks** button
2. Click **Add New Landmark** button
3. Create Landmark: *Relative_Axes*
    1. **Landmark Name:** *Relative_Axes*
    2. **Define Orientation Using:**
    3. **Existing Segment:** *Lab*
    4. Offset Using the Following **ML/AP/AXIAL** Offsets:
        1. **X:** *LAJC::X*
        2. **Y:** *LAJC::Y*
        3. **Z:** *0.0*
    5. **Do NOT Check:** *Offset by Percent (1.0 = 100%)*



Landmarks can also be created as an offset from the specified marker in a segment coordinate system or in the LAB coordinate system. In the dialog below the **vRLK** landmark is created from **RLK** as an offset in the x direction in the LAB coordinate system.

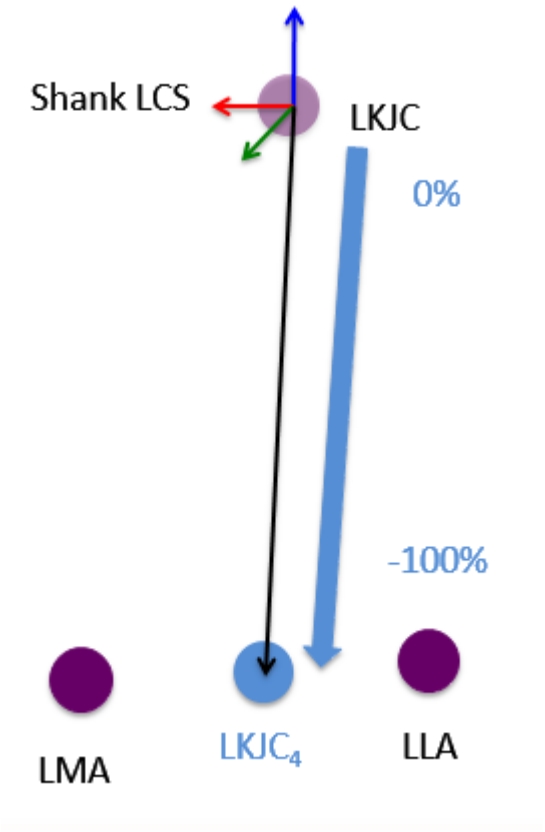


Other Examples include:

- Virtual Lab Tutorial: The LAB_O, LAB_X, and LAB_Y landmarks in the virtual lab tutorial are defined in LAB space, where the offsets refer to the distance the landmarks are created in meters.
- The following two examples describe how to define landmarks that represent stair corners. The position of targets placed on the steps are calculated from dynamic trials is used to define the landmarks.
    - Using Motion Trial Example 1
    - Using Motion Trial Example2

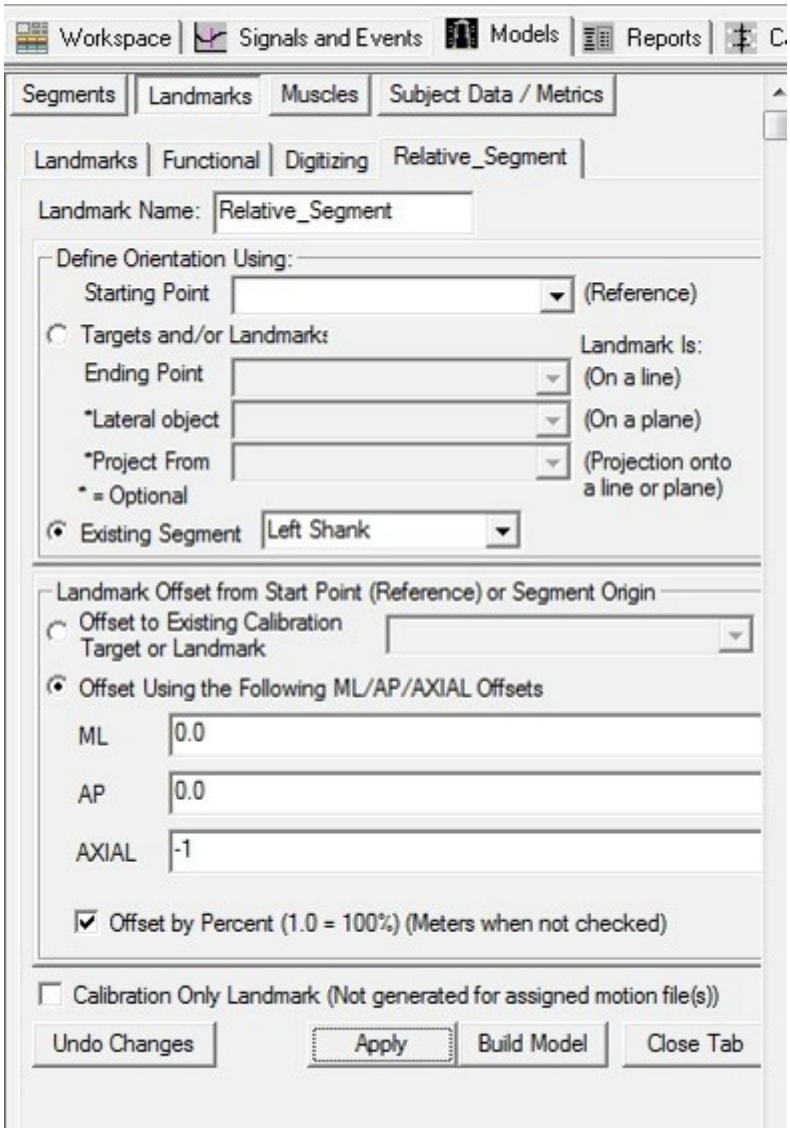
In a Segment Coordinate System

Landmarks can be created relative to a segment, i.e., in the segment coordinate system.



As an example definition relative to a segment:

1. Click **Landmarks** button
2. Click **Add New Landmark**
3. Create Landmark: *Relative_Segment*
    1. **Landmark Name:** *Relative_Segment*
    2. **Define Orientation Using:**
    3. **Existing Segment:** *Left Shank*
    4. Offset Using the Following **ML/AP/AXIAL** Offsets:
        1. **X:** *0.0*
        2. **Y:** *0.0*
        3. **Z:** *-1*
    5. **Check:** *Offset by Percent (1.0 = 100%)*



Other examples include:

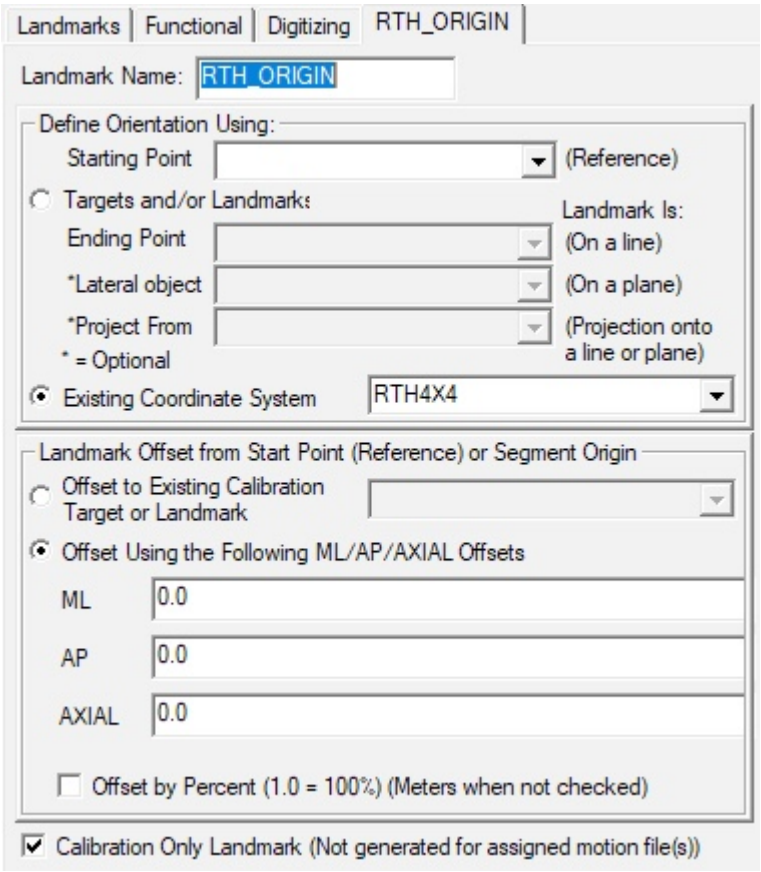
- Create a landmark relative to the thigh segment using ML, AP, and AXIAL offsets as percents.
- Creating a landmark at the end of a segment that is tracked with the segment.
- Hip Joint Centers are often defined using regression equations which locate the hip joint centers in the pelvis coordinate system:
  - Bell and Brand Regression Equations
  - Hip Landmark from Custom Regression Equation
- A Knee Alignment Device (KAD) defines the joint centers by defining landmarks in the KAD segment coordinate system
- Create a Landmark Mimicking contralateral segment. This example uses several different types of landmarks, but the end result is a landmark created in the foot coordinate system.

Relative to a 4x4 Rotation Matrix

A sample Landmark definition using a 4×4 rotation matrix:

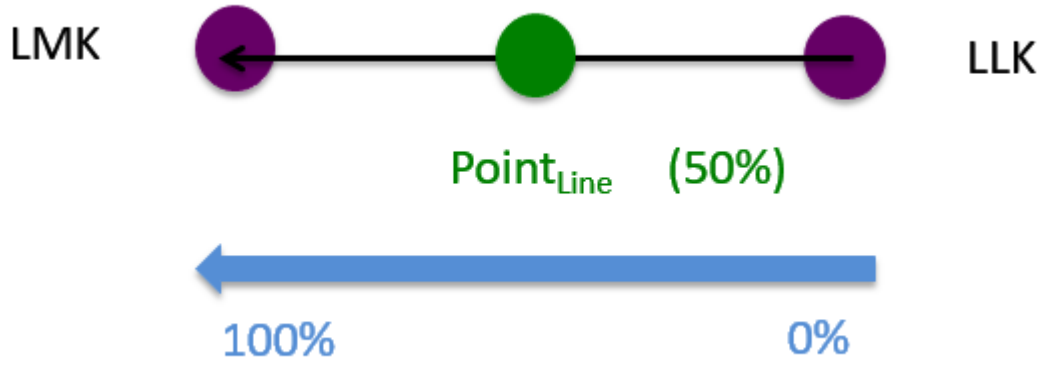
1. Create **RTH_Origin:** This will create a Landmark at the position of the Rotation signal RTH4x4
2. Click **Landmarks** button
3. Click **Add New Landmark** button
4. Create Landmark: *RTH_Origin*

1. **Landmark Name:** *RTH_Origin*
2. **Define Orientation Using:**
3. **Existing Coordinate System:** *RTH4X4*
4. Offset Using the Following **ML/AP/AXIAL** Offsets:
    1. **X:** *0.0*
    2. **Y:** *0.0*
    3. **Z:** *0.0*
5. **Check:** *Offset by Percent (1.0 = 100%)*



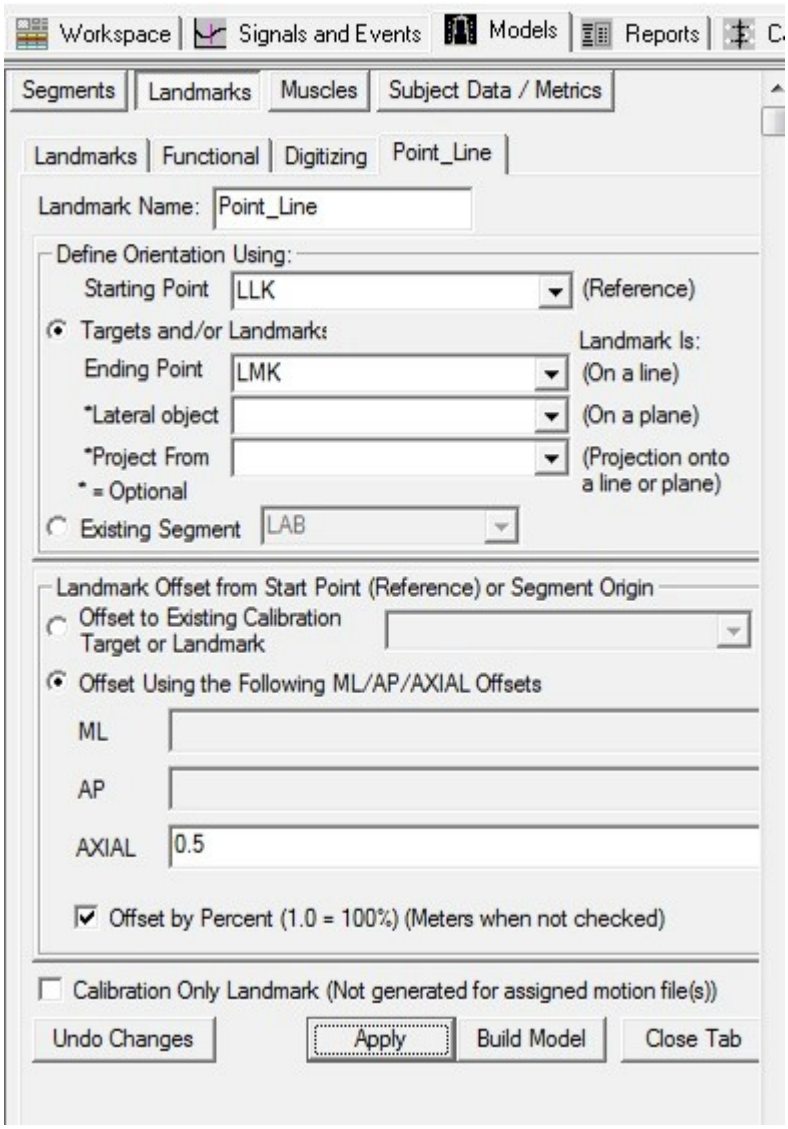
Type 2: Point on a Line

A landmark can be defined along a particular line.



As an example definition of this type of landmark:

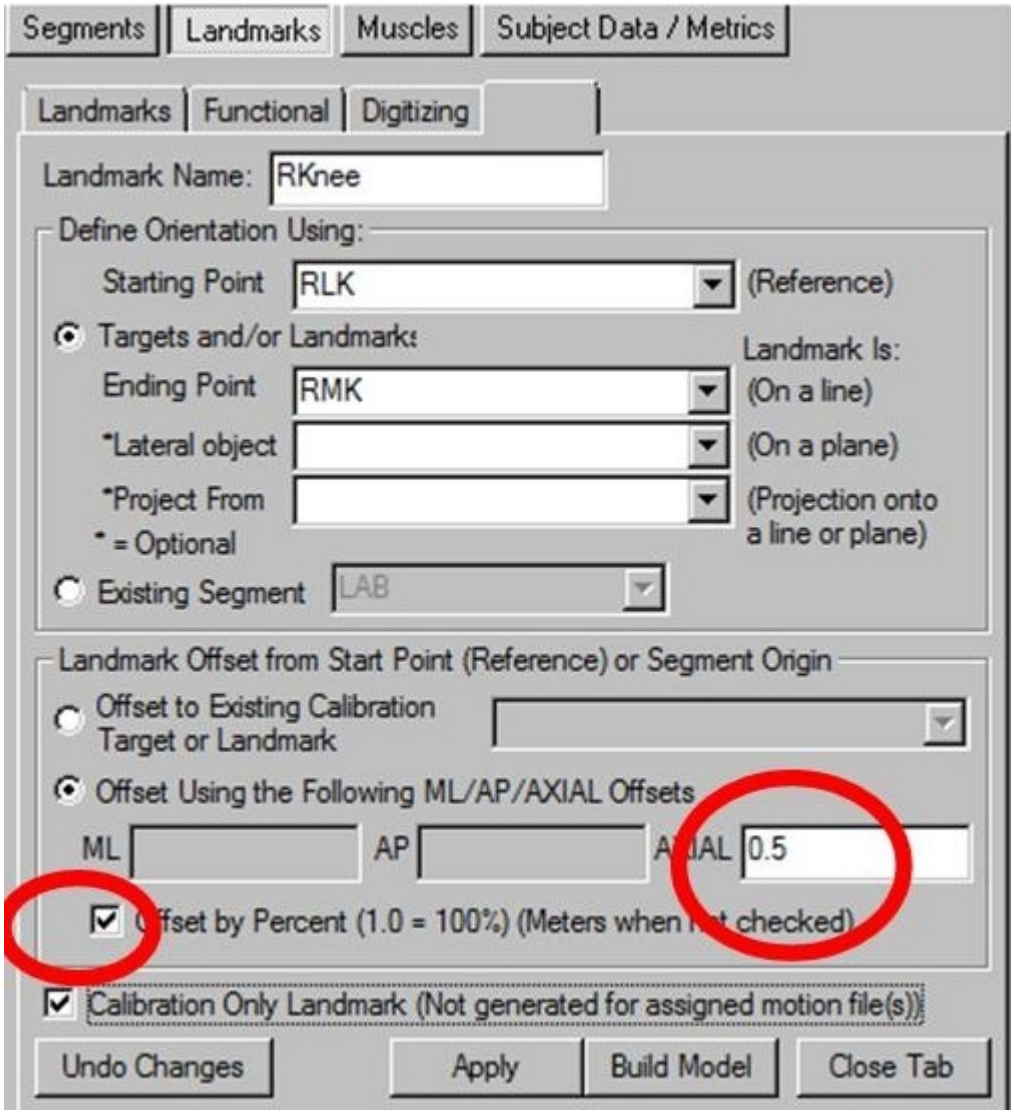
1. Create Point_Line:
    1. Click **Landmarks** button
    2. Click **Add New Landmark** button
2. Create Landmark: Point_Line
    1. **Landmark Name:** *Point_Line*
    2. **Define Orientation Using:**
    3. **Starting Point:** *LLK*
    4. **Ending Point:** *LMK*
    5. Offset Using the Following **AXIAL** Offset: *0.5*
    6. **Check:** *Offset by Percent (1.0 = 100%)*



Create a landmark as a midpoint

The landmark **RKnee** is a point that is halfway between the lateral and medial knee markers **RLK** and **RMK**. The point on a line can be defined as a distance in percentage or distance in meters (when **Offset by Percent** is checked, the distance is defined as a percentage.)

Note: When using a Point on a Line landmark, only the AXIAL offset is used.

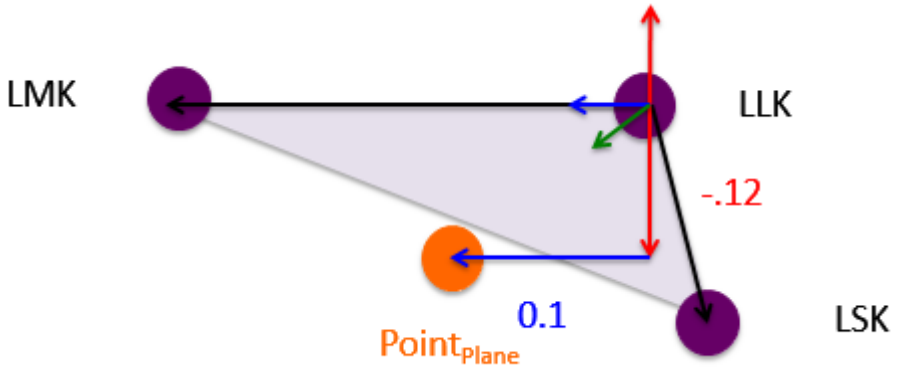


Type 3: On a Plane

A landmark can be defined as a point in a plane using manual offsets or relative offsets.

Using manual offsets

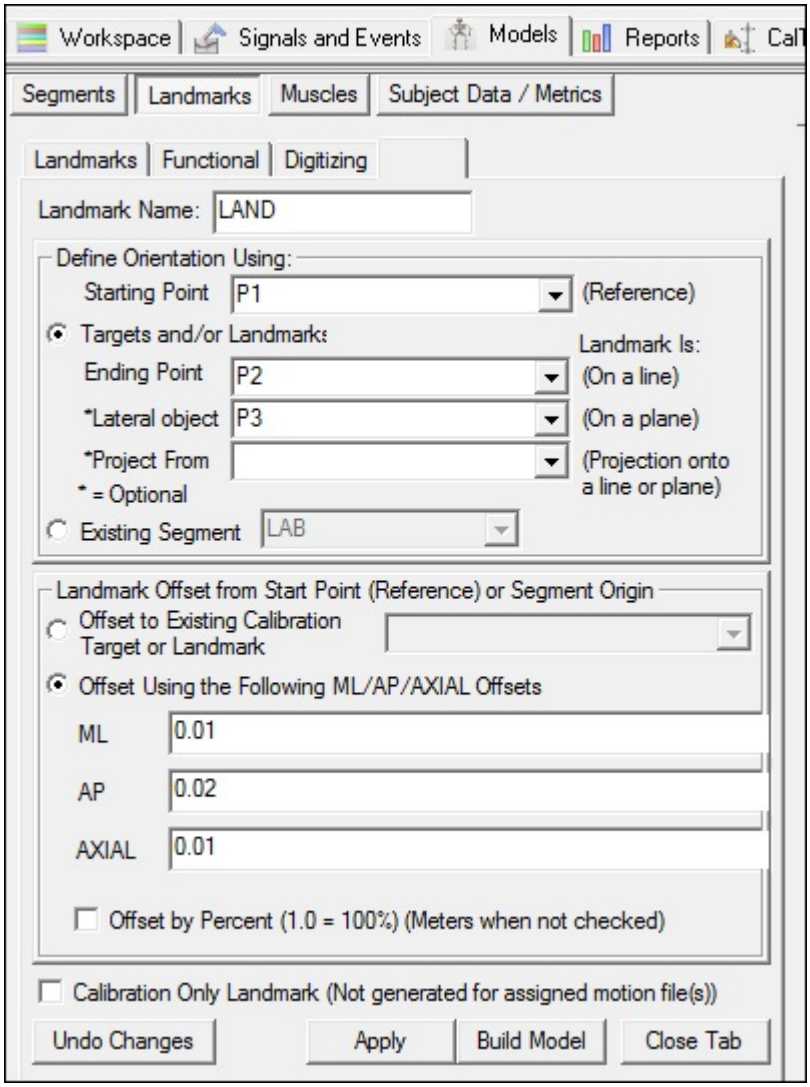
Manual offsets can be used to create a landmark relative to a plane or technical coordinate system.

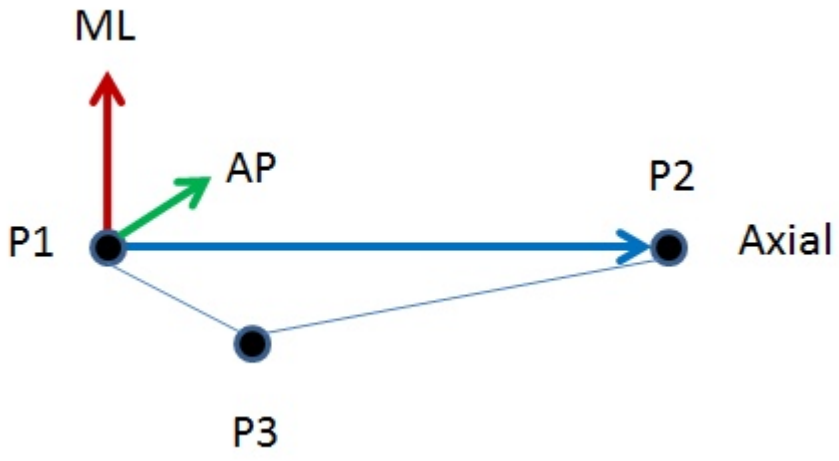


Sample landmark definition for a right-handed orthogonal coordinate system defined by three points (P1, P2, P3):

1. Create LAND:
    1. Click **Landmarks** button
    2. Click **Add New Landmark** button
    3. Create Landmark: *LAND*
        1. **Landmark Name:** *LAND*
        2. **Define Orientation Using:**
            1. **Starting Point:** *P1*
            2. **Ending Point:** *P2*
            3. **Lateral Object:** *P3*
        3. Offset Using the Following **ML/AP/AXIAL** Offsets:
            1. **X:** *0.01*
            2. **Y:** *0.02*
            3. **Z:** *0.01*
        4. **Do NOT Check:** *Offset by Percent (1.0 = 100%)*

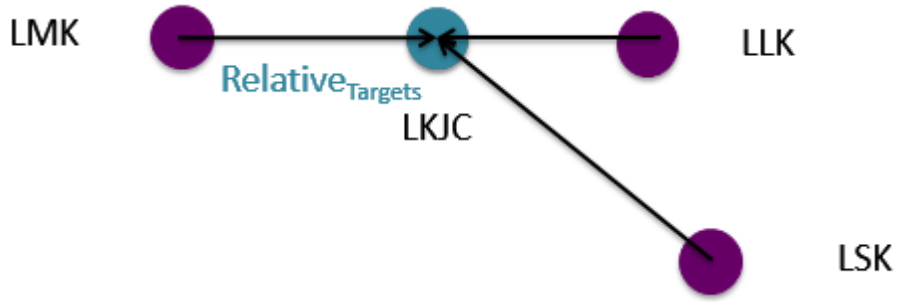
The origin of the coordinate system is at the point P1 and the **frontal plane** of the coordinate system is defined by the three points. The positive AP direction is into the screen:



A right handed orthogonal coordinate system is defined by the three points (P1, P2, P3). The origin of the coordinate system is at the point P1. The **frontal plane** of the coordinate system is defined by the three points. The positive AP direction is into the screen.	

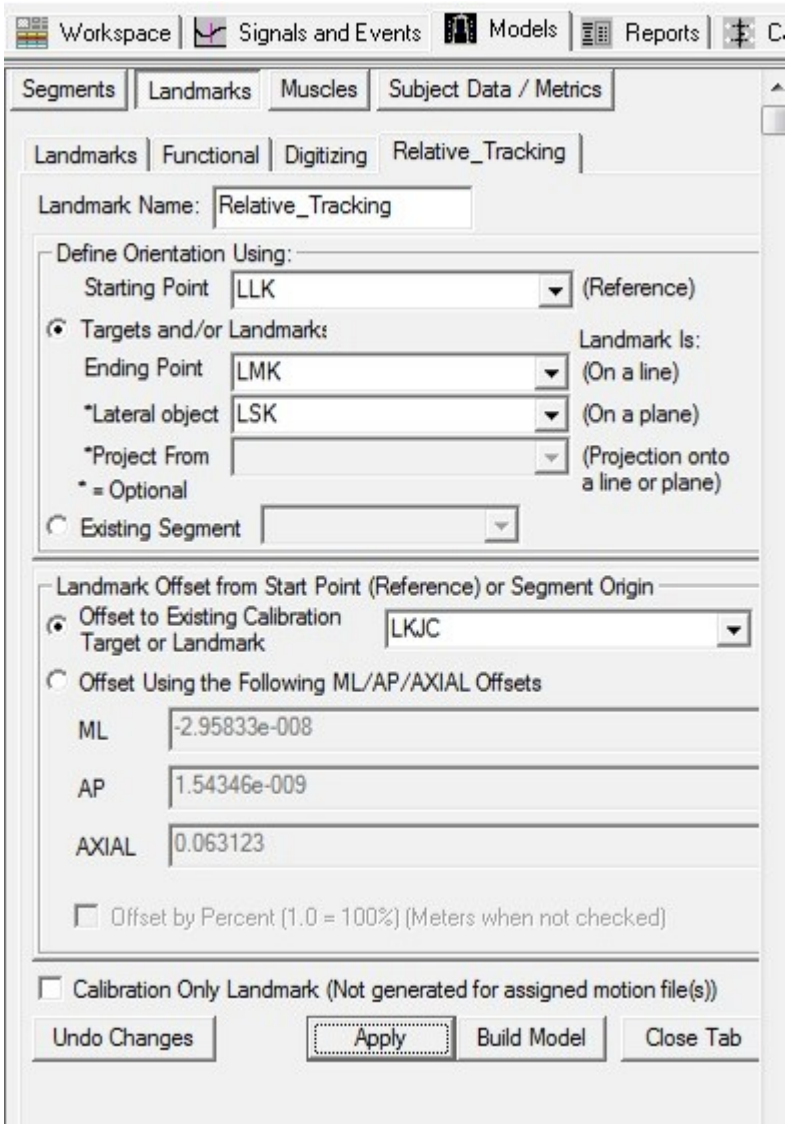
Using target/landmark offsets

Target or landmark offsets can be used to create a landmark relative to other tracked points.



This example definition creates a landmark relative to three targets. The offset of the landmark is defined using the location of a target relative to the three targets during the static trial.

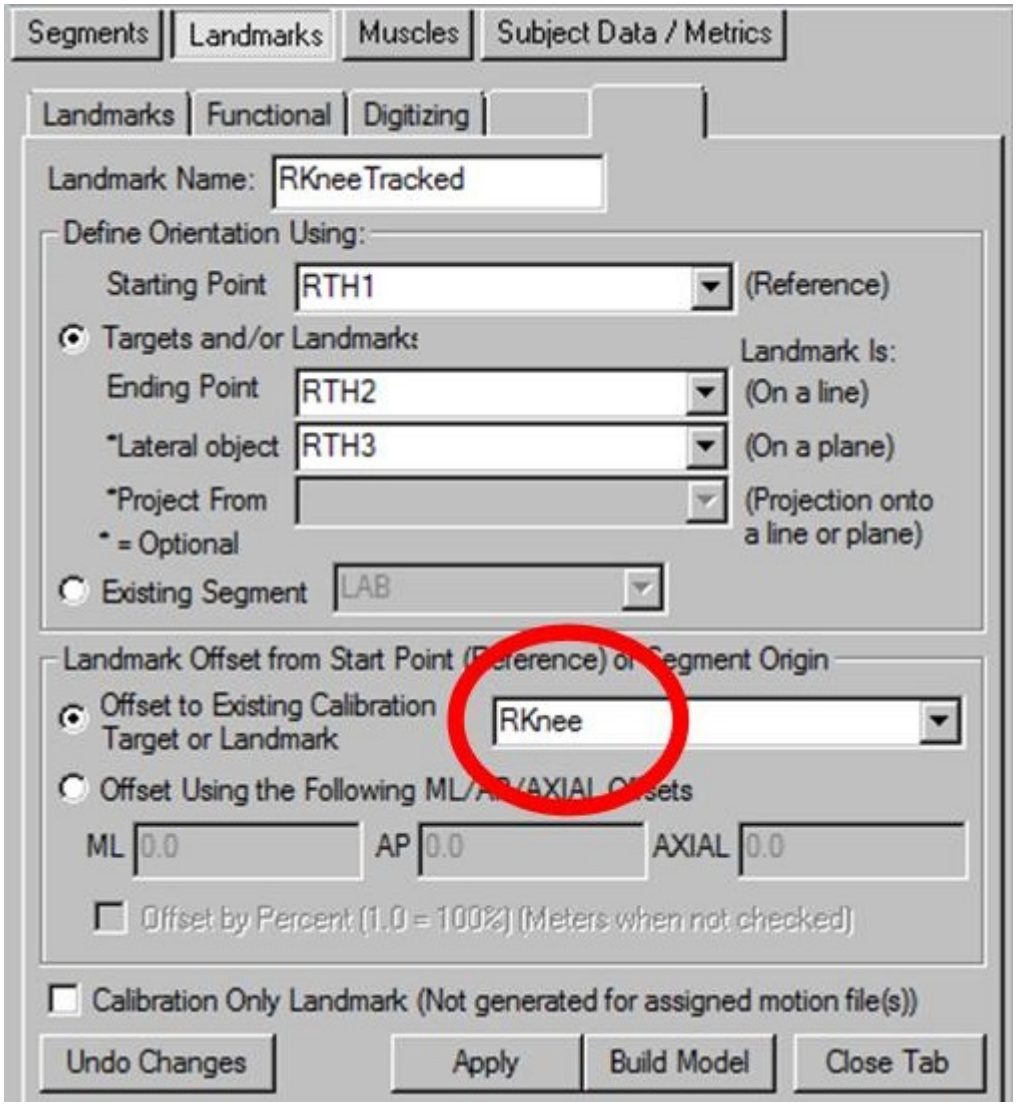
1. Create Relative_Tracking:
    1. Click **Landmarks** button
    2. Click **Add New Landmark** button
    3. Create Landmark: *Relative_Tracking*
        1. **Landmark Name:** *Relative_Tracking*
        2. **Define Orientation Using:**
            1. **Starting Point:** *LLK*
            2. **Ending Point:** *LMK*
            3. **Lateral Object:** *LSK*
        3. Offset to Existing Calibration Target or Landmark: *LKJC*
        4. **Do NOT Check:** *Offset by Percent (1.0 = 100%)*



Type 3 Examples

Another example of a Type 3 landmark is to define a landmark as a point on a plane defined by 3 points.

1. Select the Targets and/or Landmarks radio button
2. Select three targets and/or landmarks for the Reference/Axial Starting Point, Axial Ending Point and lateral object.
    1. The landmark/target reference offset is also selected.
3. The **RKnee** calibration only landmark is the point that is being tracked by 3 target markers on the thigh **RTH1**, **RTH2**, and **RTH3**.



Other Examples:

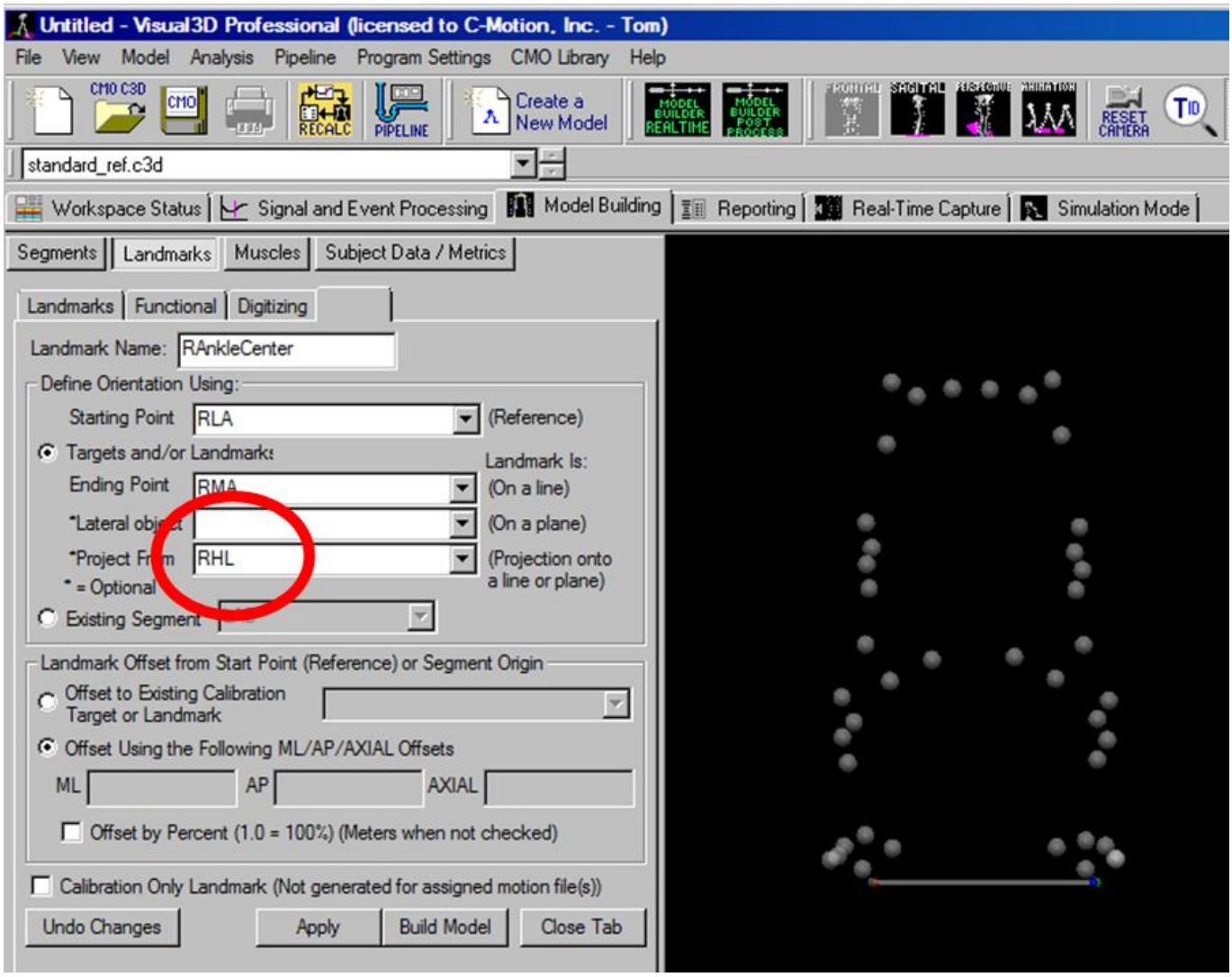
- Create a landmark using two standing trials
  - Example 1
  - Example 2
- Create a landmark using a reference location
- Define a segment endpoint relative to 3 tracking targets

Type 4: Point Projected on a Line

Point projection onto a line can be used at the shoulder to project a lateral target on to a vertical line passing through the acromium or it can be used at the knee to project lateral or medial targets on a functional axis. To define a landmark as a point projected on a line (two other points define a line in space):

1. Select the Targets and/or Landmarks radio button;
2. Select 2 targets and/or landmarks for the Reference/Axial Starting Point and Axial Ending Point;
3. Select a point to project using the Projected From combo box.

In the image below, the **RAnkleCenter** is the point that is created by projecting the **RHL** heel marker onto the line created from the lateral and medial ankle markers **RLA** and **RMA**.



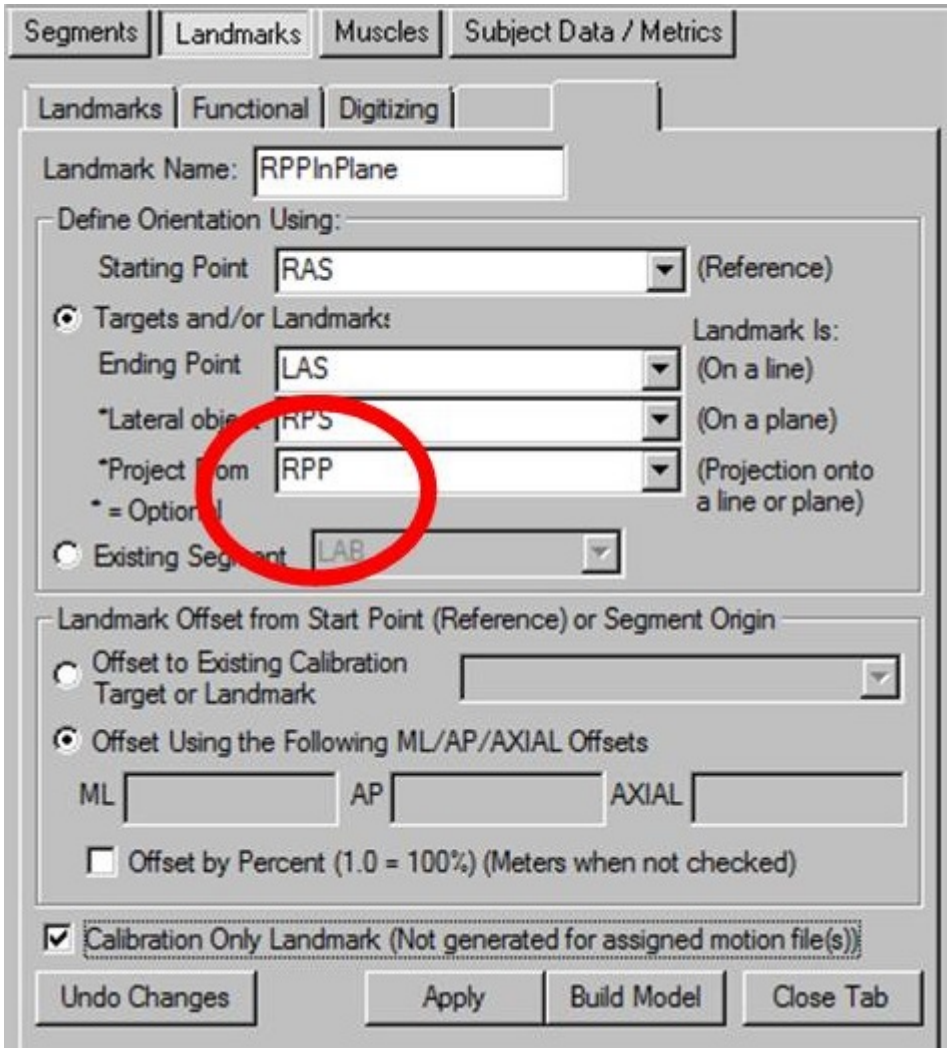
Another example can be found on the project marker onto a line example page.

Type 5: Point Projected on to a Plane

By projecting multiple landmarks onto the same plane you can build segment coordinates systems in a specific plane. To define a landmark as a point projected onto a plane defined by 3 points:

1. Select the Targets and/or Landmarks radio button;
2. Select three targets and/or landmarks for the Reference/Axial Starting Point, Axial Ending Point and Lateral object to define a plane; and
3. Select a point to project using the Projected From combo box.

In the image below, the **RPPinPlane** is the point that is created by projecting the **RPP** marker on the illiac crest onto the plane created from the right and left ASIS's (**RASI**,**LASI**) and the right PSIS **RPS** marker.



See the example project the hip joint onto a plane passing through the greater trochanters for more detail.

Type 6: Define by Offsets

Landmarks are often offsets from existing target markers. The origin of the offset is the starting point (reference point). The offset is specified as an absolute distance in meters, or as a percentage. The percentage is relative to a segment or markers.

Using regression equations as offset

Regression equations can be used as an offset in the landmark definition.

This is notably used when defining hip joint centres:

1. **Hip Landmark**: Landmarks defining the location of the hip joint center are not particularly notable except that two of the default Pelvis segment types (Coda and Helen Hayes) create hip joint landmarks automatically when the segment is created.
2. **Bell and Brand Hip**: Specifying the Hip Joint Landmark using Bell and Brand. This page will also illustrate how to create a generic pelvis technical coordinate system and hip landmarks.

3. **Hip Landmark from Custom Regression Equation**: Specifying the Hip Joint Landmark using a custom regression equation

Offsets relative to the Segment

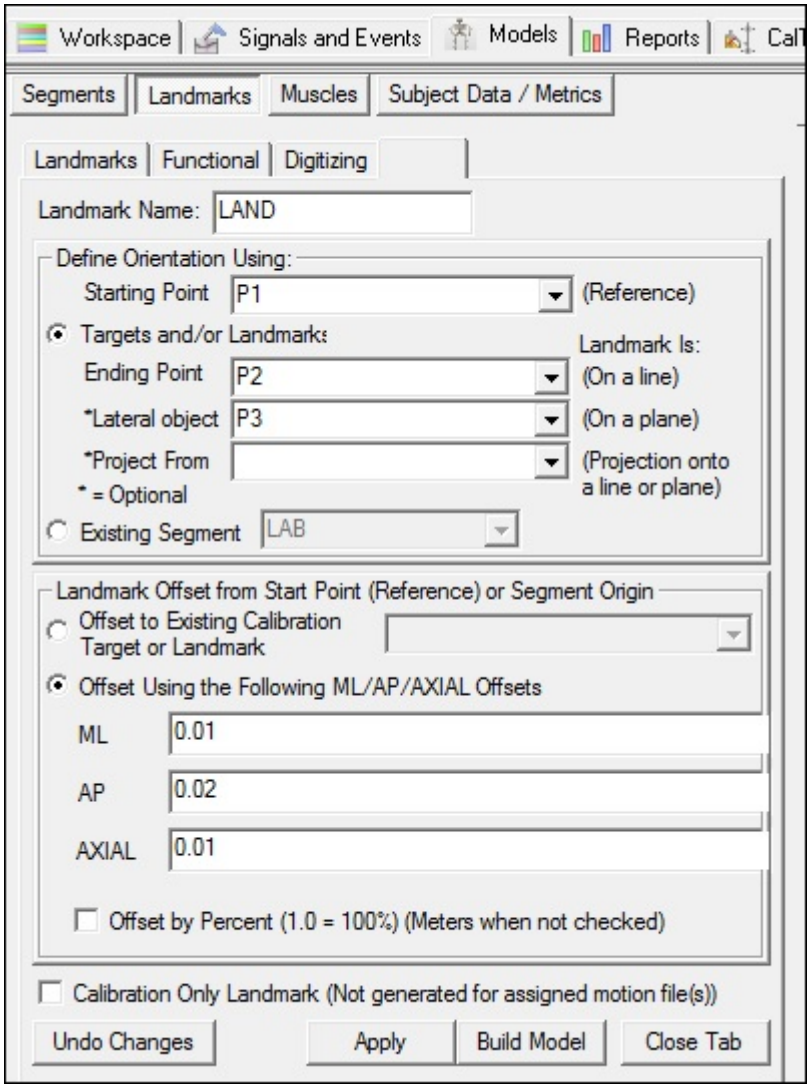
Landmarks can be created relative to a segment, which is to say within in the segment coordinate system. To define a landmark in a segment coordinate system in the **Landmarks** Mode:

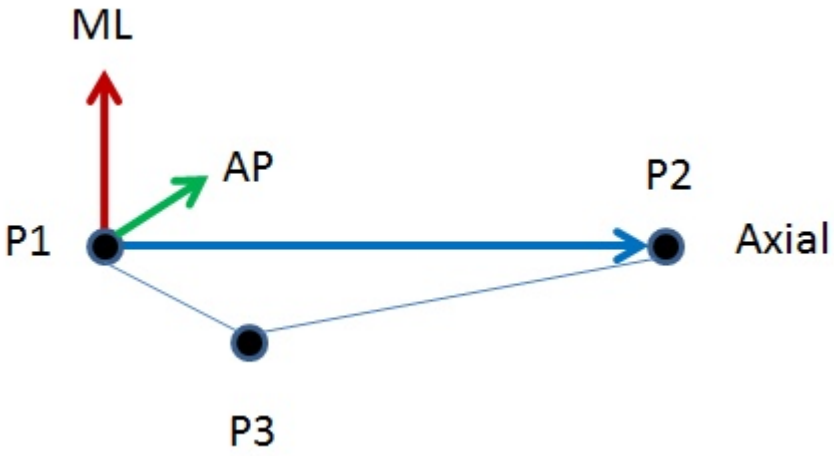
1. Select the **Existing Segment** radio button;
2. Select a segment in the existing segment combo box below the button. Segment landmarks are, by default, offset from the segment origin. If you would like to offset the landmark from a different location you must select a **Reference/Axial Starting Point** marker/landmark location;
3. The landmark offsets can be specified in any coordinate system that has been defined in the model. When defining a landmark relative to a segment, the 3 components of the offset are defined anatomically as ML, AP, and AXIAL boxes.

As a special example, if you would like to offset the landmark in lab space simply select the **LAB** segment in the existing segment combo box. When the landmark is relative to the **LAB** the offsets are the X, Y and Z directions of the lab.

Type 7: Relative to Three Points

Landmarks can be created relative to three locations, which can be handy when removing markers in the motion trials.





A right handed orthogonal coordinate system is defined by the three points (P1, P2, P3) with the origin of the coordinate system at the point P1. The **frontal plane** of the coordinate system is defined by the three points and the positive AP direction is into the screen.

Type 8: Digitized Landmarks

Digitized landmarks are defined using a digitized pointer and again result in a “virtual marker” being

computed by Visual3D relative to the positions of other, existing markers. The goal of digitized landmarks is to allow users to track anatomical landmarks without having to place markers on that location. See instructions for using a digitizing pointer to learn more.

Type 9: Functional Landmarks (Joints)

Functional landmarks indicate the locations of functional joints. Calculating functional joint positions requires movement of one segment relative to another segment. The chosen algorithm then searches for a point (or for a one degree of freedom joint, an axis) that is stationary relative to the 2 segments (or 2 sets of markers).

Visual3D's functional joint calculations have been adapted from two papers:

1. Schwartz MH, Rozumalski A (2005) A new method for estimating joint parameters from motion data. Journal of Biomechanics, 38, 107-116; and
2. Jensen E, Lugade V, Crenshaw J, Miller E, Kaufman K (2016) A principal component analysis approach to correcting the knee flexion axis during gait. Journal of Biomechanics, 49(9), 1698-1704

Creating a Landmark Using the Pipeline

If you want to create a landmark using a pipeline command and you already know how to create the landmark interactively in Model Builder Mode, you can save the model template to disk. Open the model template and search for the Landmark definition. You can then cut-and-paste the definition into a pipeline. The only difference will be that you must specify the Model that is to be used; e.g. the model template already defines which model is to be used to create the landmark.

Landmarks and Muscles

Muscles] are defined by linear segments connecting a series of landmarks. These landmarks represent insertion points and are tracked relative to the trial's markers. Any of the rules for creating landmarks in Visual3D described above can be used to describe these landmarks.

Landmark Examples

Create a Landmark mimicking contralateral segment

It was not possible to place anatomical landmarks on the medial and lateral ankle of the subject because the subject was missing one lower limb. It was possible to place markers on the foot prosthesis consistent with the existing foot. Assuming symmetry in the two foot segments the user wanted to create landmarks representing the location of the medial and lateral ankle of the missing shank relative to the foot coordinate system consistent with the location of the medial and lateral

ankle in the existing segment.

Create Landmarks from a Knee Alignment Device

The Knee Alignment Device (KAD) is manufactured by Motion Lab Systems. The KAD is used to assist in defining the frontal plane of the thigh segment. This page describes the KAD and shows how it is implemented to create the frontal plane and landmarks in Visual3D.

Create a Landmark using two standing trials

Landmarks can be created from two static standing trials.

Replacing missing markers

We collected 2 sets of studies for the same person, and we collected one static trial of the lower extremity for each set of the study. We forgot to add the GT markers for the first static trial. Based on what we have right now (a complete 2nd static trial and the 1st static trial with GT markers missing), is it possible for us to create a virtual GT marker for the first static trial? The answer is yes, landmarks can be created to calculate missing tracking markers.

Consider the following right thigh segment constructed using static markers RPPT, RAPT, RPDT, RADT. These tracking markers are saved to a model template, but for the next subject the static trial is missing the RAPT marker. A landmark can be created to replace the missing tracking marker.

Create Landmarks from a Motion Trial

Landmarks can be created from the motion trials.

Using Motion Trial Example 1

This example creates landmarks from Targets in a movement trial but not in the standing trial. In this example, a movement trial contains 4 markers that have been placed on the corners of an object. The standing trial does not contain these markers, but needs the corner locations for defining an object (segment).

Using Motion Trial Example2

A structure (i.e. stairs) can be defined by placing markers at vertices, then connecting these vertices. It isn't always practical, however, to place these markers during the standing trial, so it would be useful to have a separate motion trial that contained only these markers. In this example, we demonstrate how to get the marker locations from a movement trial and create landmarks. In the movement trial for this example, markers are placed on the steps of a set of stairs.