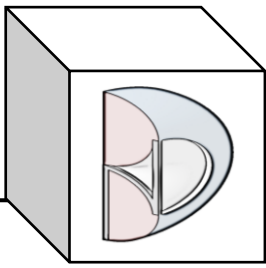


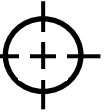
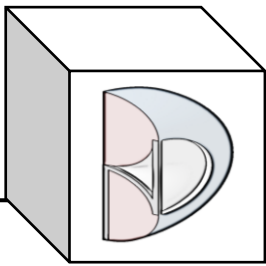
BND TechSource

The background of the slide is a blue-tinted image of a manikin (a 3D model of a human figure) riding a bicycle. The manikin is in a dynamic pose, leaning forward. The bicycle is a standard road bike. The background shows a blurred city street with buildings and trees.

Ergonomic Manikin Manipulation using CATIA V5 DMU Kinematics (Steps 5 - 11 the optimized solution)

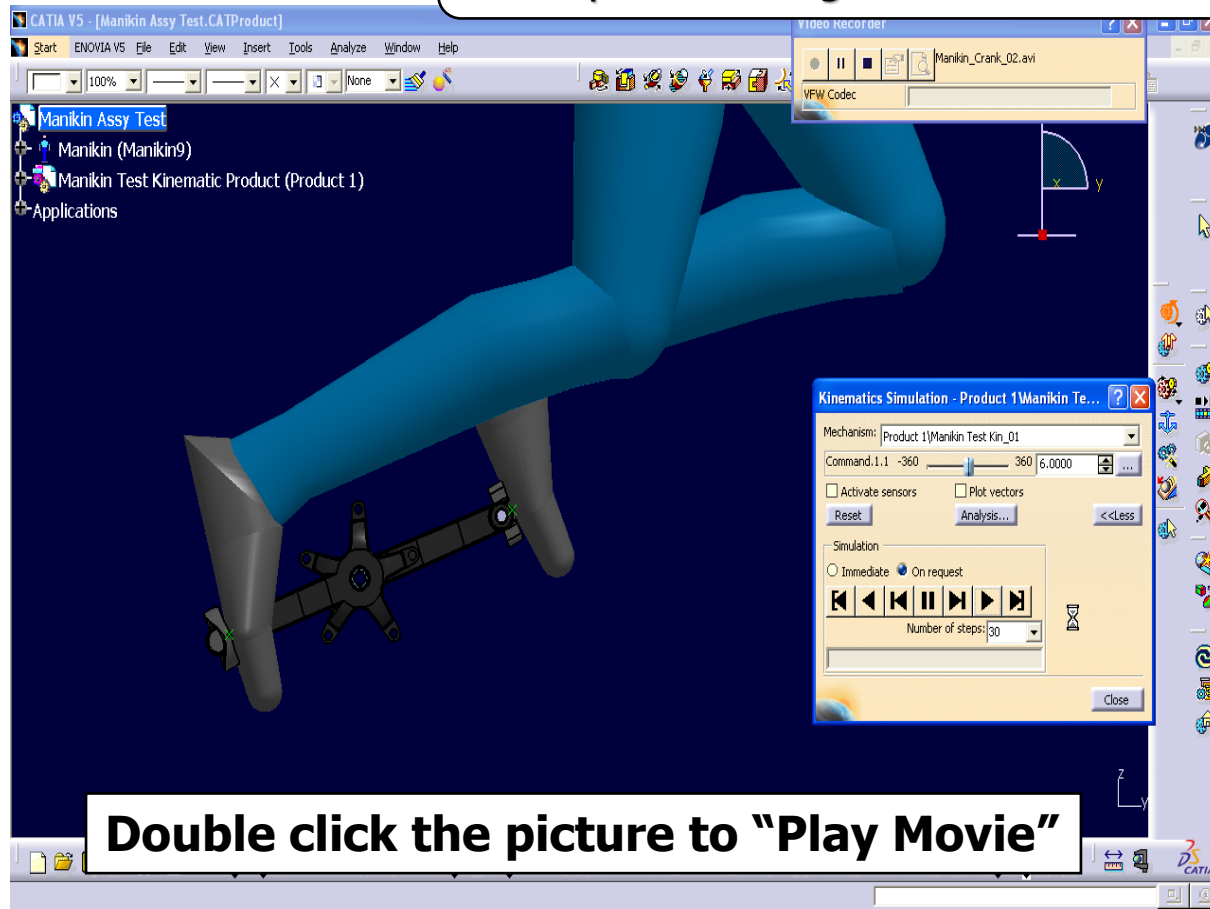


- In the previous example, we showed a simple solution to manipulate an Ergonomic Manikin using CATIA DMU Kinematics.
- In that example the angle of the feet do not follow the angle of the pedals.
- In this example we will optimize the pedals to maintain contact with the feet.



- Previous example:

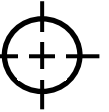
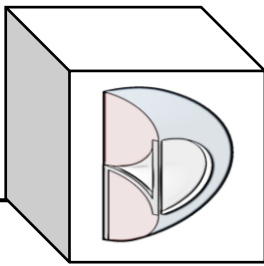
The angle of the feet do not follow the angle of the pedals during rotation.



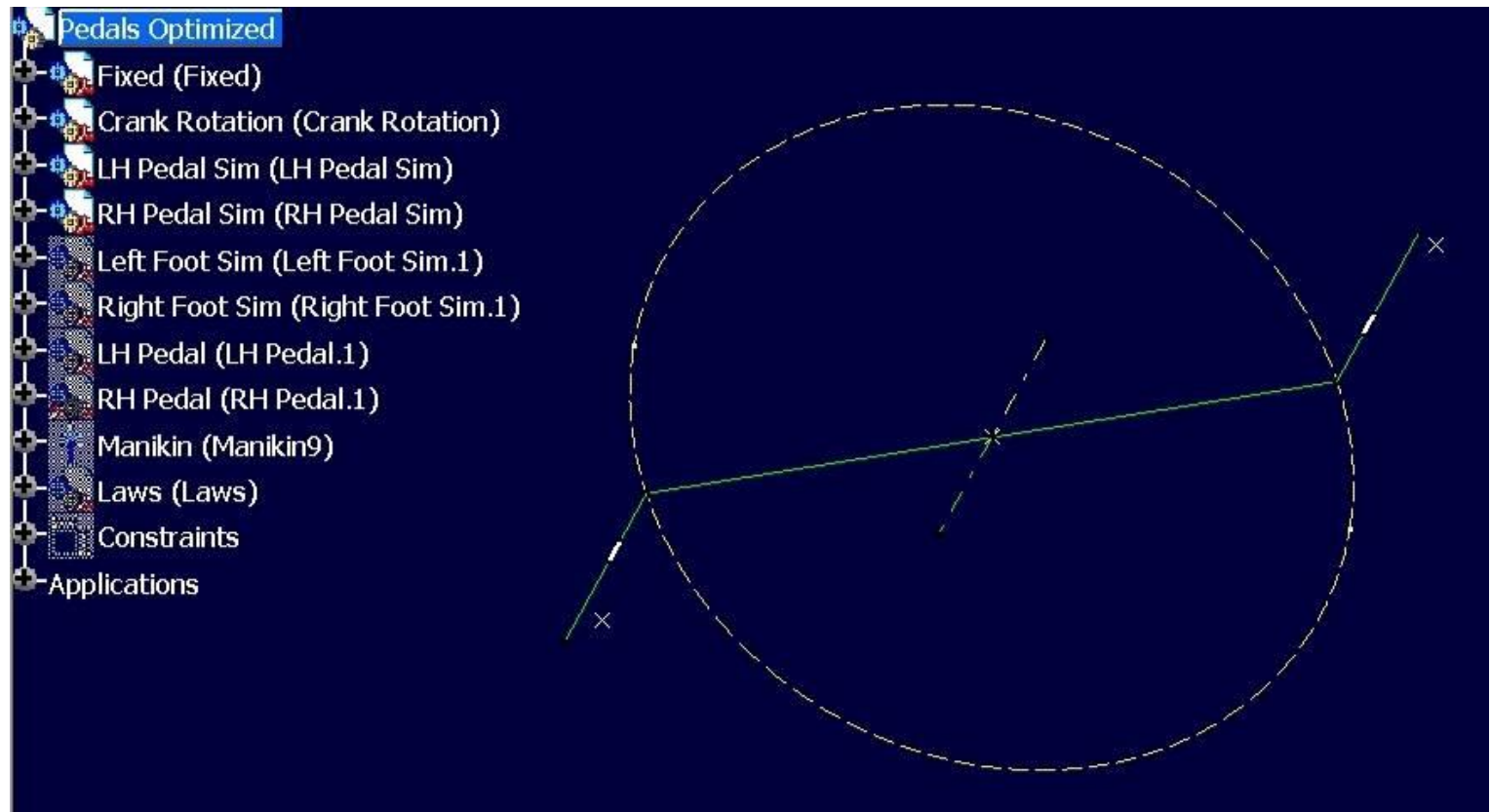
Double click the picture to "Play Movie"

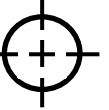
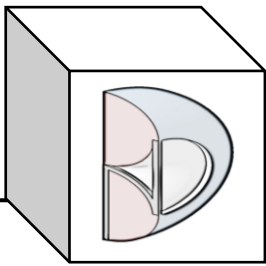


- The rotation angle of the pedals is set to a 1:1 ratio of the crank rotation within the kinematic set.
- While the Manikin may be “attached” to the pedals, it is *driven* by the kinematic set and therefore not editable inside the Kinematic function.
- The main problem to solve in this example is to get the pedals to follow the feet.

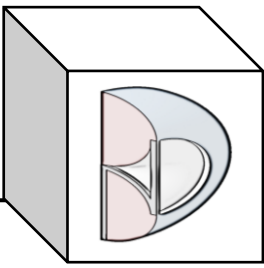


- Step 5: Create a Product for a “stick figure” kinematic mechanism.

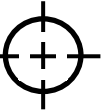




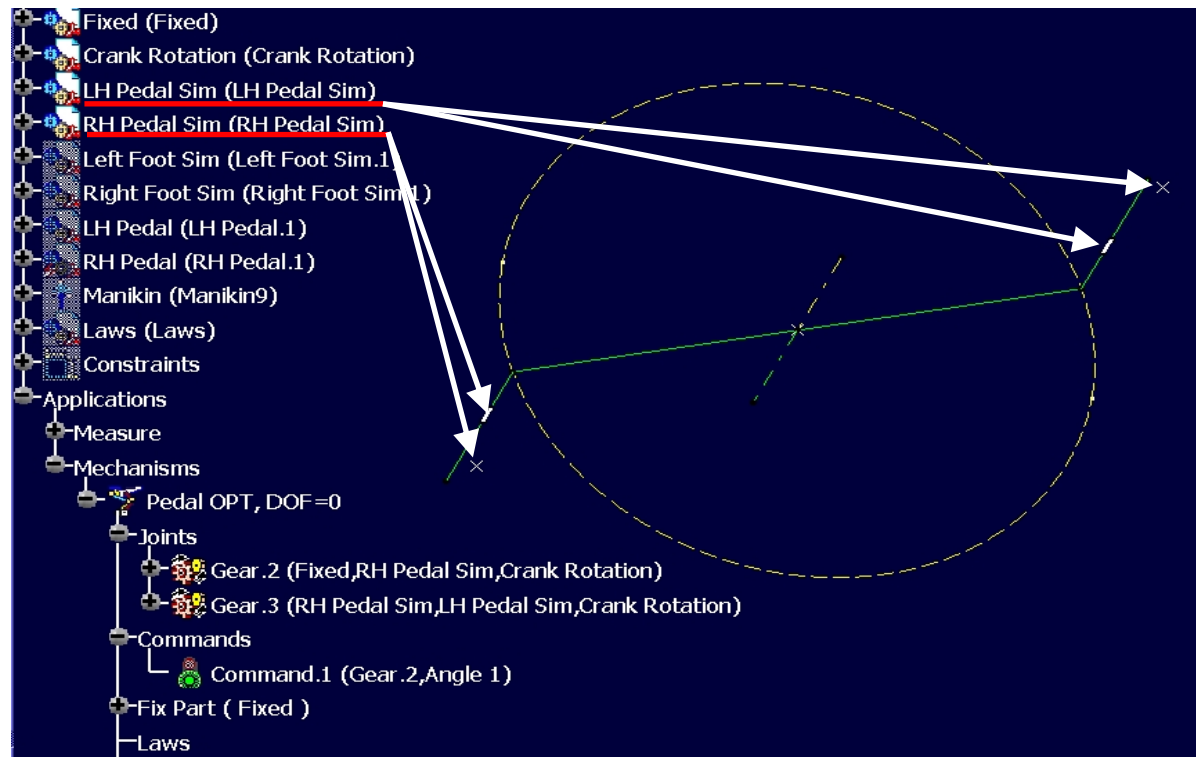
- There will be four Parts to build the kinematic mechanism:
 - Fixed
 - Crank Rotation
 - LH Pedal Simulator
 - RH Pedal Simulator



- Other Parts within the Product will be:
 - Manikin (Ergonomic Design & Analysis)
 - Left Foot Simulator
 - Right Foot Simulator
 - LH Pedal (3D Part)
 - RH Pedal (3D Part)
 - Laws

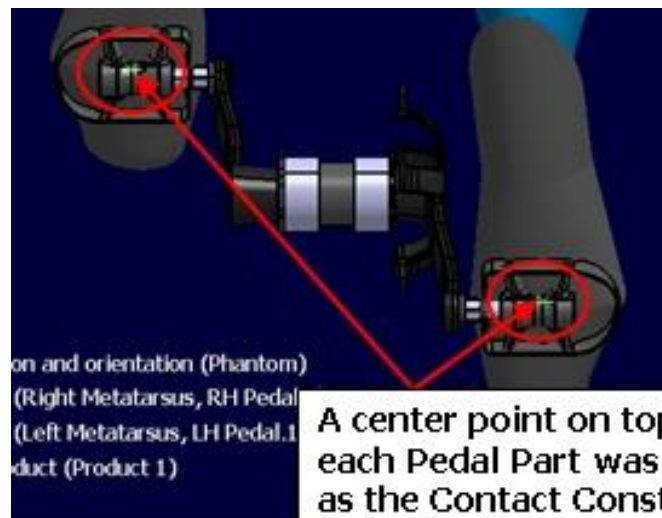


- The kinematic mechanism will start with the Fixed Part and two Gear Joints between the Fixed, Crank Rotation, and Pedal Sim Parts.

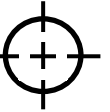




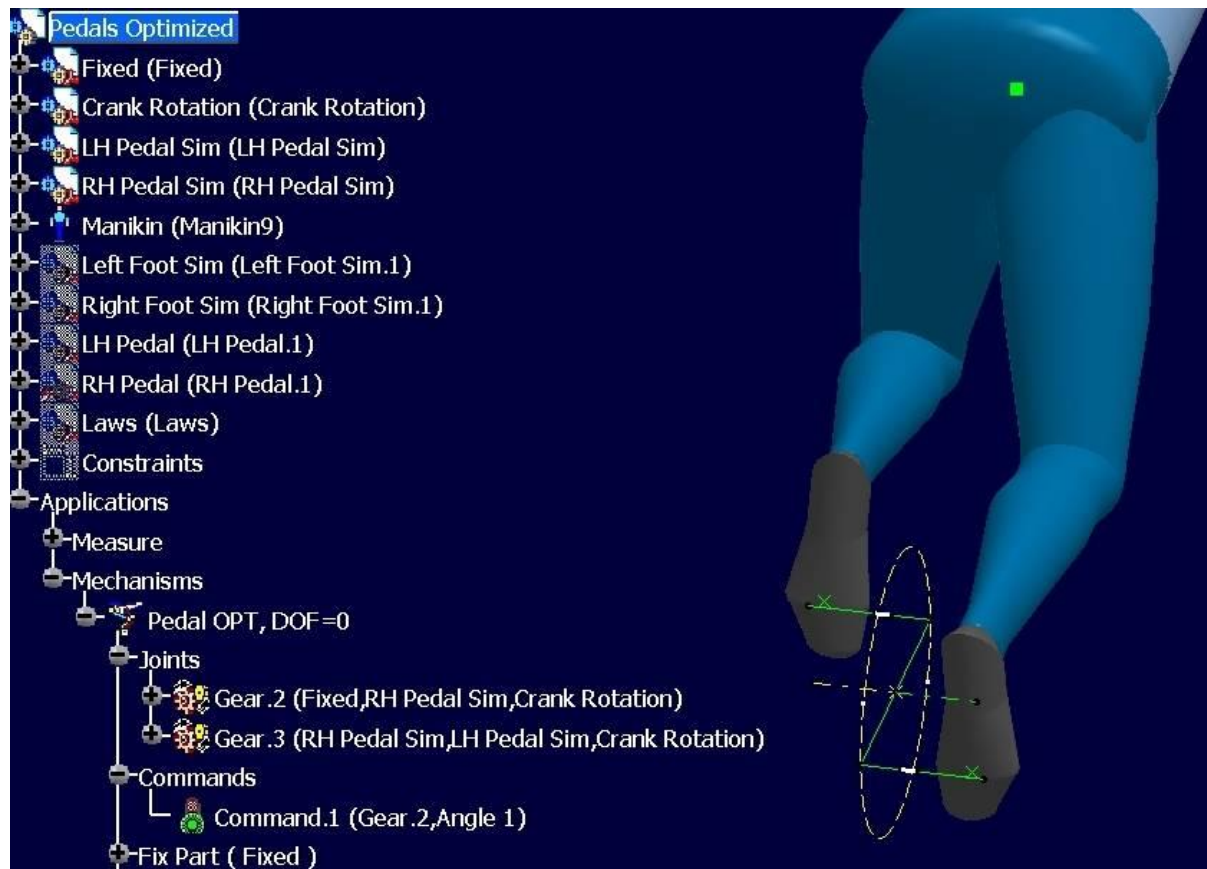
- The LH & RH Pedal Sim Parts consist of a centerline for the pedal pivot and a point.
- They will be used to “attach” the Manikin to the kinematic mechanism as in the previous example.

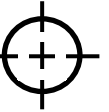


A center point on top of each Pedal Part was used as the Contact Constraint to the foot.

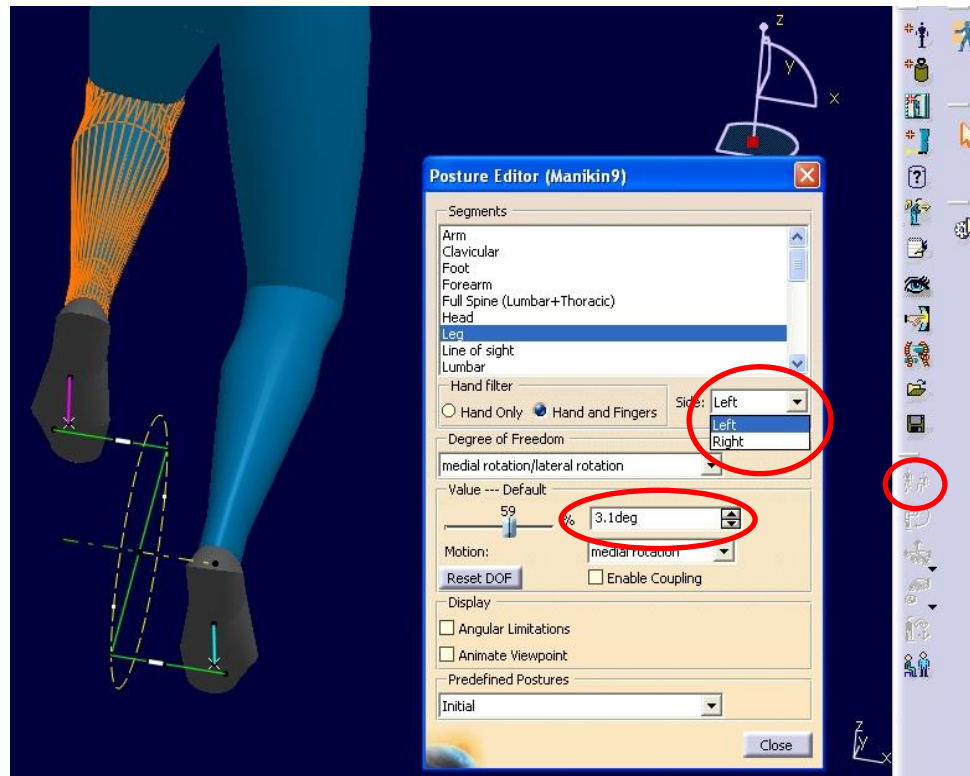


- Step 6: Load the Manikin from the previous example.



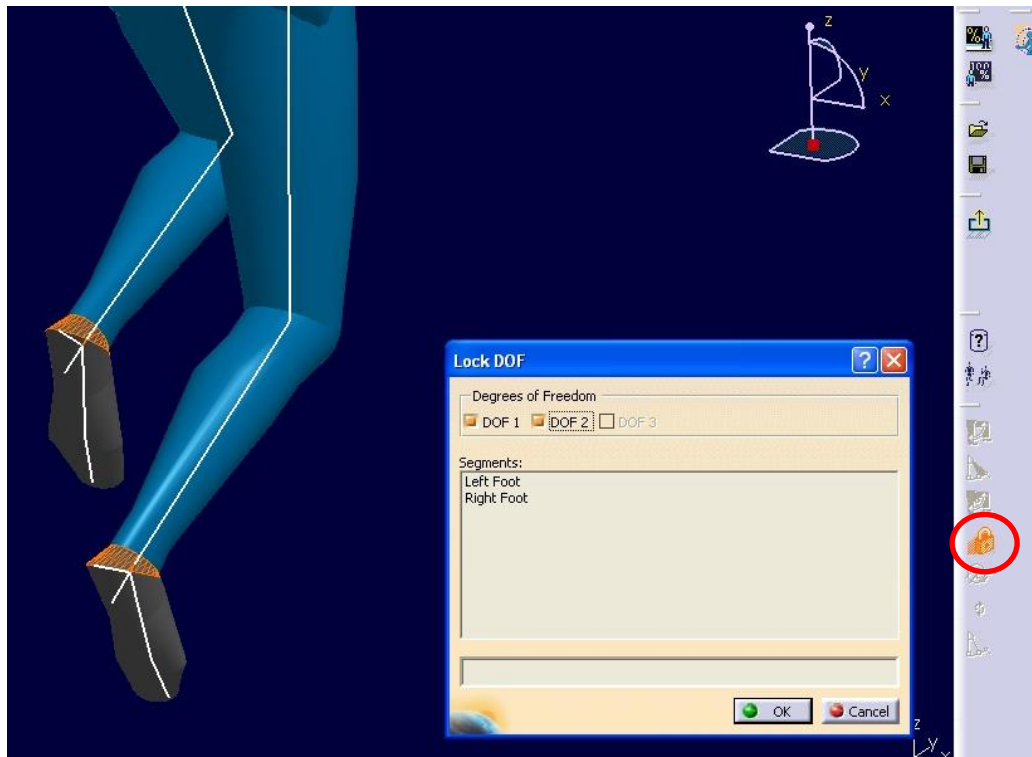


- Ensure the DOF values for the Feet, Legs, & Thighs are correct and symmetric before locking the DOF.



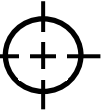
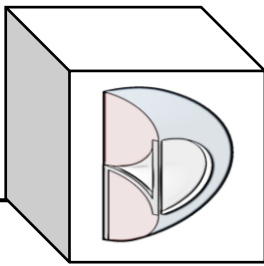


- Open Human Posture Analysis. Lock the Feet DOF 1 & 2, Leg DOF 3, & Thigh DOF 2.



**You MUST LOCK
the DOF each
time you read
the Product!**

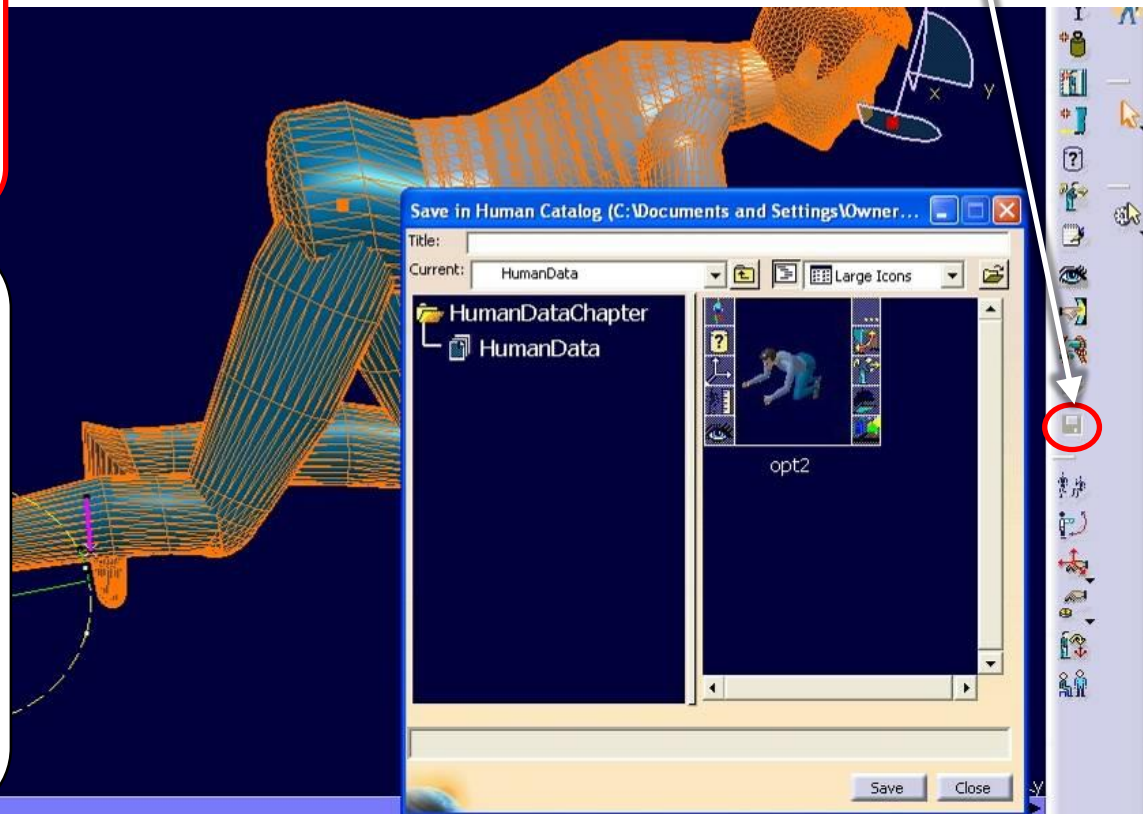
**If you run the
kinematic set
without doing
this, you may
experience
unwanted
results!**

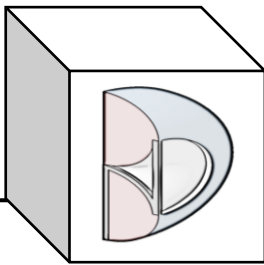


- A helpful tip at this point would be to Save a Manikin Profile in the desired position.

You MUST LOCK the DOF each time you read the Product!

If you save a Manikin profile after locking the DOFs, when that profile is loaded correctly, it maintains these locked DOFs





■ More on Locked DOFs...

After applying the manikin profile check the Properties of the Angular Limitations.

Angular Limitations

Body elements	DOFs	Lower limit	Upper limit	Manikin
Right Thigh	flexion/extension	None	None	Manikin1
Right Thigh	medial rotation/lat...	None	None	Manikin1
Right Leg	flexion/extension	None	None	Manikin1
Right Foot	dorsiflexion/plant...	49.0	71.5	Manikin1
Right ForeArm	flexion/extension	50.0	27.8	Manikin1
Left Thigh	flexion/extension	None	None	Manikin1
Left Thigh	medial rotation/lat...	None	None	Manikin1
Left Leg	flexion/extension	None	None	Manikin1
Left Foot	dorsiflexion/plant...	49.0	71.5	Manikin1
Left ForeArm	flexion/extension	50.0	27.8	Manikin1

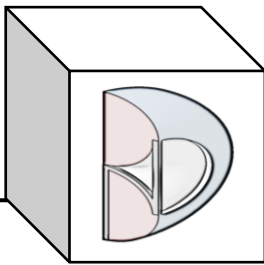
No DOFs locked.

Load 'Manikin_93%_Locked_DOFs' From Human Catalog (m...)

Current: HumanData

Manikin_93%...DOFs

OK Apply Close



■ More on Locked DOFs...

Angular Limitations must be chosen alone to apply the locked DOFs. Check the Properties to verify.

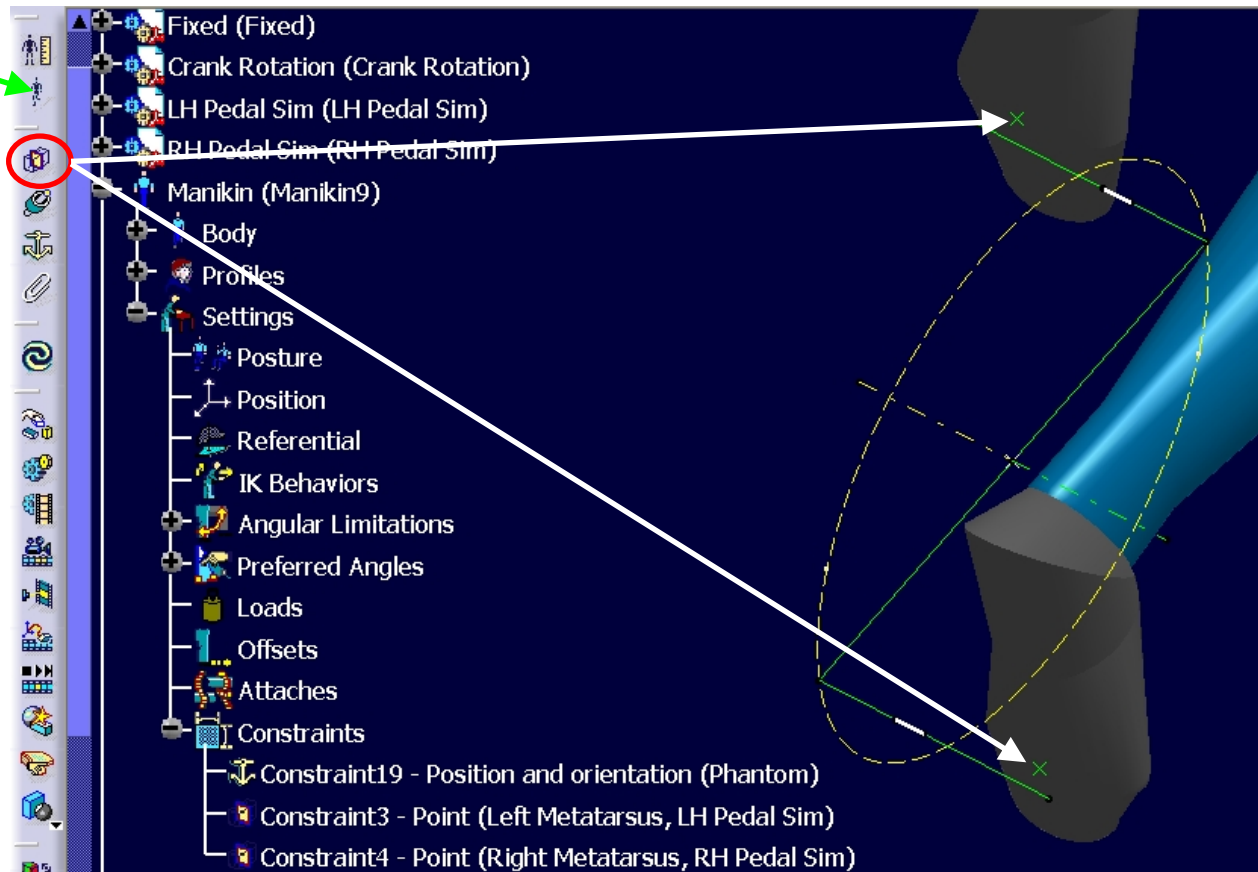
DOFs locked.

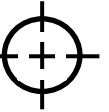
Body elements	DOFs	Lower limit	Upper limit	Manikin
Right Thigh	flexion/extension	None	None	Manikin1
Right Thigh	abduction/adduction	5.0 deg	Lock	Manikin1
Right Thigh	medial rotation/lat.	None	None	Manikin1
Right Leg	flexion/extension	None	None	Manikin1
Right Leg	medial rotation/lat.	3.1 deg	Lock	Manikin1
Right Foot	dorsiflexion/plant.	3.3 deg	Lock	Manikin1
Right Foot	eversion/inversion	0.2 deg	Lock	Manikin1
Right ForeArm	flexion/extension	50.0	27.8	Manikin1
Left Thigh	flexion/extension	None	None	Manikin1
Left Thigh	abduction/adduction	5.0 deg	Lock	Manikin1



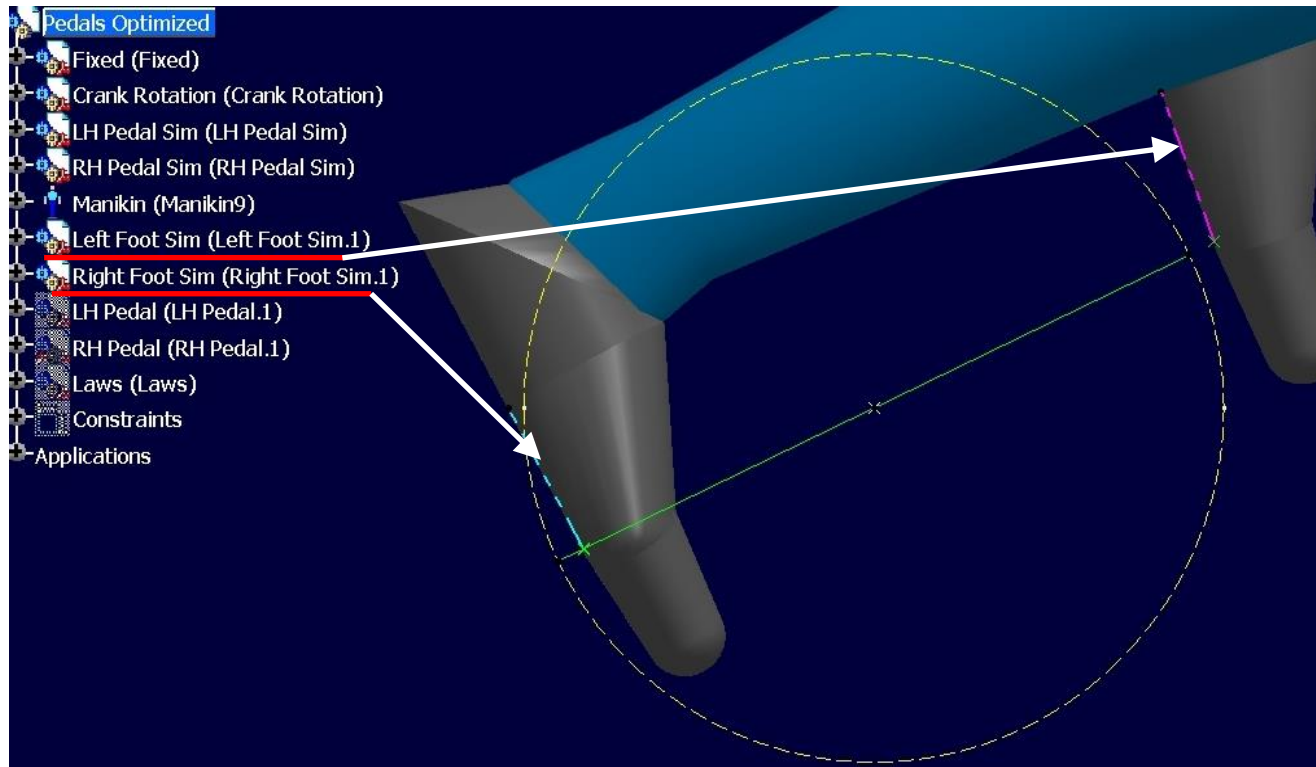
- Constrain the feet to the points in each Pedal Simulator Part (use Contact Constraint).

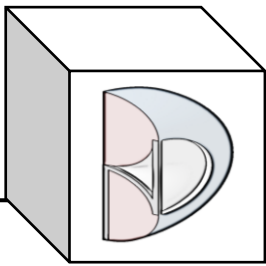
Human
Posture
Analysis



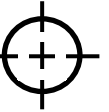


- Step 7: Create a line inside each Foot Simulator Part. This will be used later to measure the foot angle relative to the pedal.

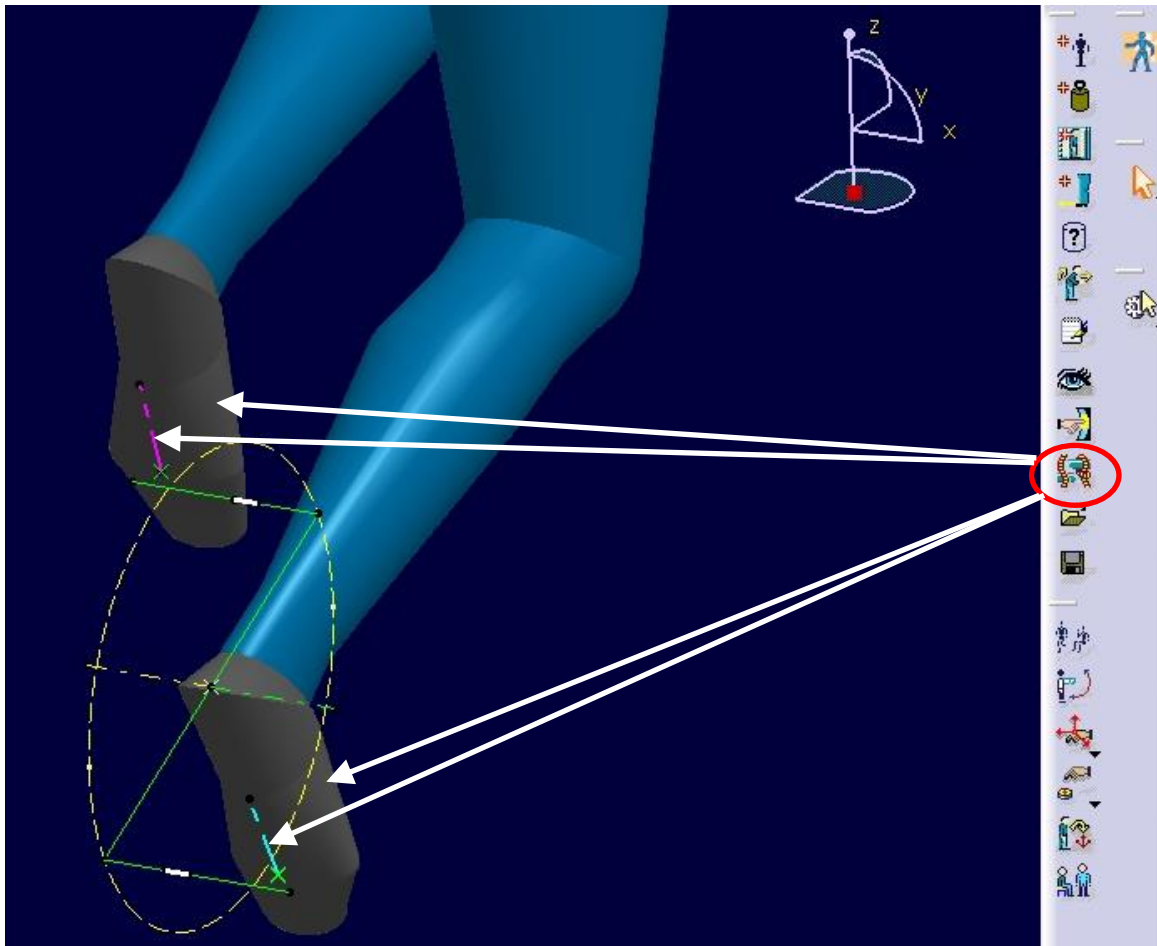


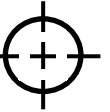
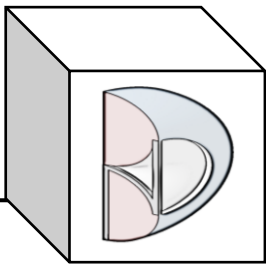


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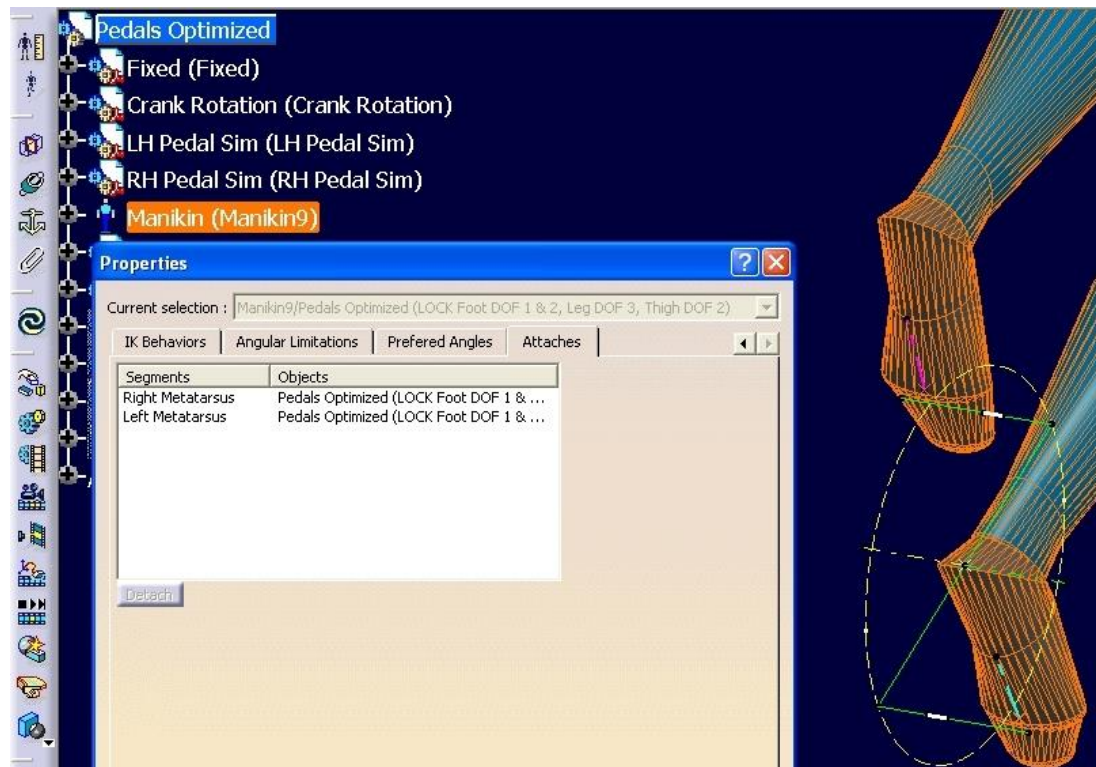


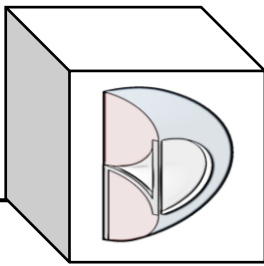
- Attach the Feet Simulator Parts to each foot.



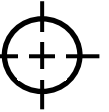


- Attaches to the Manikin can be verified by right-clicking the Part name from the tree, and open Properties.

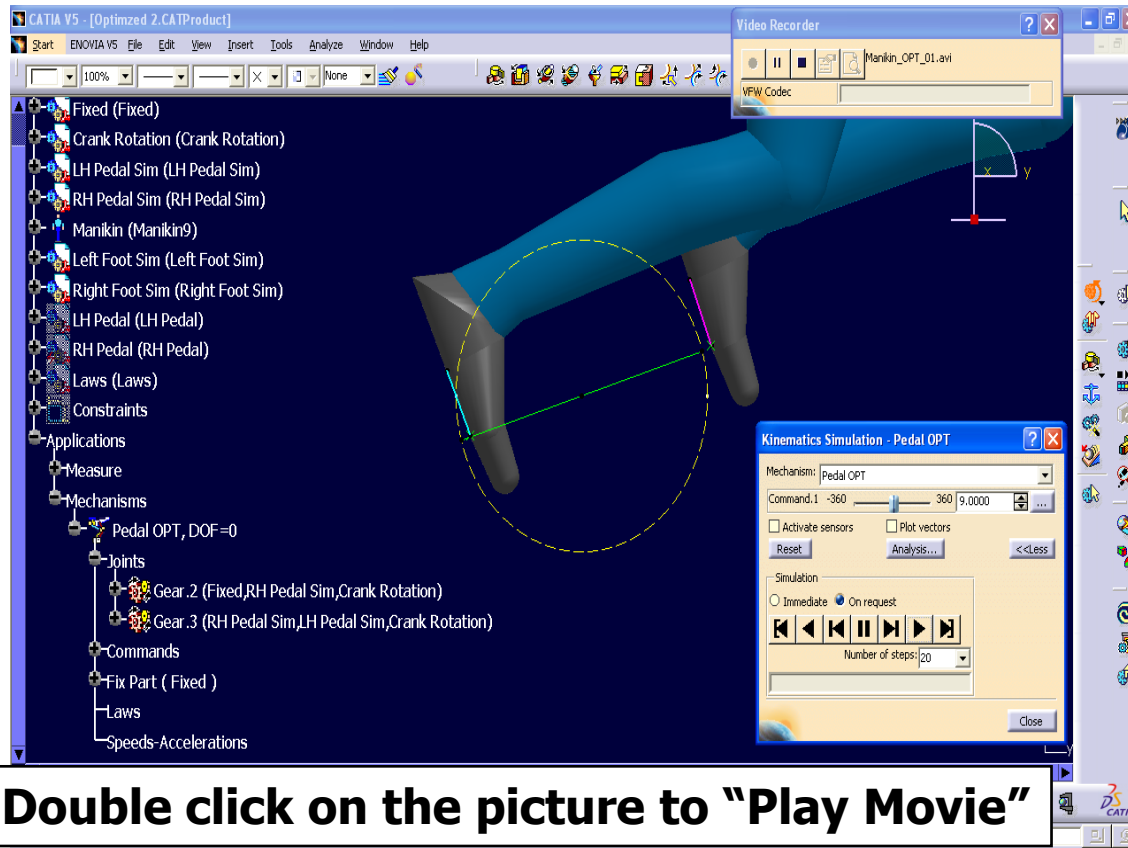




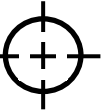
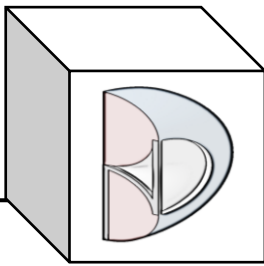
BND TechSource



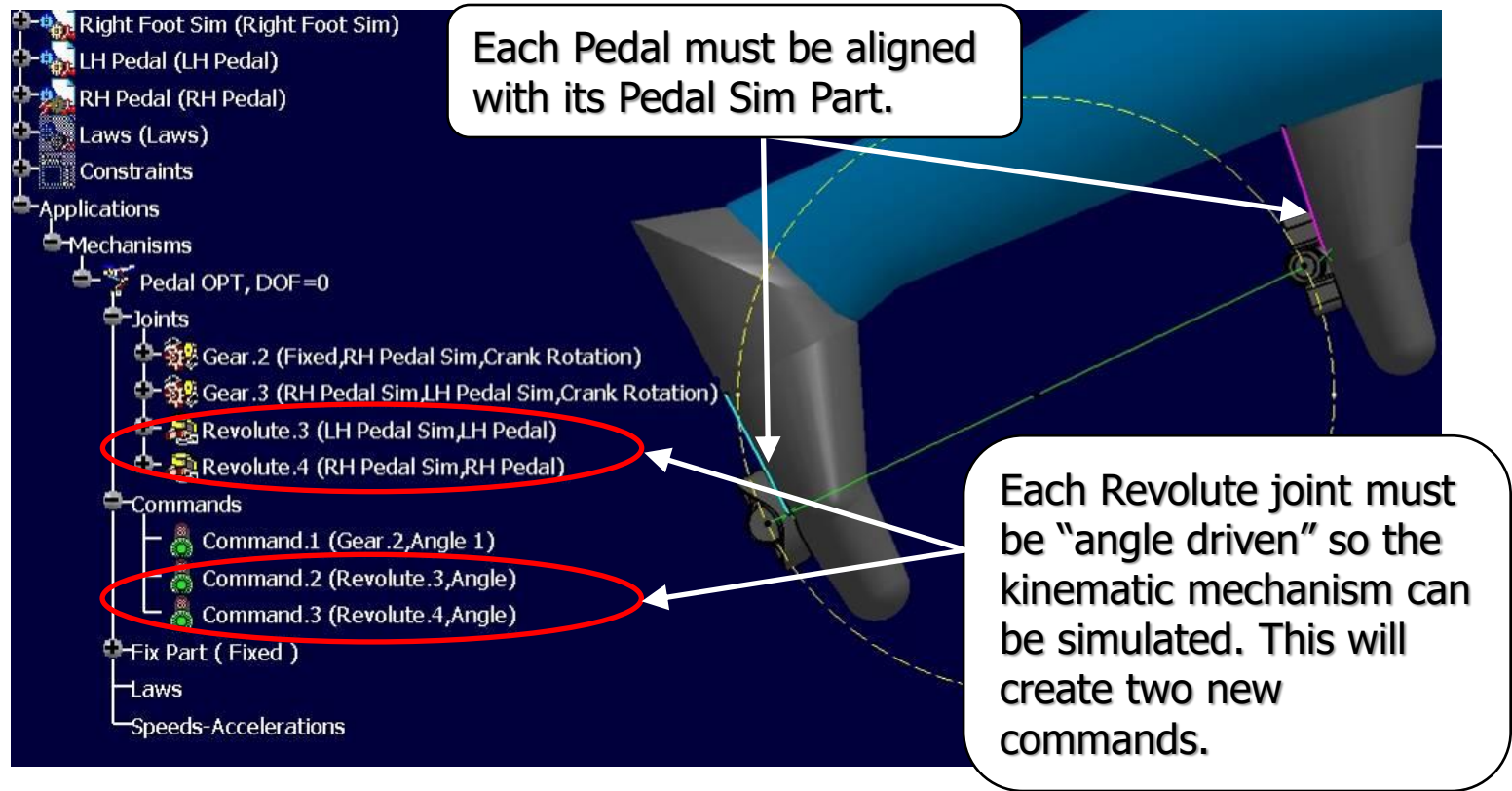
- Run a test using DMU Kinematics.



Double click on the picture to "Play Movie"

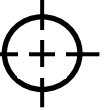


- Step 8: Load in the 3D Pedals. Create two Revolute joints between each Pedal and Pedal Simulator Parts.



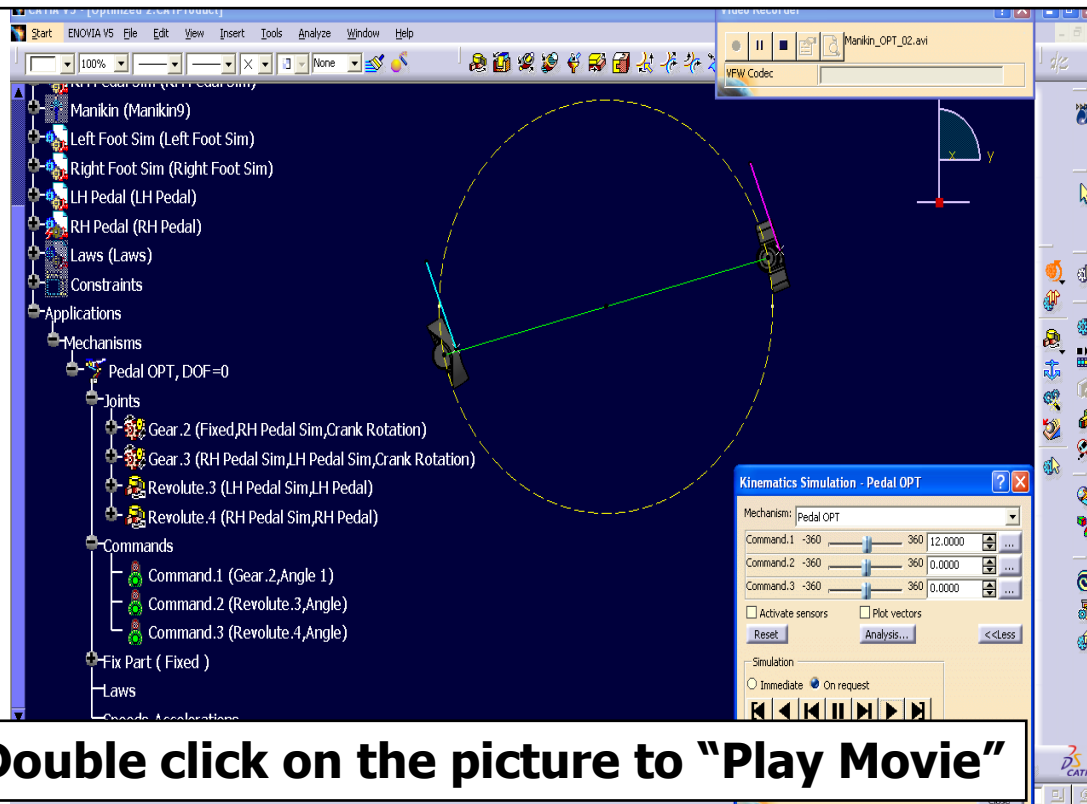


BND TechSource

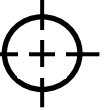


- Run a test using DMU Kinematics.

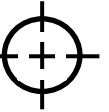
Run the simulation with a value only for Command 1. Notice the angular deviation between the Pedal and Pedal Sim Parts.



Double click on the picture to "Play Movie"



- The Pedal Sim Parts are “attached” to the Manikin.
- The Manikin is constrained to the kinematic mechanism.
- This means the angular deviation due to the kinematic simulation occurs outside the kinematic mechanism.
- To correct this, we must measure the angular deviation and apply the measurement back into the kinematic mechanism.



- Step 9: Measure the angular deviation.

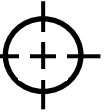
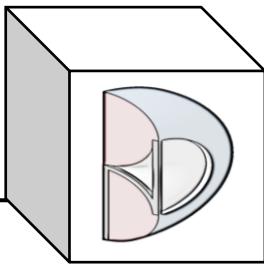
Rotate the 3D Pedals rearward 30 deg. to open an angular gap which can always be measured as positive.

Parameters for Compass Manipulation

Coordinates	
Reference	Absolute
Along X	-106.00mm
Along Y	-42.18mm
Along Z	75.61mm

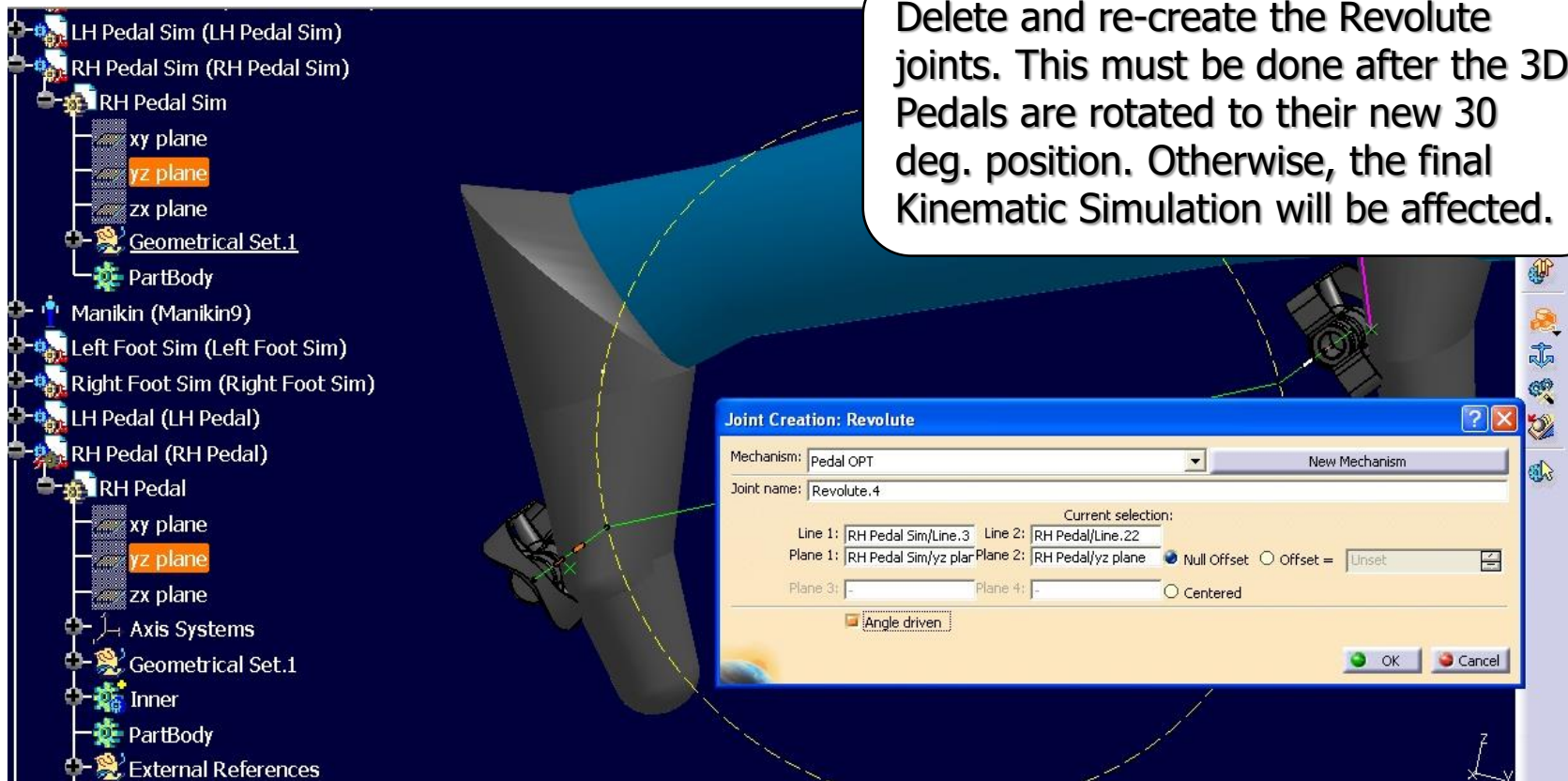
Increments	
Translation increment	Rotation increment
Along U	0.00mm
Along V	0.00mm
Along W	0.00mm

Measures	
Distance	Angle
0.00mm	0.0deg



- Out with the old...In with the new.

Delete and re-create the Revolute joints. This must be done after the 3D Pedals are rotated to their new 30 deg. position. Otherwise, the final Kinematic Simulation will be affected.





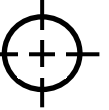
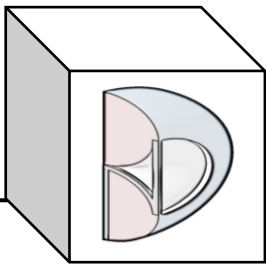
- Ensure the Pedal rotation direction is correct.

The screenshot displays a software interface with a tree view on the left and a 3D model on the right. The tree view includes the following items:

- Constraints
- Applications
- Measure
- Mechanisms
 - Pedal OPT, DOF=0
 - Joints
 - Gear.2 (Fixed,RH Pedal Sim,Crank Rotation)
 - Gear.3 (RH Pedal Sim,LH Pedal Sim,Crank Rotation)
 - Revolute.3 (RH Pedal Sim,RH Pedal)
 - Revolute.4 (RH Pedal Sim,LH Pedal)
 - Commands
 - Command.1 (Gear.2,Angle 1)
 - Command.2 (Revolute.3,Angle)
 - Command.3 (Revolute.4,Angle)

A callout box points to the 'Revolute.3' joint in the tree, stating: "Double-click Command.2".

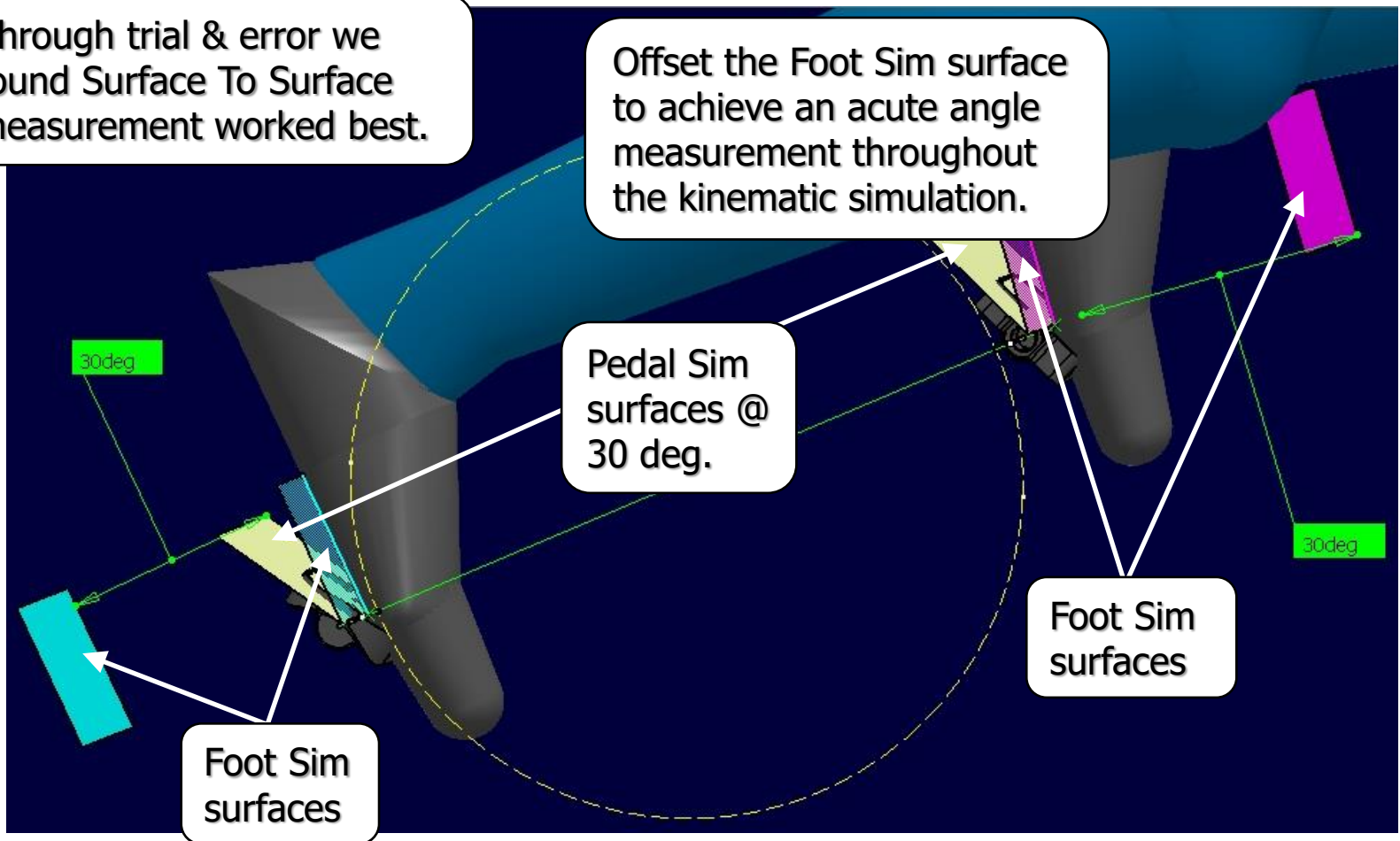
Another callout box points to a blue arrow in the 3D model, stating: "Picking the arrow will reverse the rotation direction".

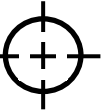
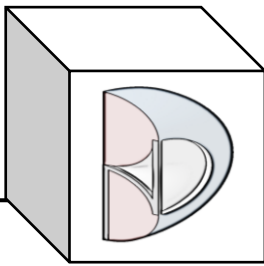


- Create Surfaces to measure between.

Through trial & error we found Surface To Surface measurement worked best.

Offset the Foot Sim surface to achieve an acute angle measurement throughout the kinematic simulation.





- Prepare the test using DMU Kinematics.

The screenshot displays the SolidWorks DMU Kinematics environment. On the left, the Feature Tree shows the model structure with 'LH Pedal (LH Pedal)', 'RH Pedal (RH Pedal)', 'Laws (Laws)', 'Constraints', 'Applications', 'Measure', 'LH Measure', 'RH Measure', and 'Mechanisms'. The main area shows a 3D model of a pedal mechanism with a green dashed arc indicating a 30-degree angle.

Two callout boxes provide instructions:

- Pick Yes on the LH & RH Angular Measures.** This points to the 'Sensors' window, where the row 'Pedals Optimized(LH Measure)Angle' is circled in red, and the 'Observed' column is set to 'Yes'.
- Click Activate sensors.** This points to the 'Kinematics Simulation - Pedal OPT' window, where the 'Activate sensors' checkbox is circled in red.

Sensors Window:

Sensor	Unit	Observed
Pedal OPT(Joints(Gear.2)Angle 2	Degree	No
Pedal OPT(Joints(Gear.3)Angle 1	Degree	No
Pedal OPT(Joints(Gear.3)Angle 2	Degree	No
Pedal OPT(Joints(Revolute.3)Angle	Degree	No
Pedal OPT(Joints(Revolute.4)Angle	Degree	No
'Pedals Optimized(LH Measure)Length'	Millimeter	No
'Pedals Optimized(LH Measure)Max Distance'	Millimeter	No
'Pedals Optimized(LH Measure)Angle'	Degree	Yes
'Pedals Optimized(LH Measure)Pt1x'	Millimeter	No
'Pedals Optimized(LH Measure)Pt1y'	Millimeter	No
'Pedals Optimized(LH Measure)Pt1z'	Millimeter	No

Kinematics Simulation - Pedal OPT Window:

Mechanism: Pedal OPT

Command.1: -360 to 360, 0.0000

Command.2: -360 to 360, 30.0000

Command.3: -360 to 360, 30.0000

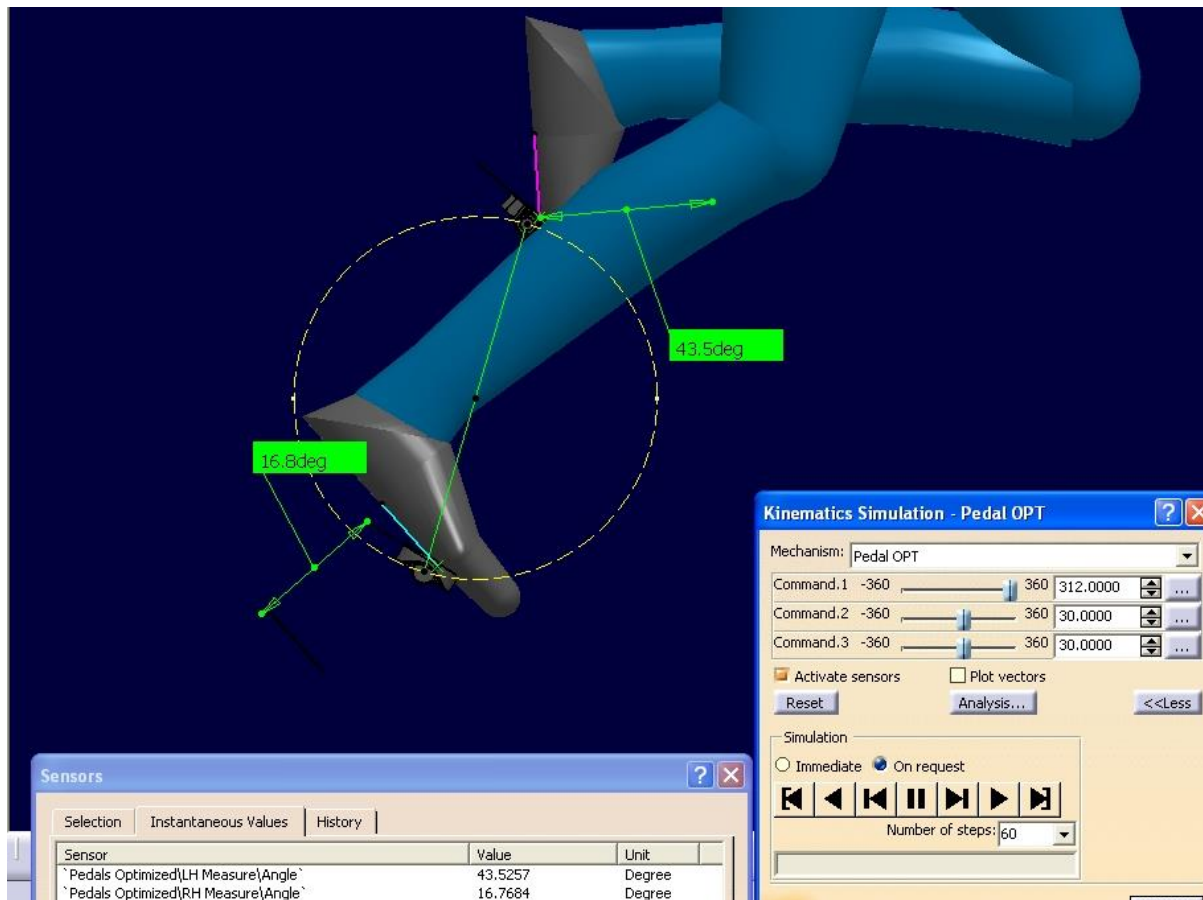
☒ Activate sensors ☐ Plot vectors

Simulation: ☐ Immediate ☒ On request

Number of steps: 60

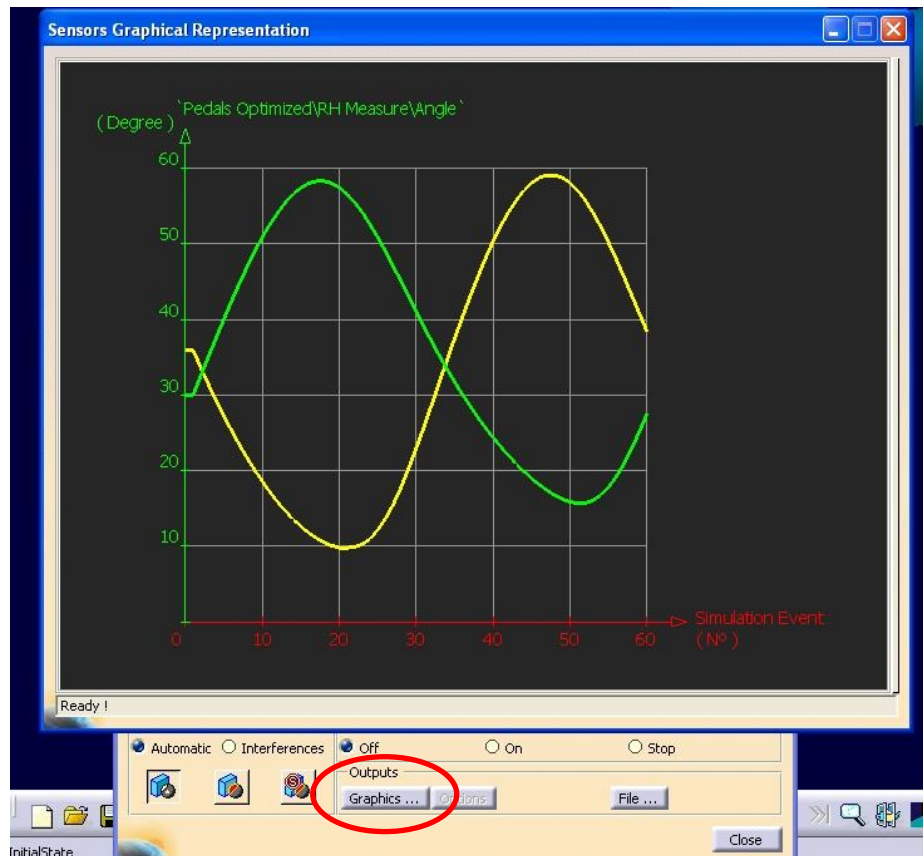


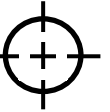
- Run a test using DMU Kinematics.





- The graphic results show measurement output as acute angles.





- Step 10: Set up Functions for the Commands.

The screenshot displays the BND TechSource software interface. On the left, the 'Laws' tree view is visible, showing a hierarchy of components: Laws (Laws), Constraints, Applications, Measure (LH Measure, RH Measure), Mechanisms (Pedal OPT, DOF=0), Joints (Gear .2 (Fixed,RH Pedal Sim,Crank Rotation), Gear .3 (RH Pedal Sim,LH Pedal Sim,Crank Rotation), Revolute .3 (LH Pedal Sim,LH Pedal)), Command.1 (Gear .2,Angle 1), Command.2 (Revolute .3,Angle), Command.3 (Revolute .4,Angle), Fix Part (Fixed), and Laws. The 'Command.3 (Revolute .4,Angle)' is highlighted with a red circle. A callout box points to it with the text 'Select the Command.' Another callout box points to the 'Function' icon in the bottom toolbar with the text 'Select the Function icon.' The 'Formulas: Command.3' dialog box is open on the right, showing a table with one row: 'Pedal OPT\Commands\Command.3\Angle' with a value of '30.0deg'. The 'Add Formula' button is highlighted with a red circle and a callout box with the text 'Select Add Formula.' The bottom toolbar contains various icons, including a 'Function' icon (a circle with 'f') which is circled in red.

Select the Command.

Select the Function icon.

Select Add Formula.

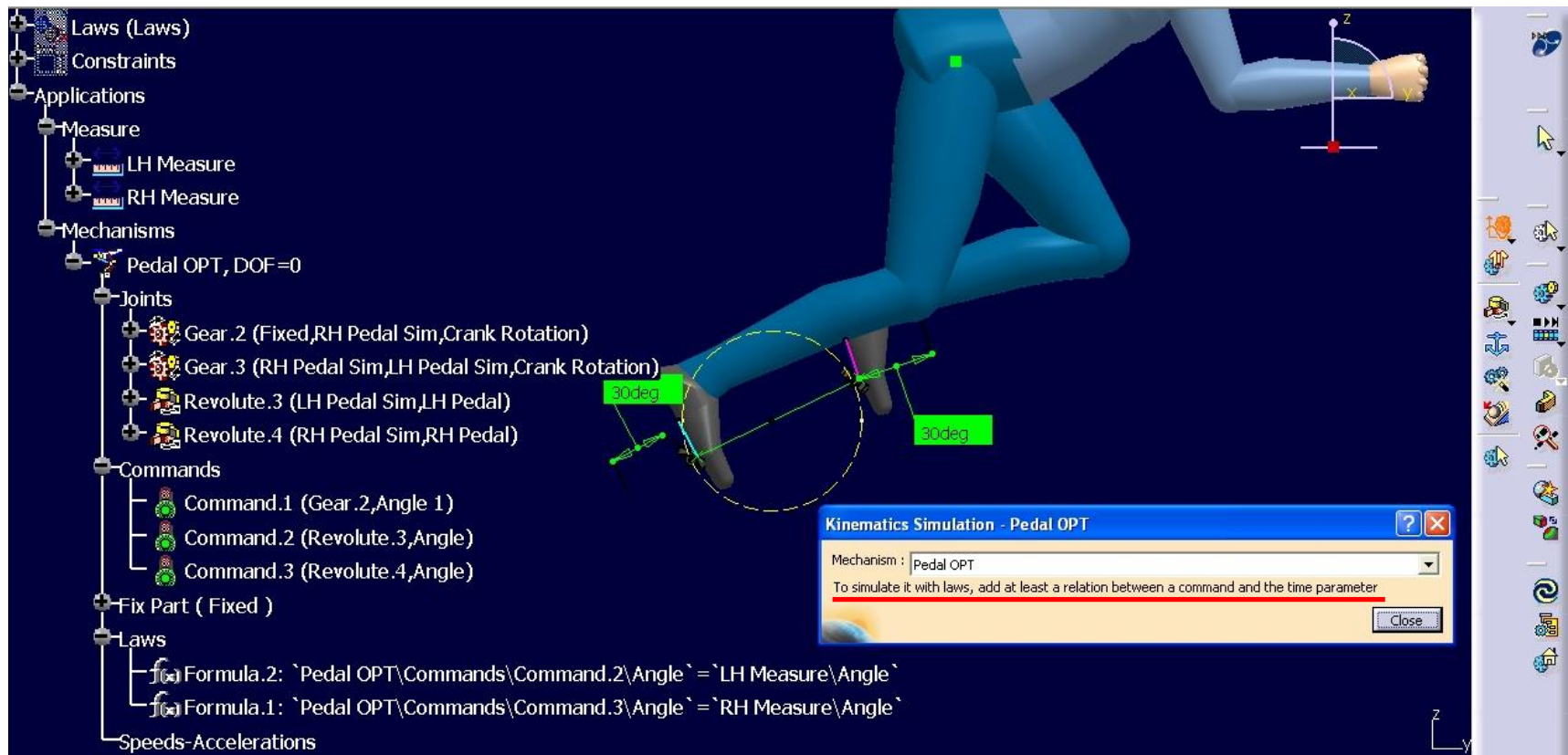
- Setting up the Functions (RH shown, repeat for LH).

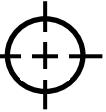
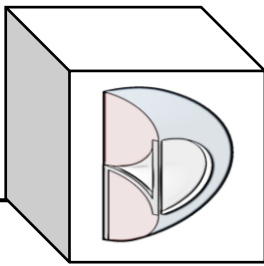
Select Angle from Parameters list.

Double-click RH Measure\Angle from Members of Angle list.



- To run a kinematic simulation with Laws, there must be a Law created relative to time.





■ Create a Time Law.

Kinematic Laws must be Curves. Therefore, to get a linear time relationship to rotation, Connects with Point Continuity are used.

This Law will allow rotation to 360 deg. Then return back 360 deg.

Connect Curve Definition

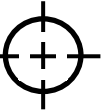
First Curve	Second Curve
Point: Point.2	Point: Point.4
Curve: Line.2	Curve: Line.3
Continuity: Point	Continuity: Point
Tension: 1	Tension: 1

Reverse Direction (button)

OK Cancel



BND TechSource



- Apply the time Law to Command.1

Double-click Command.1

Select Law Sketch

Select Link

Sketch Selection for Command.1

Select the sketch you want to link the command
Sketch name: Pedals Optimized/Laws/Laws/Geometrical Set.1/Sketch.1
Maximum time value: 100

Command Edition: Command.1 (Angle 1)

Command name: Command.1
Command value: 0.0deg

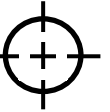
Reset to Zero

Law Management

Import... Display... Edit **Link...** Unlink...

OK Cancel

Formula.2: `Pedal OPT\Commands\Command.2\Angle` = `LH Measure\Angle`
Formula.1: `Pedal OPT\Commands\Command.3\Angle` = `RH Measure\Angle`



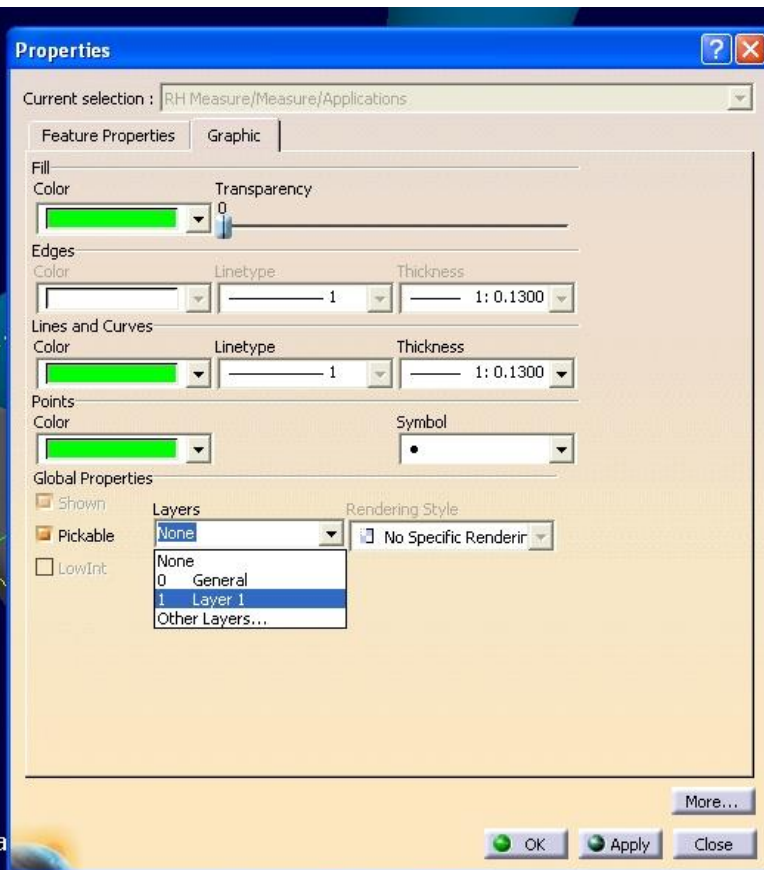
- Step 11: Clean up the appearance.

Pedals Optimized
Fixed (Fixed)
Quick Rotation (Quick Rotation)

Transfer the surfaces & time law to the same layer as the measurements.

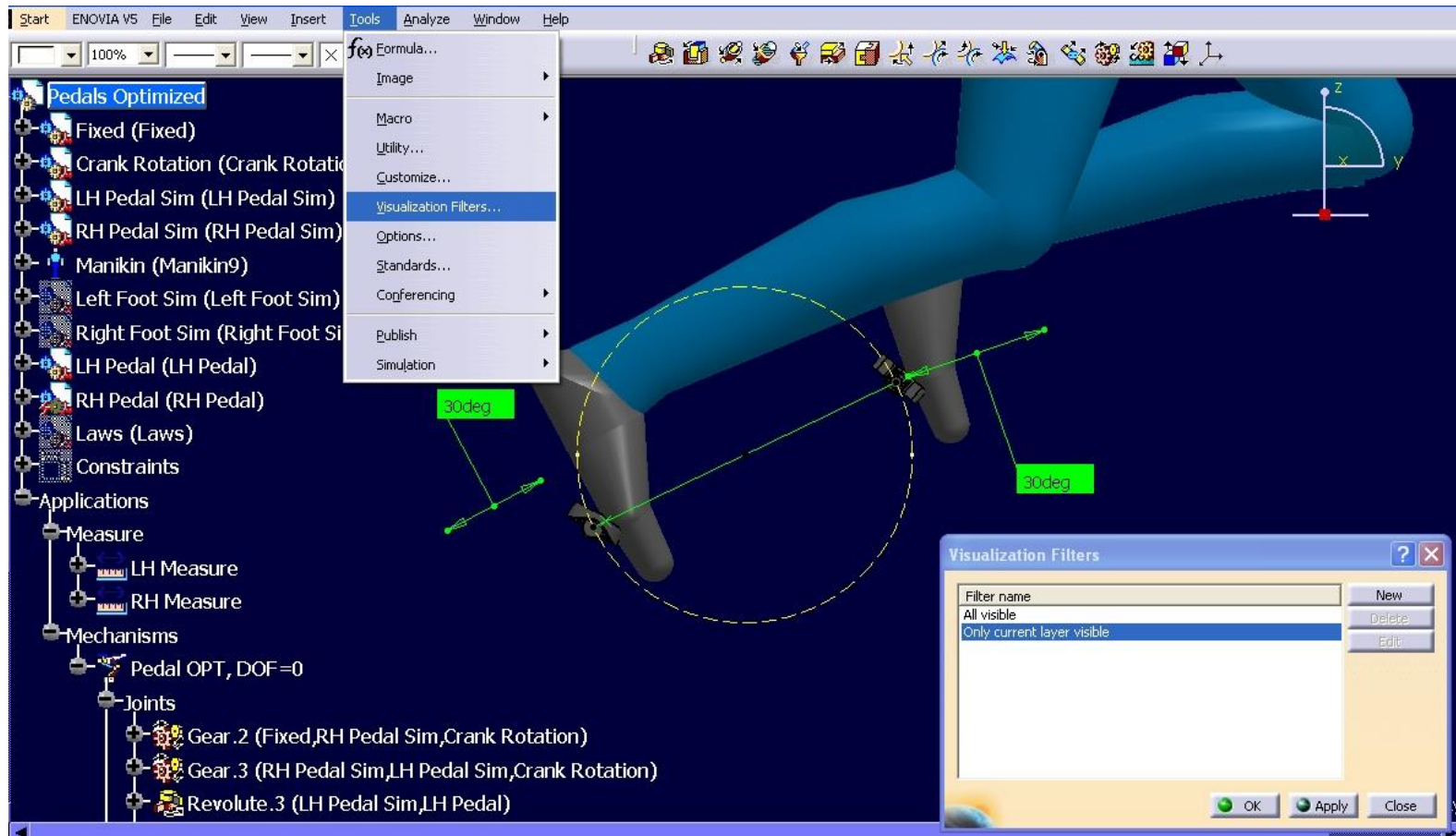
Left Foot Sim (Left Foot Sim)
Right Foot Sim (Right Foot Sim)
LH Pedal (LH Pedal)
RH Pedal (RH Pedal)
Laws (Laws)
Constraints
Applications
Measure
LH Measure
RH Measure

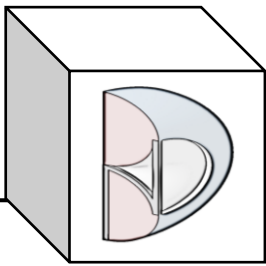
Measures can be put onto another layer because they won't stay hidden during the kinematic simulation.



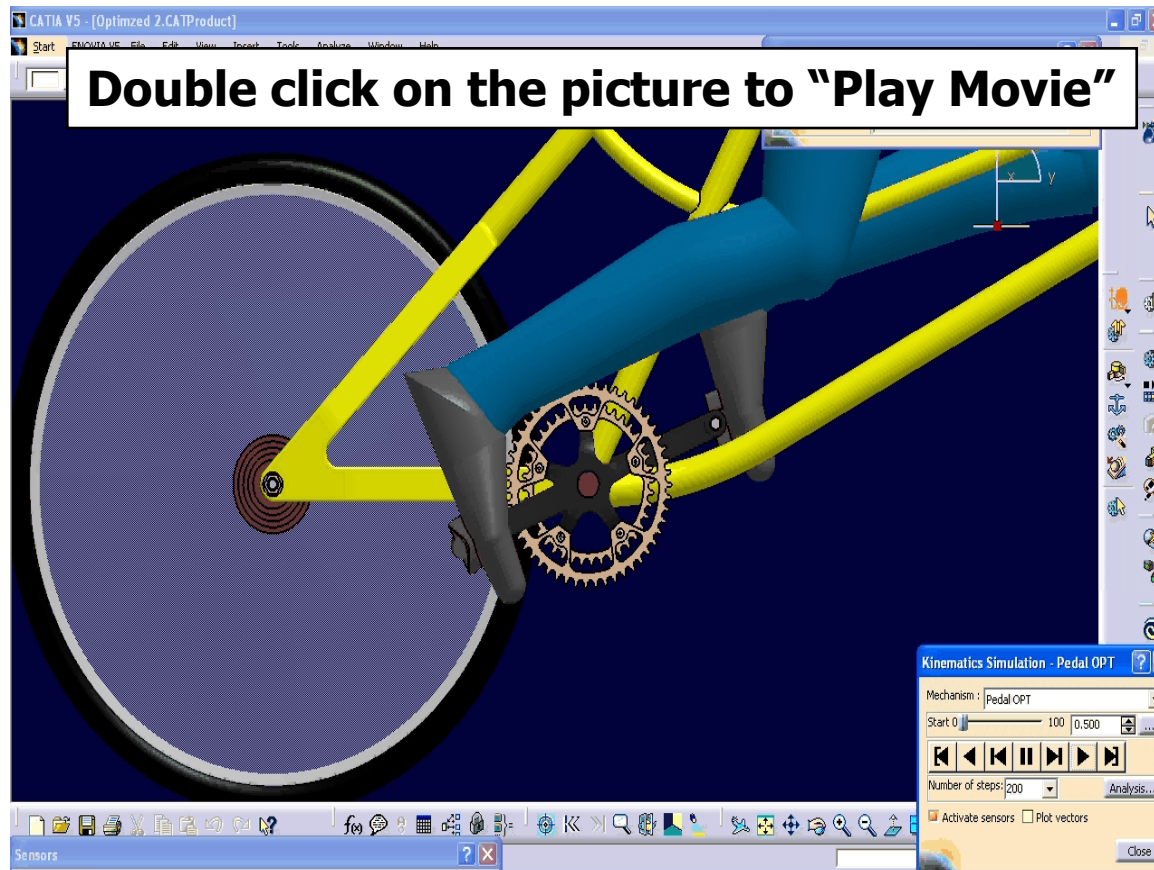


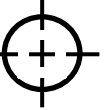
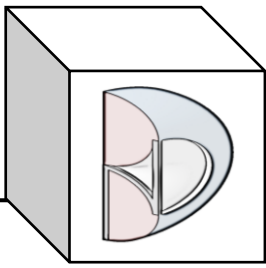
- Apply a Filter for the Kinematic simulation.





- Run the DMU Kinematic Simulation with Laws.





■ Conclusion:

This is an example of how to use CATIA DMU Kinematics along with Ergonomic Design & Analysis to simulate a 3D Manikin pedaling a bicycle.

We hope this will help those who need this type of simulation.

As always, we are open to any discussions this may bring.

Please ***subscribe*** to our YouTube channel!

