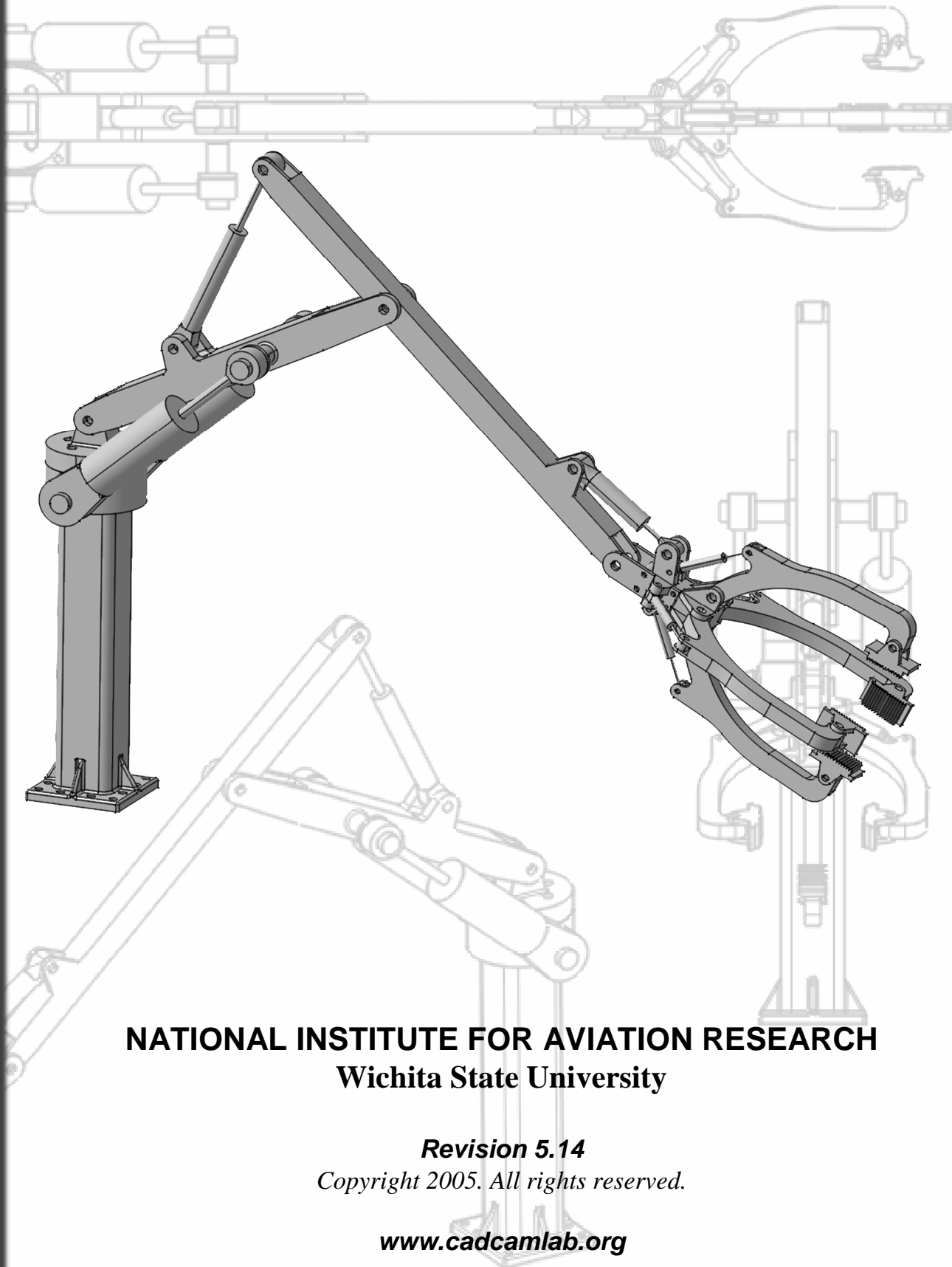


CATAV5

Fitting Simulation & Kinematics



**NATIONAL INSTITUTE FOR AVIATION RESEARCH
Wichita State University**

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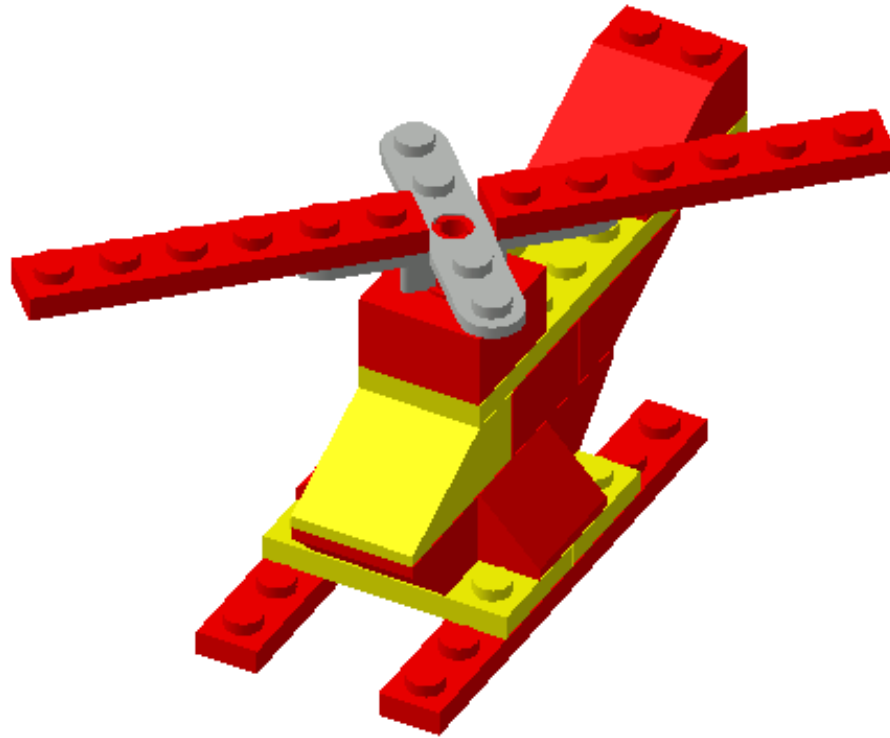
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Advanced Tracks

Sometimes creating each individual track is unnecessary. There are a number of operations that can be applied to tracks that will hasten the simulation process.

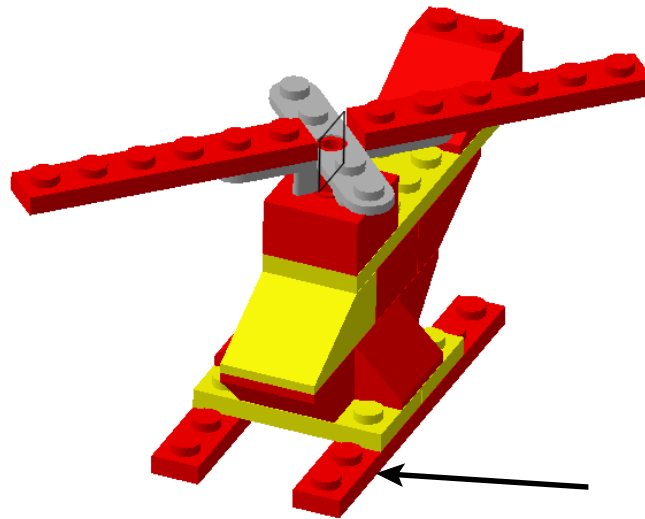
Open the **Advanced Tracks** document located in the *Advanced Tracks* directory.



Mirroring Tracks

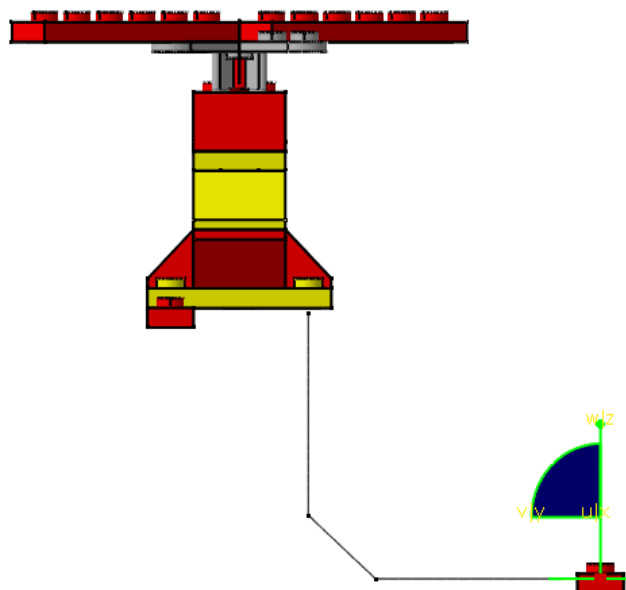
To mirror a track, all you have to do is place the compass on the mirror plane, with the base of the compass (the XY plane) on the mirror plane. The ZX primary plane for the propeller will work just fine.

Unhide the ZX plane in the *Propeller*. Just expand out the tree for the propeller, and then unhide the ZX plane.

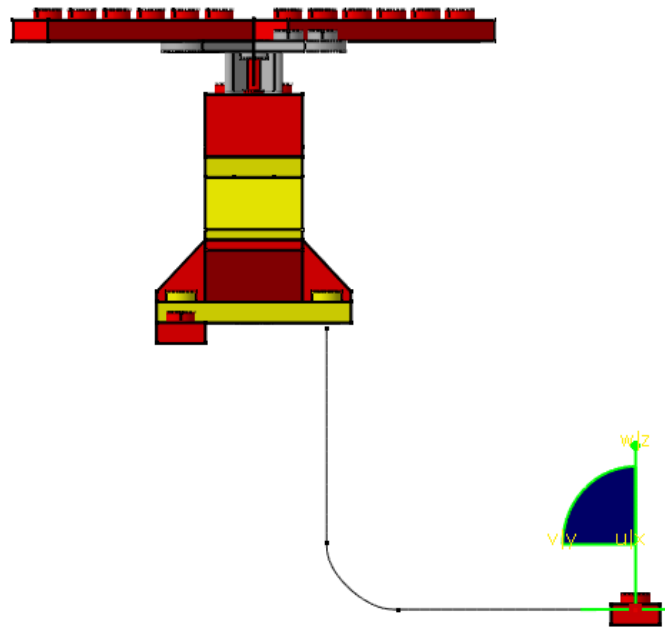


Select the track icon. Select the right landing pad as shown above. The right landing pad will be labeled 1x8 Thin Block.1. You will probably want to modify the parameters for compass manipulation to have a 0 inch *Translation increment* for *Along W*. This will allow for smaller movements in the W direction.

Create the following track. This track will be created with the *Interpolator* set to *Linear*. Do not worry about moving the pad front to back, only along the YZ plane.



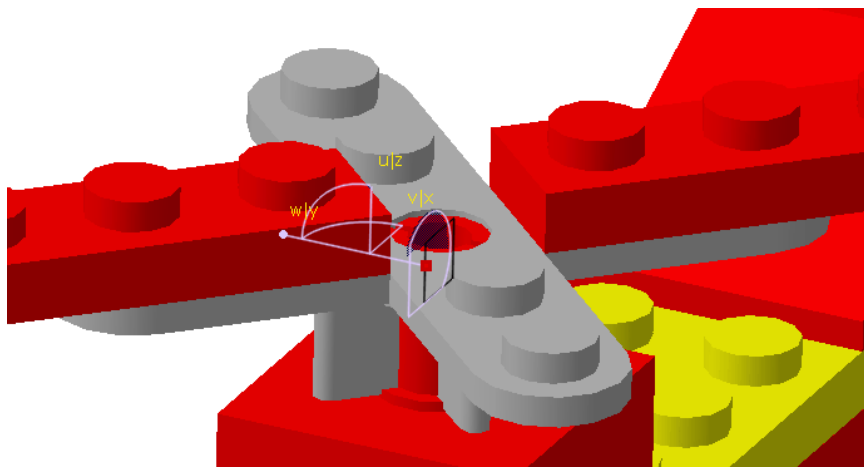
Change the *Interpolator* to *Composite spline*. If you remember, before when you changed the *Interpolator* to a composite spline, the only thing that seemed to happen is the object slowed down as it went around a corner. Notice what happens this time.



What is really happening with a composite spline is, the points that are close together are converted to a spline, whereas the longer stretches are left as lines. This makes for more fluid and smooth motions as the track progresses.

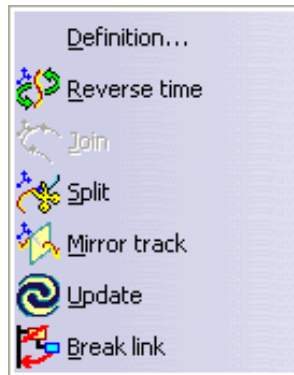
Select *OK* when done. That has one track done. Now, the other pad needs to have the exact same track applied, but in a mirrored fashion.

Drag the compass and place it on the *Propeller* plane. This may be a bit of a trick. Make sure that you are zoomed in on the plane. To drag the compass, select the large red dot on the center of the base of the compass, and then drag it to one of the edges of the plane. You will have to drag it to the edge before it will stick to the plane. The result should look something like this.




Now it is time to mirror the track so that it can be used for the other helicopter pad.

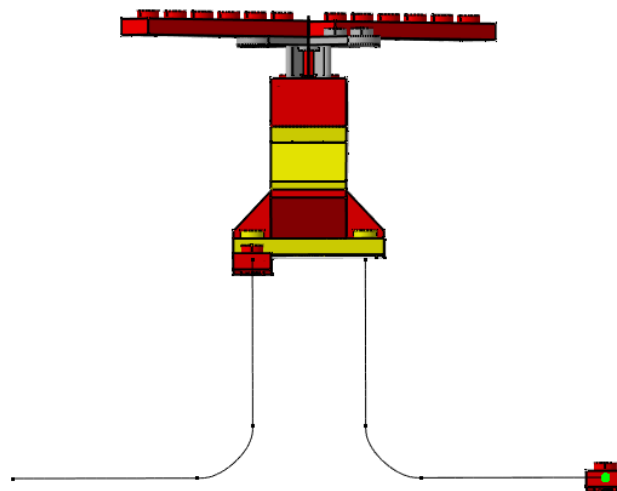
With the third mouse button, select on the track just created, and then select the track object. Notice there are a series of operations that can be applied to the track.



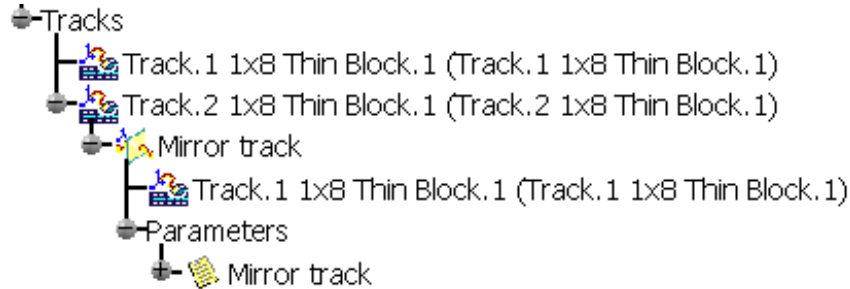
- Definition* Takes you back to the definition of the track
- Reverse time* Reverses the track and make it run backwards
- Join* Joins two different tracks together
- Split* Spits a track into different segments
- Mirror track* Mirrors a track around the base plane of the compass
- Update* Updates the track if changes have occurred
- Break link* Erases the history of a track, making it a stand-alone track

Select *Mirror track*.  This mirrors the track around the base plane of the compass. It is mandatory that the compass be in a proper location before trying to mirror the track.

Now that you have the track in place, you need to associate it to the other landing pad.



Notice the new track. The new track has a long line of sub branches. Take a quick look at the various sub branches.




The first sub branch is the *Mirror track* branch. It shows what operation has been performed. The next branch down is the *Track.1 1x8 Thin Block.1* branch, the track that was mirrored. The *Parameters* branch is the parameters of the mirror. This defines what the track was mirrored around, and other various information about the mirroring of the track.


Double select the new track. This should be *Track.2 1x8 Thin Block.1*, but just know it is the second track. This will take you back to the definition of the first track.

Select the *Object field*. This will bring up the *Track Positioning* window. Last time you told it to not keep the positioning of the track. Since the mirrored track is in the correct place as it is, then you will want to keep the positioning.

Select *Keep Positioning* from the *Track Positioning* window. Now the track will not move, but will still work with the second block.

Select the *1x8 Thin Block (1x8 Thin Block.2)*. You may have to select it from the tree. The original block will lay on top of the second one, making it difficult to select graphically.

Select *OK* when you are done, then select the reset position icon.  Now you are ready to replay the two of them to see how they look.

Select the player icon and then the first track.  The *Player* toolbar appears.

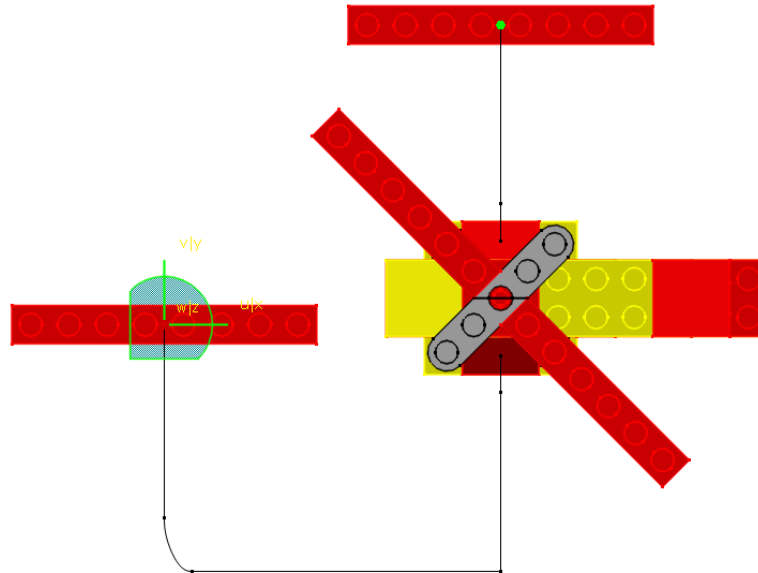
Select the skip to begin icon and then the play forward icon. The block moves down and to the right.

Select the second track and play it. The block moves down and to the left.


Close the *Player* toolbar. You can close the window by selecting the X in the upper right corner or you can select the player icon again. You are going to make a modification to the first track.

Double select on the first track. You have to select the player icon to turn it off. Otherwise, the player will change back to the first track, waiting for you to replay it.

Move the landing pad straight forward, and inward as shown below. Select *OK* when done. Do not worry about the Z movements, Just assume everything is along the XY plane.




Notice the other track did not change as you thought it might. You are going to remove the old track and then mirror the track again.

Select the player icon and select *Track.2 1x8 Thin Block.2*.  The *Player* toolbar appears.


Select the skip to begin icon and close the *Player* toolbar. This will locate that block at the original position.

Delete *Track.2*. You are going to create a new track by mirroring the modified one.

Drag the compass and position it on the plane again. You must define a mirror plane with the compass.


Press the third mouse button while on *Track.1 1x8 Thin Block.1*, select the object name and select *Mirror track*.  The modified track is mirrored. You will need to change the object it is associated with.

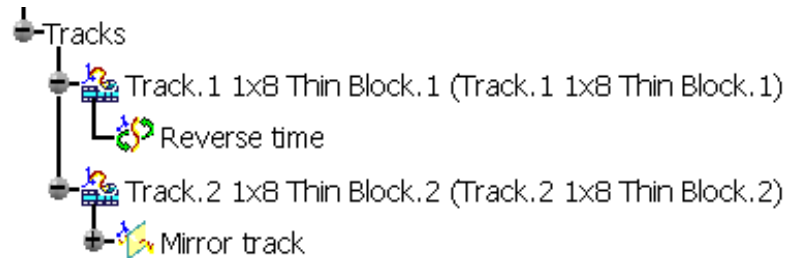
Double select *Track.2 1x8 Thin Block.1*, select in the *Object* box, turn on *Keep positioning* and select the *1x8 Thin Block (1x8 Thin Block.2)*. You will probably need to select it from the tree.

Select *OK*, then select the reset position icon.  Now you should be able to replay both of the tracks. Now that you have the two landing pads dis-assembling, it is time to reverse the tracks to put it back together.

Reversing Tracks

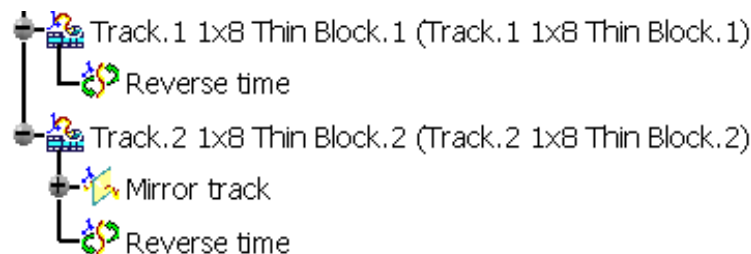
With the third mouse button, select on the first track, and then the track object. This is going to bring up the contextual menu for the track.

Select *Reverse time*.  This is going to reverse the time for the track. Notice a *Reverse time* branch is added to the tree.



Select the player icon and the first track. Select the skip to begin icon and then play the track. Notice the landing pad now starts at the end of the track, and finishes where it originally was. Even though the second track is a mirror of the first track, the operations performed on the tracks do not mirror. This means that if you replay the second track, it will not be in reversed time.

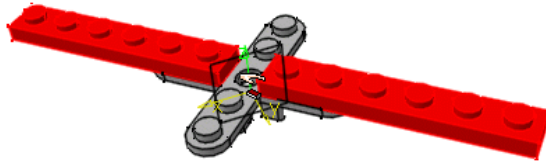
Close the *Player* and reverse the time for the second track. This is just the same process as before, select on the track with the third mouse button, select the track object, and then select *Reverse time*. This will add another branch to the track.



Now the second track, *Track.2 1x8 Thin Block.2*, has two operations performed on it, a mirror and a reverse time. You can have as many operations performed on a track as you want. There is another method to run a track in reverse that does not utilize a reverse time operation. This will be looked at next.


Create a shuttle that consists of the *Propeller* and both blades. Select the *Propeller* first in order to have the shuttle axis located at the center of the *Propeller*. Remember, if you want to move several pieces at the same time, you will have to put them in a shuttle.

Name the shuttle **Prop & Blades**. Do not select *OK* just yet.



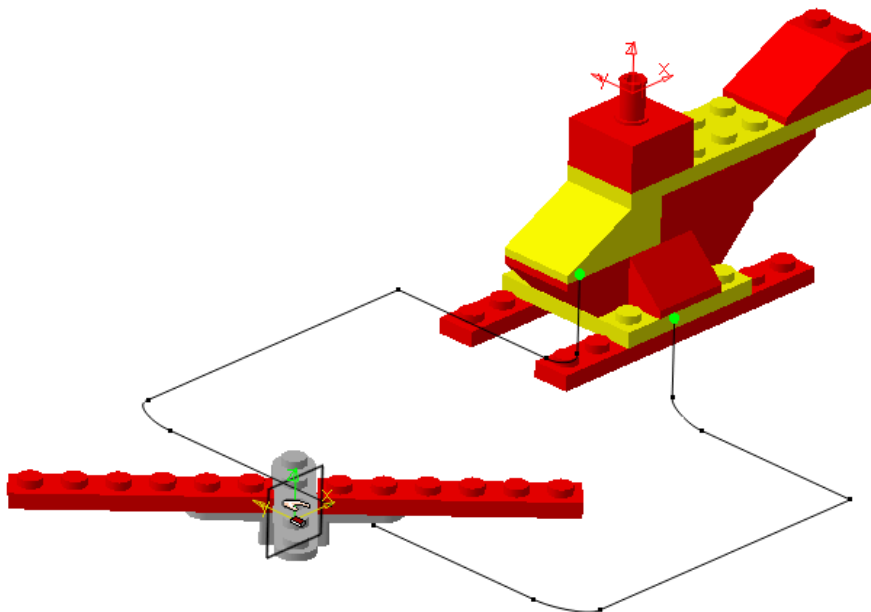
The second method of assembly requires that the parts be in their initial location before you begin the track. This means that the prop and blades need to be moved away from the rest of the assembly. Before you do that though, you will need to define a snapping axis.

A snapping axis is a set location and orientation that the compass will snap to when it is within a range. You can control the range with *Tools, Options, Digital Mockup, DMU Fitting, DMU Manipulation* tab. You can adjust the *Snap Sensitivity* based on *Position* and *Orientation*.

Select the snapping axis icon.  The icon is located in the *Manipulation* toolbar. You only need to select this once. You should see a small red axis appear at the base of the compass. The red axis can be difficult to see with all of the other red pieces around, so if you do not identify it immediately, do not worry.

Now that you have the snapping axis defined, you can move the shuttle.

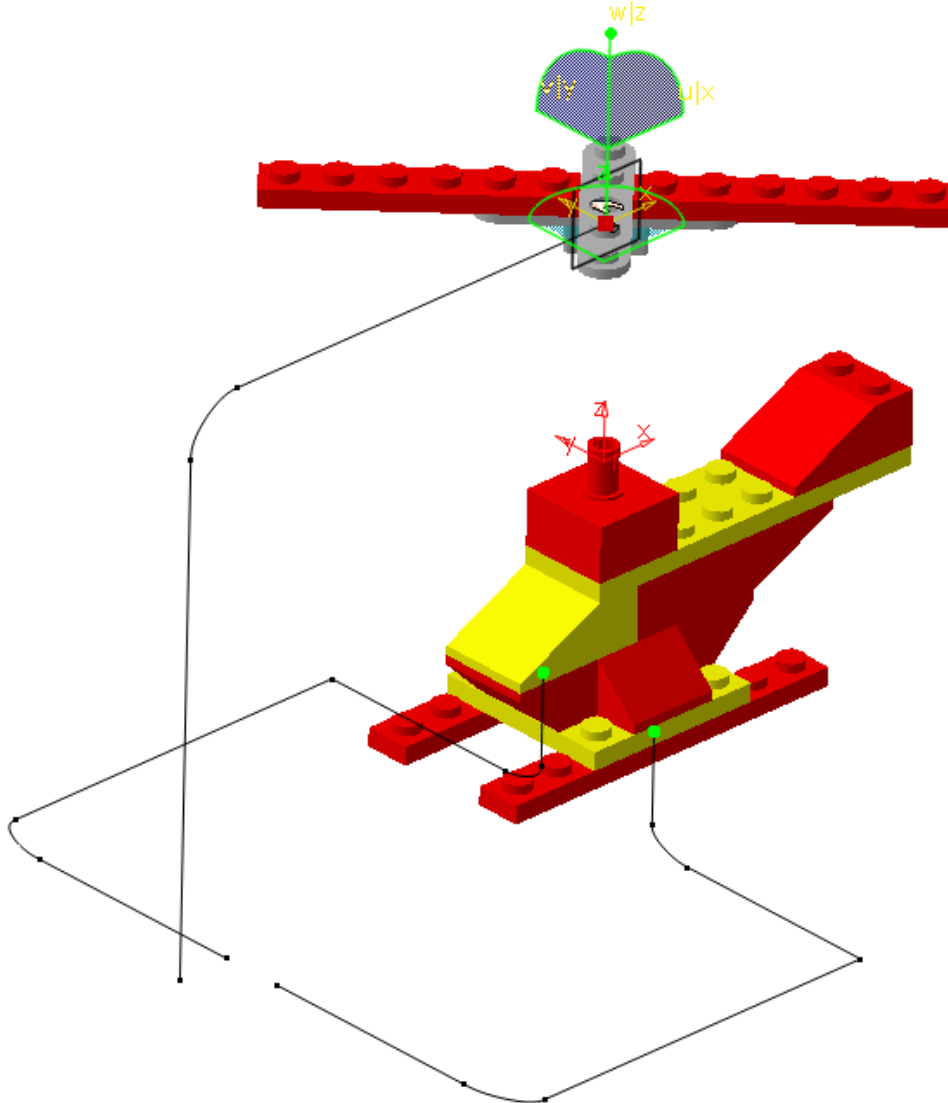
Move the shuttle to the location shown below. It is not important how you get the shuttle there. You are not recording a track, only setting the initial position of the shuttle.



Select *OK*. Now you are ready to create the track.

Select the track icon and then select the *Prop & Blades* shuttle. Notice you also have the ability to define a snapping axis from within the track. This would allow you to create a track that removed a part, then brought it back to the same location.

Create a track similar to the following but do not select *OK*. The track does not need to be exactly as shown, but you want the propeller to be above the snapping axis you created.



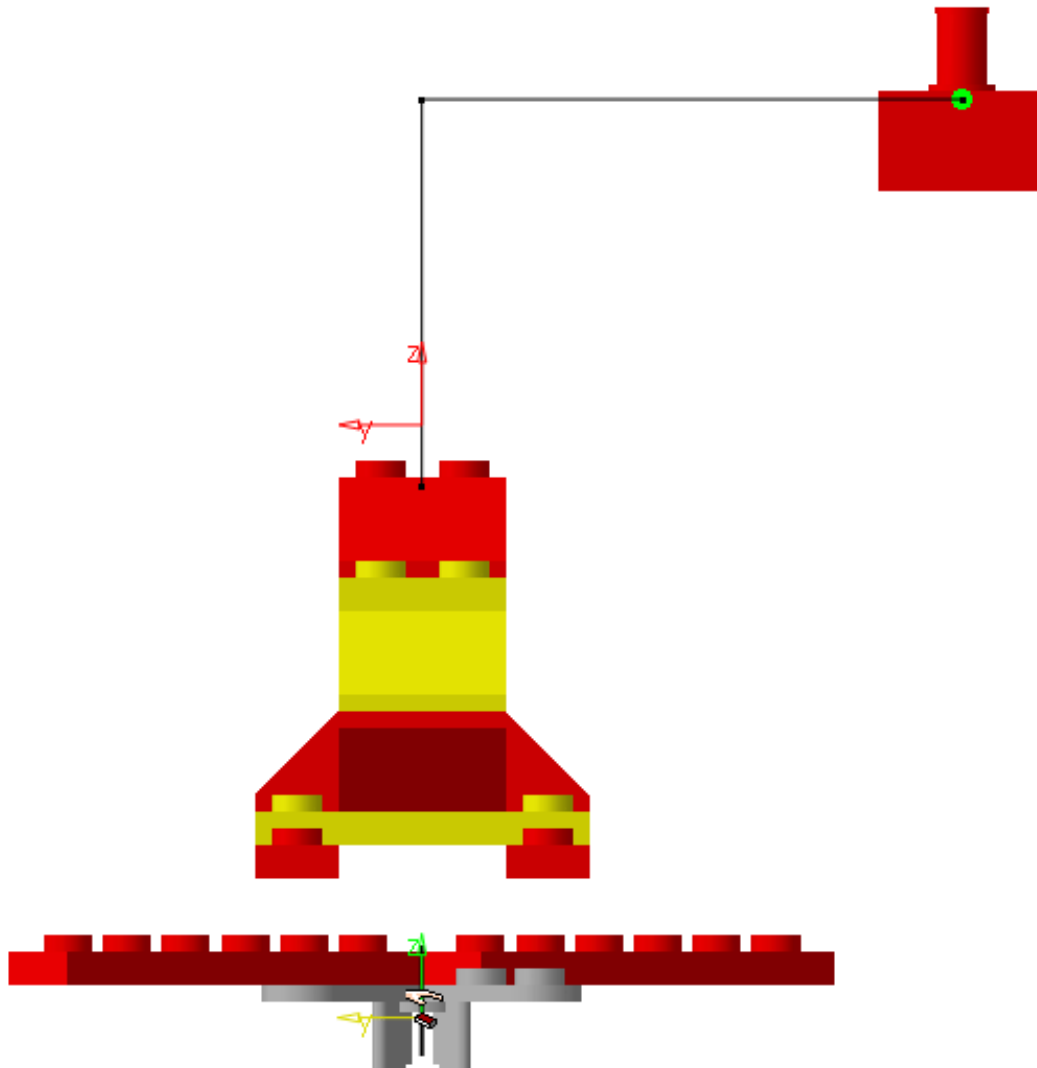
Now move the compass straight down to the snapping axis. Notice once you get close to the snapping axis, the propeller and blades snap to the position, regardless of where the compass is. This insures that propeller and blades go back into the exact spot that they were in before.

Record the last step and select *OK* when done. This will finish the track.

Play the track to make sure everything looks good and return it to the beginning. This will make it easier to move the other pieces.

Create the following track for the 2x2 Block for Rotating and select *OK* when done. Do not make any X movements, just move the block up and over.

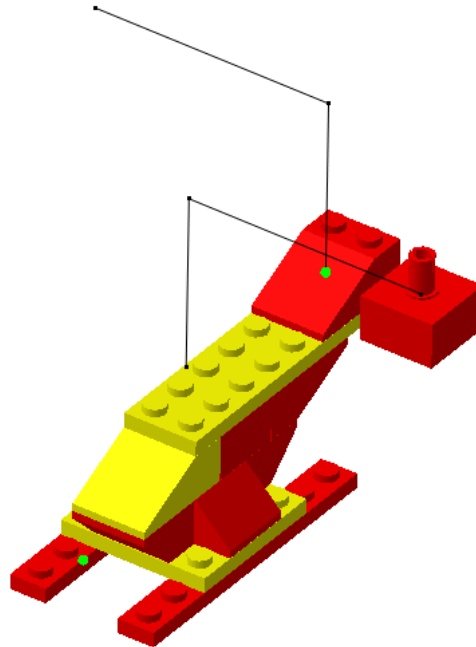
Note: The other tracks are hidden for clarity.



You are going to be removing/assembling several different pieces, however, you can re-use this portion of the track.


Copy and paste the track. Just select with the third mouse button on the fourth track, and then select copy. Select on the main *Tracks* branch and select *Paste*. This will create a second Track.4 in the tree.

Change the object to be the 2x3 Slanted Block (2x3 Slanted Block.2) for the copied track and select OK. This will be the red slanted block at the tail of the helicopter. Notice what happened when you changed the track. The track flipped sides.



This is not too much of a problem. However, if you remember from earlier, when you copy and paste a track, that means the two are linked together. This means that if you try to modify the track for the propeller block, then you will also be modifying the track for the tail. This is not what you are after.

With the third mouse button select on the copied track and then select the track object. You can also select the third mouse button on the track itself. You do not have to select it from the tree each time.

Select *Break link* from the contextual menu.  This will break the link between the two tracks. Nothing will physically change. The name of the track will still be the same and the track will not be modified.

Move the 2x2 Block for Rotating to the end of its track. You can do this by selecting the player icon, selecting its track and selecting the skip to end icon.

Select the track icon and then select the 2x2 Block for Rotating again. Notice this starts a new track. Not to worry, this is easily fixed.

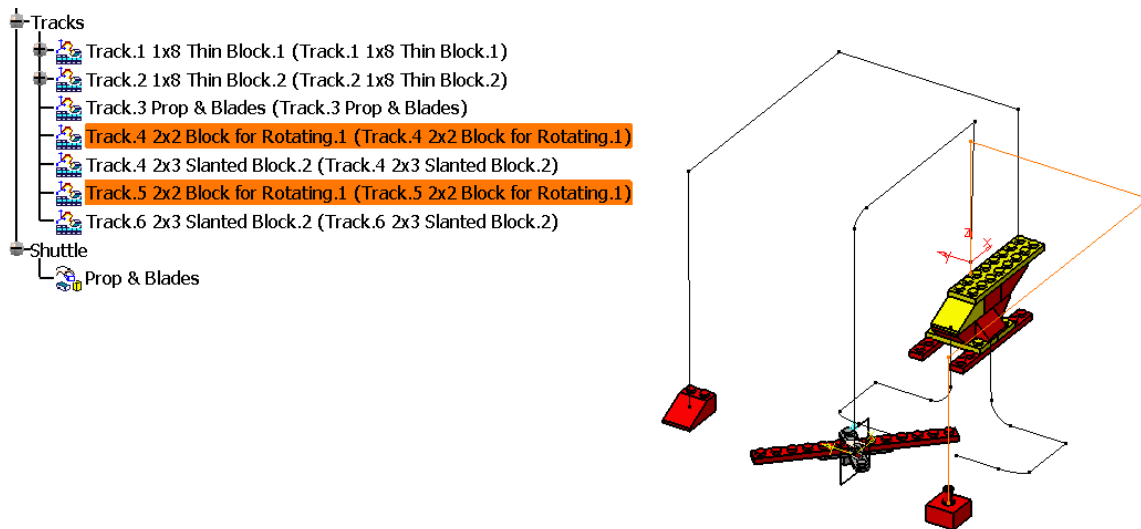
Create a track to move the block to the front of the helicopter by the propeller and blades. Select OK when done. The two tracks will be joined together in a bit.

With the slanted block at the end of its current track, add an additional track to move it by the propeller and blades also. Select OK when done. You will need to move the slanted tail to the end of the track in the same manner as you did the rotating block.

Joining Tracks

At this point, your workspace should look something like the following image. Your track numbers may not be the same, but the position of them should be. Joining tracks is similar to concatenating curves. The difference is, the tracks do not need to meet end to end. In this example, the tracks do match end to end, but just keep in mind that they do not have to. Also keep in mind that you can join together as many tracks as you want. You are not limited to joining two tracks to each other. The trick with joining tracks is keeping the order correct. The end of the first track you select, and the beginning of the second track you select will be the two endpoints that get connected.

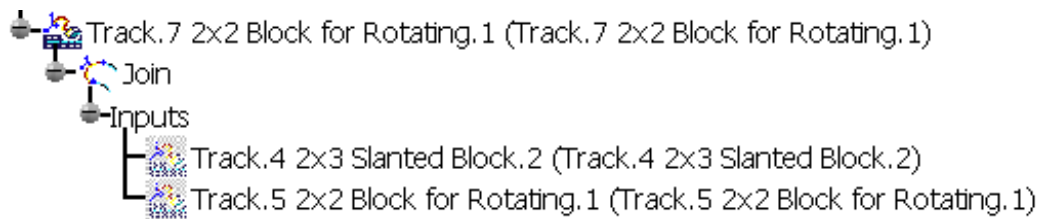
Select the fourth track, *Track.4 2x2 Block for Rotating.1 (Track.4 2x2 Block for Rotating.1)* and the sixth track, *Track.5 2x2 Block for Rotating.1 (Track.5 2x2 Block for Rotating.1)*. This should be the two tracks that make up the path for the rotating block. You should see both of them highlighted in the workspace.



Make sure you selected the fourth track, *Track.4 2x2 Block for Rotating.1 (Track.4 2x2 Block for Rotating.1)* first. Remember, the end of the first track selected gets linked to the beginning of the second track.

With the third mouse button select on one of the highlighted tracks and select *Selected objects*. The join option will be selectable.

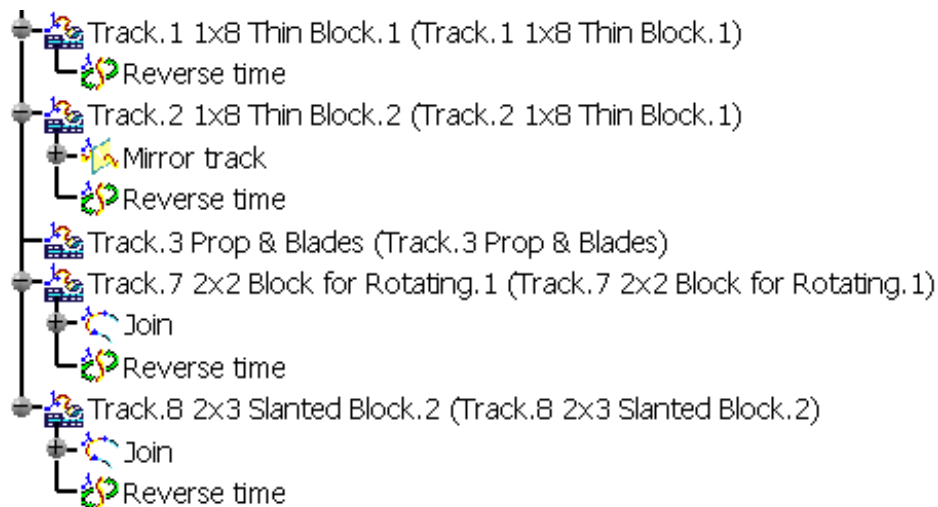
Select Join.  Notice both tracks disappeared and a new track was added to the tree.



When multiple tracks are joined together, they are included in the join as inputs. The inputs are then hidden and are no longer shown. The resulting track, *Track.7 2x2 Block for Rotating.1* in this case, is a combination of the other two. You can apply other operations on the new track, but to modify it, you must return to the underlying tracks to change the path.

Select the other two tracks and join them together. Be sure you select them in the right order. Replay the two tracks to make sure they are correct when you are done. Now that you have the two tracks ready, you still need to reverse the time to make them assemble the helicopter.

Reverse the two joined tracks. Remember, all you need to do to reverse the track is to select on the track with the third mouse button (in this case *Track.7* and *Track.8*) and select the object for the track and then *Reverse time*.



Replay your track to make sure everything looks good. This would be a good time to save your assembly too.

This will be all the further that the helicopter will be assembled. You are more than encouraged to finish out the helicopter. Before leaving this exercise though, you are going to want to create a sequence for the assembly.

Select the edit sequence icon. This time you are not going to want to put the tracks into the sequence in the same order you created them.

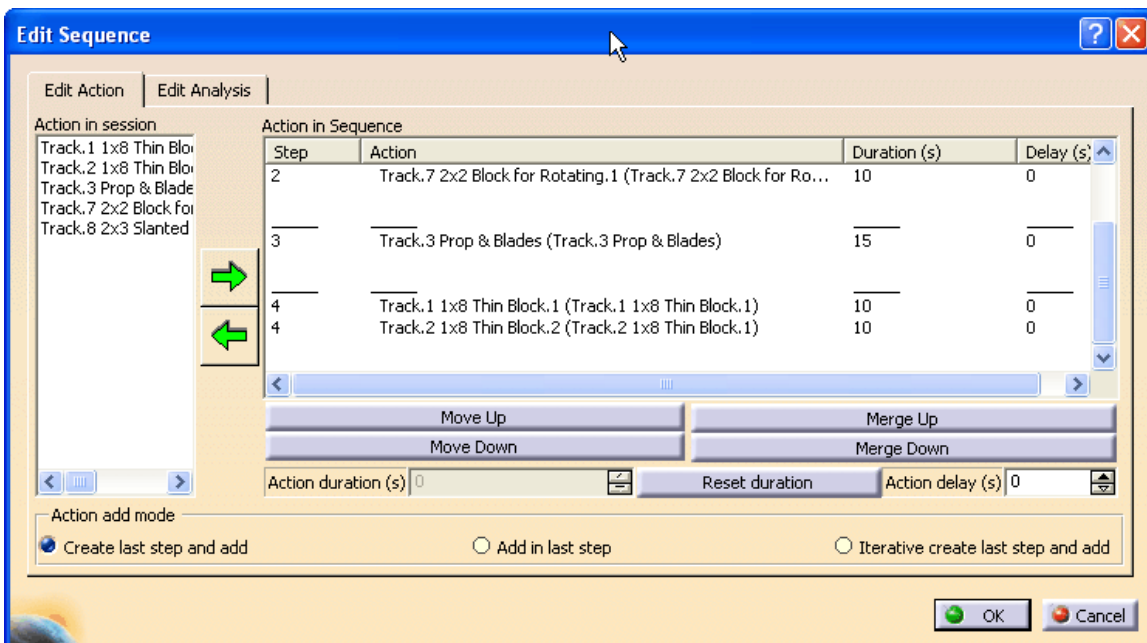
Put the last track, *Track.8 2x3 Slanted Block.2*, into the sequence. Change the duration to 10s. The last track should be the tail piece.

Add in the second to last track, *Track.7 2x2 Block for Rotating.1*. Make the duration 10s also. This is the main piece that you want to put onto the helicopter before the prop and blades.

Add the third track, *Track.3 Prop & Blades*, to the sequence. Set the duration to 15s. This should be the prop and blades.

Add the first two tracks in simultaneous mode. Set the duration to 10s each.

Remember, to add them in simultaneous mode, all you have to do is highlight both of them at the same time in the *Action in session* field and then select the right arrow.



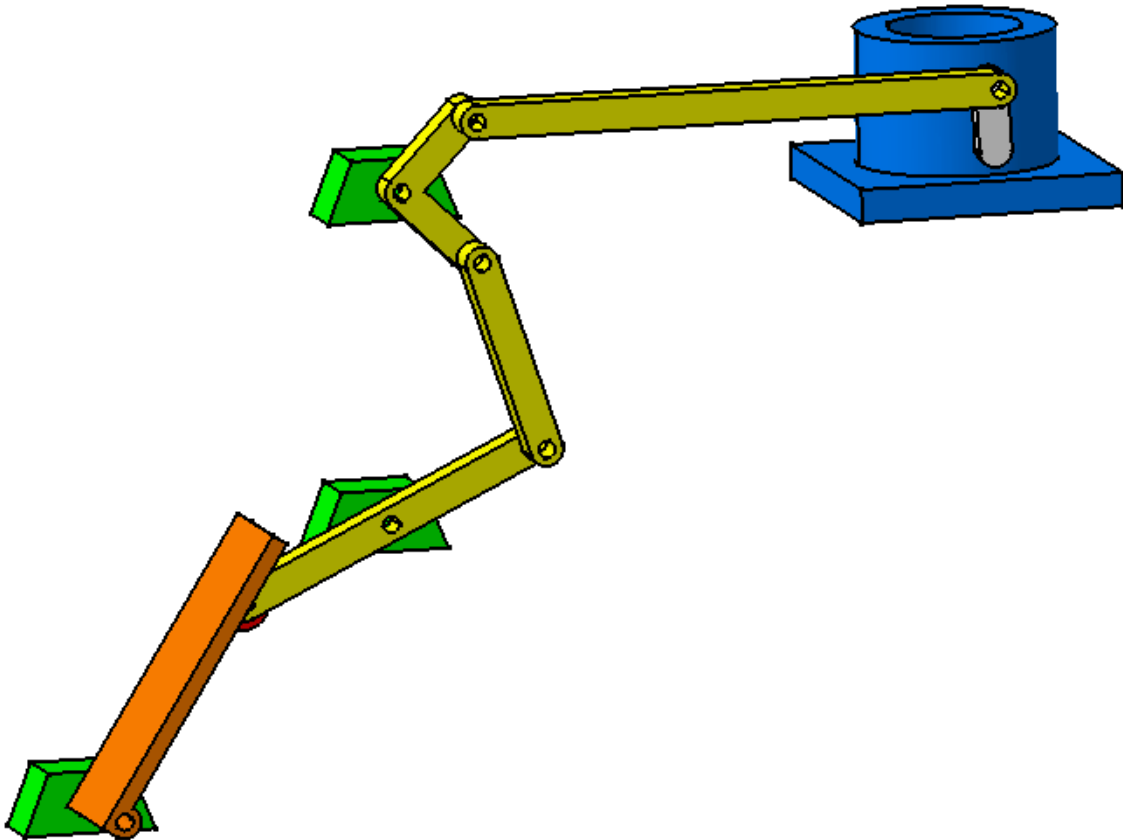
Select *OK* and then play the sequence. This completes creating a fitting simulation showing assembly instead of dis-assembly.

Save and close your document.

Sensors

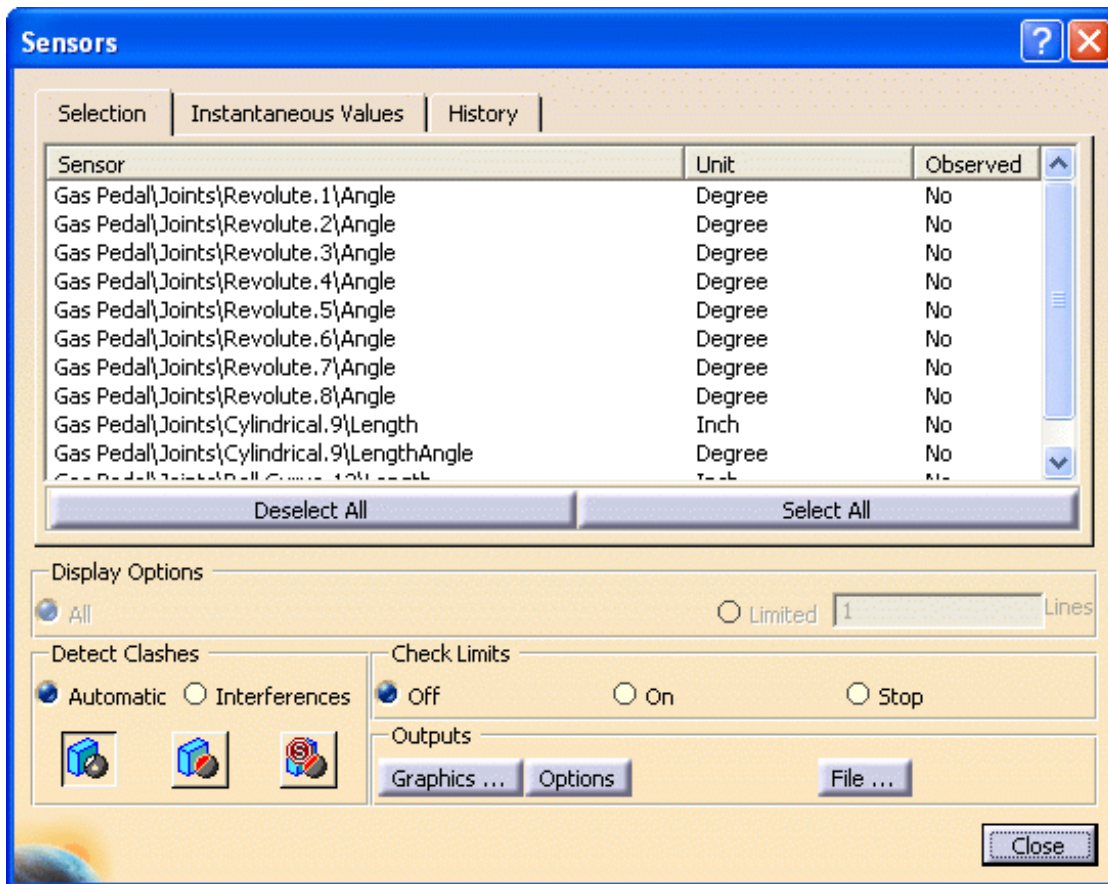
Sensors are used for a variety of reasons. They can be used to monitor values of various joints, determine speeds and accelerations, check joint limits, check for interferences and compute distances. The values can be shown on a graph or they can be exported into a text file or an Excel spreadsheet file.

Open the *Sensors* document located in the *Sensors* directory. You will see a gas pedal mechanism with joints already defined.



Select the simulation with commands icon. Sensors are located within the simulation with commands and simulation with laws options.

Turn on the *Activate Sensors* option. The *Sensors* window appears.



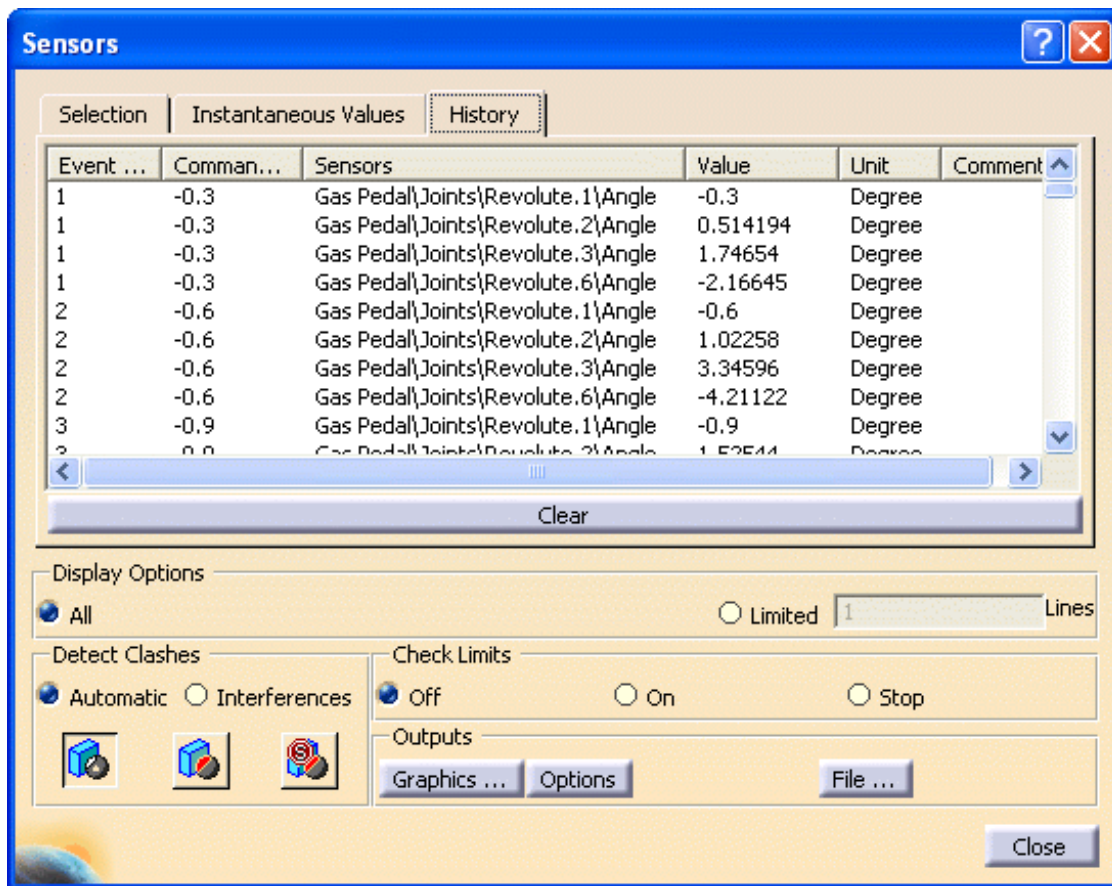
- Selection* Allows you to select which items you want to be observed
- Display Options* Defines if you want *All* of the lines displayed or just a *Limited* number of lines shown
- Detect Clashes* This will either automatically detect clashes or only the interferences that you specified. The icons located here allow you to specify whether you want the clash detection off, on or have it stop the simulation when a clash occurs.
- Check Limits* This will check the limits of all the joints. You can turn this *Off*, *On* or have the simulation *Stop* when a joint limit is reached.
- Outputs* Allows you to look at the output using a graph or to write the output to a file
- Instantaneous Values* Shows the values at the current moment of time
- History* Shows the values at every moment of time in the simulation

Select the *Revolute.1\Angle*, *Revolute.2\Angle*, *Revolute.3\Angle*, and *Revolute.6\Angle*. You should see a *Yes* in the *Observed* column for each item.

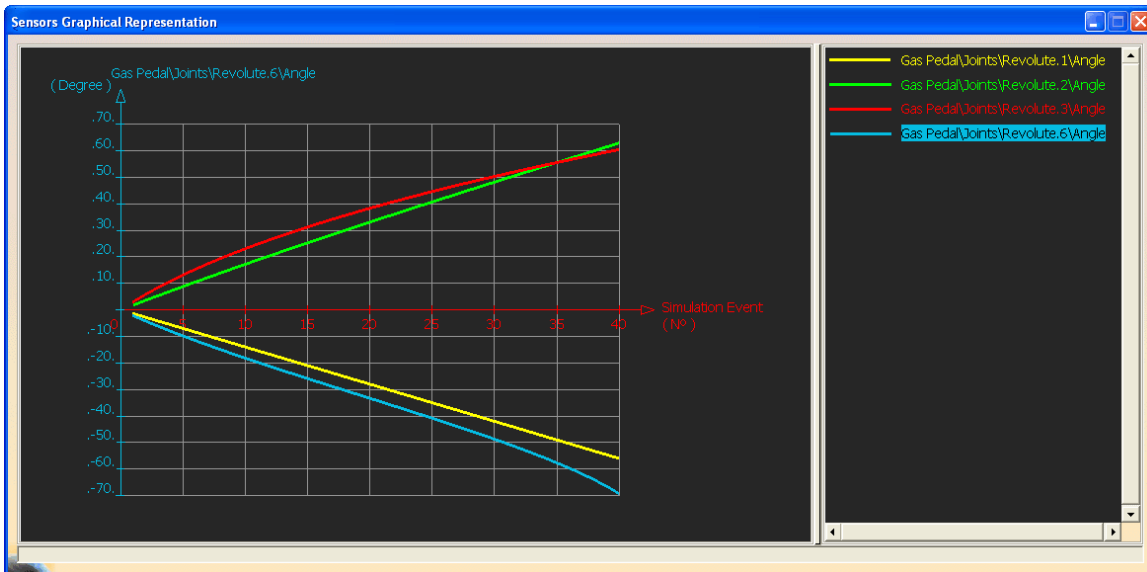
Select the *Instantaneous Values* tab in the *Sensors* window. This will show the current value at each step.

Turn on the *On request* option, drag the slider all the way to the left, change the *Number of steps* to 40 and select the play forward icon. The simulation begins playing. Notice the values change as the simulation runs.

Select the *History* tab in the *Sensors* window. A list of all the sensors and their values at each command value is shown.



Select the **Graphics...** button in the window. The *Sensors Graphical Representation* window appears. This shows a graph of all the values for each sensor. The scale of the graph will change for each sensor selected. Currently, the *Revolute.6\Angle* is selected therefore the scale applies to the blue curve associated with this sensor.



Select the **Revolute.1\Angle** sensor. The scale changes to go from -15 to 15. Notice the color of the scale values changes to match the color of the curve.

Select the **Revolute.2\Angle** sensor. The scale changes to go from -20 to 20.

Select the **Revolute.3\Angle** sensor. The scale changes to go from -40 to 40.

Close the *Sensors Graphical Representation* window. You can do this by selecting the X in the upper right corner.

Select the **File...** button in the window. The *Save As* window appears.

Go to your directory and save the output as an Excel spreadsheet with the name of **Gas Pedal**. This will save the data you collected into a spreadsheet.

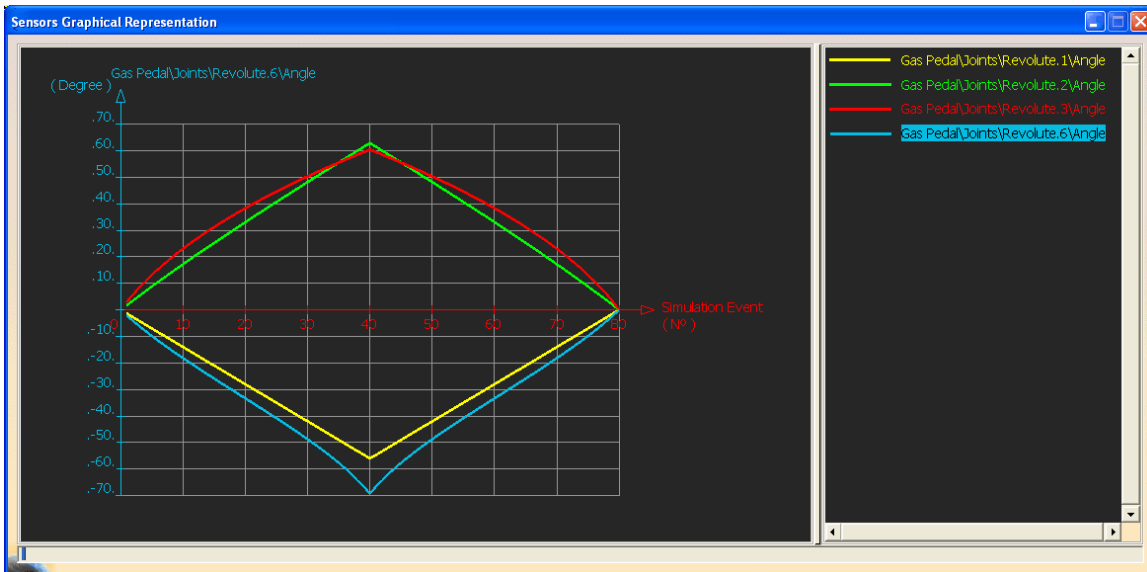
Minimize CATIA and go to your directory and open the Gas Pedal spreadsheet.
 Microsoft Excel should automatically run and show the spreadsheet as shown below.

Event Number	Gas Pedal	Gas Pedal	Gas Pedal	Gas Pedal	Revolute Angle (Degree)
1	1	-0.3	0.514194	1.74654	-2.16645
2	2	-0.6	1.02258	3.34596	-4.21122
3	3	-0.9	1.52544	4.82832	-6.15975
4	4	-1.2	2.02304	6.2146	-8.03004
5	5	-1.5	2.51564	7.52015	-9.83545
6	6	-1.8	3.00348	8.75662	-11.5863
7	7	-2.1	3.48679	9.93307	-13.2908
8	8	-2.4	3.96578	11.0568	-14.9567
9	9	-2.7	4.44067	12.1336	-16.5865
10	10	-3	4.91166	13.1685	-18.1881
11	11	-3.3	5.37893	14.1655	-19.7645
12	12	-3.6	5.84266	15.1281	-21.3195
13	13	-3.9	6.30303	16.0592	-22.8563
14	14	-4.2	6.76021	16.9615	-24.3778
15	15	-4.5	7.21436	17.8371	-25.887
16	16	-4.8	7.66563	18.6882	-27.3863
17	17	-5.1	8.11418	19.5163	-28.8782
18	18	-5.4	8.56014	20.323	-30.3651
19	19	-5.7	9.00366	21.1098	-31.8494
20	20	-6	9.44487	21.8779	-33.3334
21	21	-6.3	9.88391	22.6283	-34.8193
22	22	-6.6	10.3209	23.3622	-36.3097
23	23	-6.9	10.7559	24.0804	-37.8071
24	24	-7.2	11.1892	24.7838	-39.3139
25	25	-7.5	11.6208	25.4731	-40.8332
26	26	-7.8	12.0507	26.149	-42.3679
27	27	-8.1	12.4793	26.8123	-43.9214
28	28	-8.4	12.9064	27.4634	-45.4974
29	29	-8.7	13.3324	28.103	-47.1003
30	30	-9	13.7571	28.7315	-48.7348
31	31	-9.3	14.1809	29.3494	-50.4069
32	32	-9.6	14.6037	29.9571	-52.1232
33	33	-9.9	15.0257	30.5551	-53.8922
34	34	-10.2	15.4469	31.1438	-55.7242
35	35	-10.5	15.8675	31.7234	-57.6325
36	36	-10.8	16.2876	32.2943	-59.6343
37	37	-11.1	16.7072	32.8568	-61.7533
38	38	-11.4	17.1264	33.4112	-64.0236
39	39	-11.7	17.5454	33.9578	-66.4968
40	40	-12	17.9643	34.4968	-69.2594

Close Microsoft Excel and maximize CATIA. You should return to where you left.

Select the play back icon. This will play the simulation backwards.

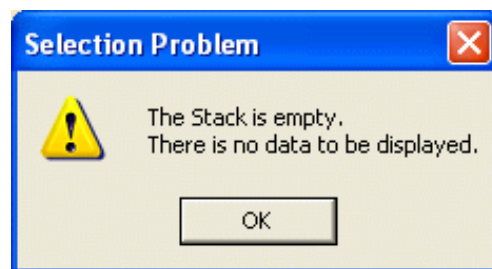
Select the **Graphics...** button again. The *Sensors Graphical Representation* window appears. Notice that the graphs show the values for the simulation playing forward and backward. This is because you did not clear the history, therefore it just continues to add the data onto the end.



Close the *Sensors Graphical Representation* window.

Select the **Clear** button in the *Sensors* window. The *History* is cleared.

Select the **Graphics...** button. A *Selection Problem* window appears telling you that there is no data to display.



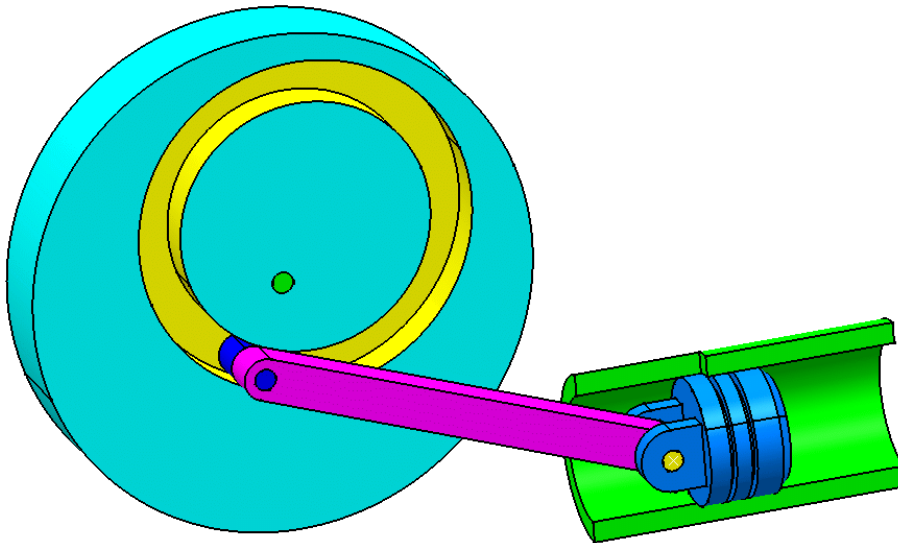
Select **OK** and select **Close** in both windows.

Close your document. You are going to look at some other uses of sensors.

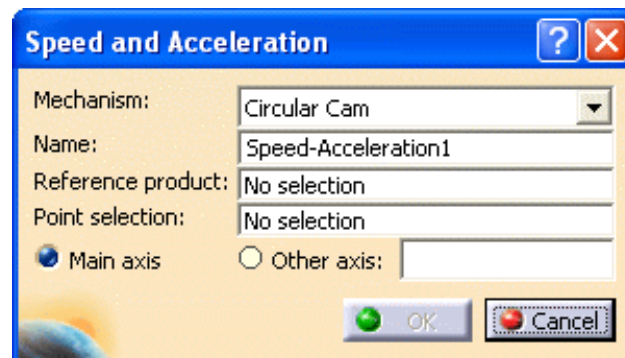
Speed and Acceleration

In order to determine speed or acceleration you must have a law applied to your mechanism. The law involves time therefore allowing a speed or acceleration to be calculated.

Open the Speed and Acceleration document located in the *Speed* directory. There is a mechanism defined with a law that will turn the cam around at 5 degrees per second.



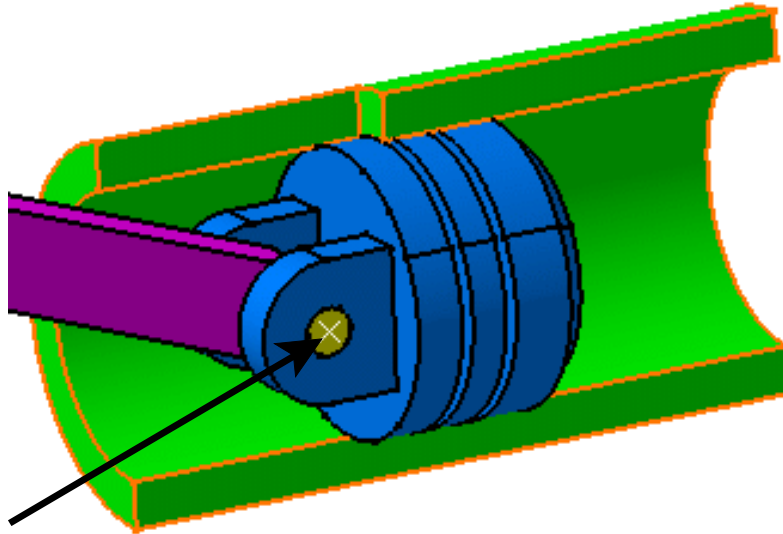
Select the speed and acceleration icon.  The *Speed and Acceleration* window appears.



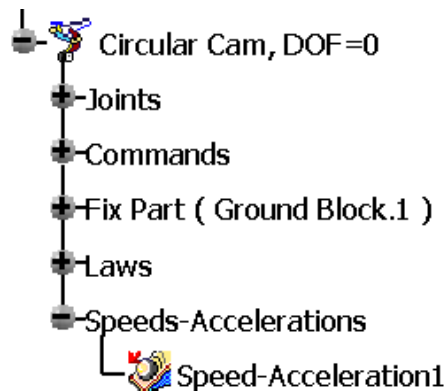
<i>Mechanism</i>	Defines which mechanism the speed and acceleration computation will be added to
<i>Name</i>	Specifies the name of the speed and acceleration computation
<i>Reference product</i>	Defines the product that the speed and acceleration will be based from
<i>Point selection</i>	Specifies the point where the speed and acceleration will be calculated at
<i>Main axis / Other axis</i>	Defines the axis system the computation will be related to

Select the green channel as the *Reference product*. You are going to calculate the speed in reference to the fixed channel.

Select the point shown below as the *Point selection*. This is the location of your mechanism where you want the speed and acceleration to be computed. You are going to use the *Main axis*.



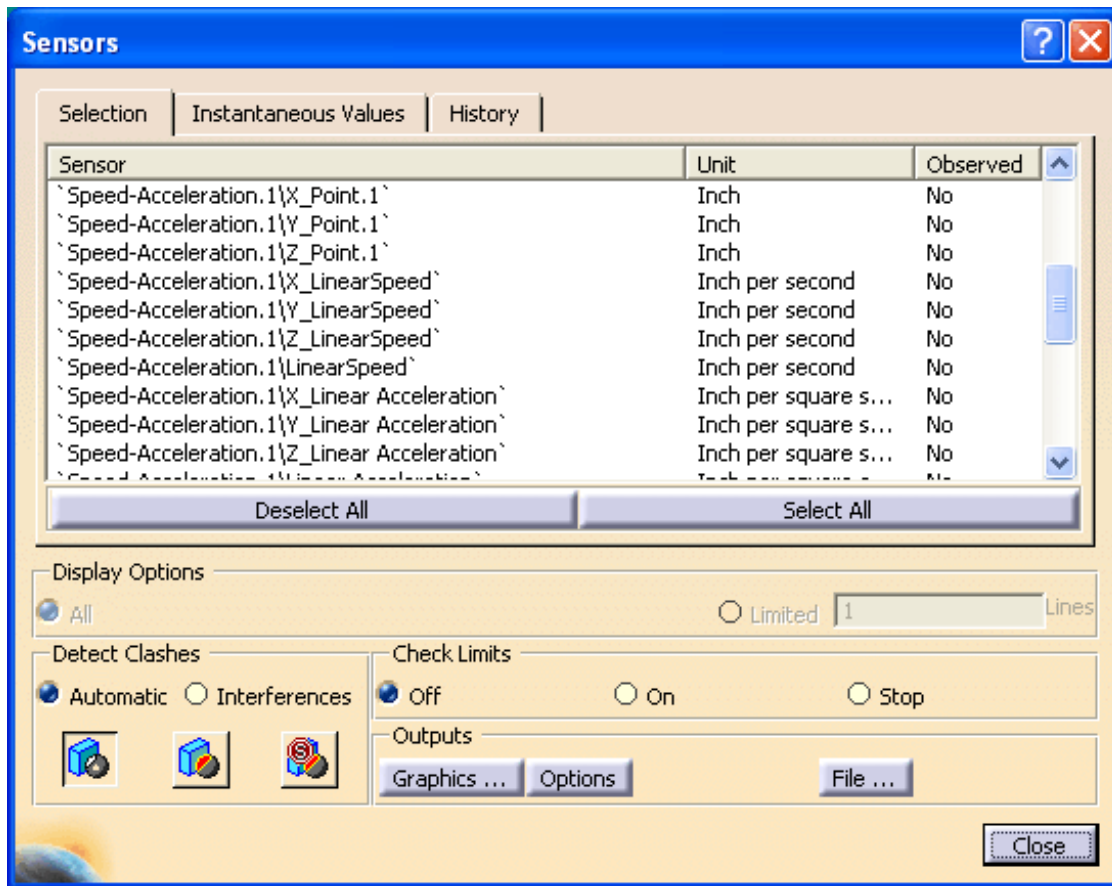
Select **OK**. *Speed-Acceleration1* appears under the *Speeds-Accelerations* branch of your mechanism.



Select the **simulation with laws icon**. It is located under the simulation with commands icon.

Select the **start icon to go to the 0 location**.  This will allow you to play the simulation from start to finish.

Select the *Activate Sensors* option. The *Sensors* window appears. You should see some speed and acceleration sensors available in the list.



Select the *Y_LinearSpeed* and *Y_Linear Acceleration* options so they will be observed. You do not need to select the other components.

Select the play forward icon. The simulation plays for 144s. Since the cam is turning at a rate of 5 degrees per second, it will perform two complete revolutions.

Select the **Graphics...** button in the **Sensors** window. The **Sensors Graphical Representation** window appears. The graphs of the speed and acceleration in the Y direction are shown.



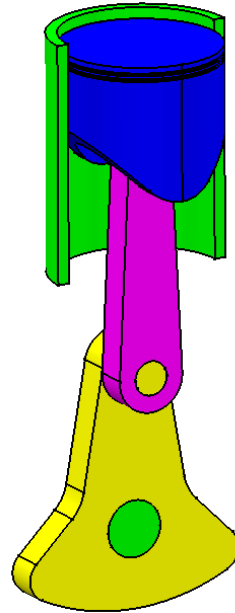
Close all of the windows.


Save and close your document.

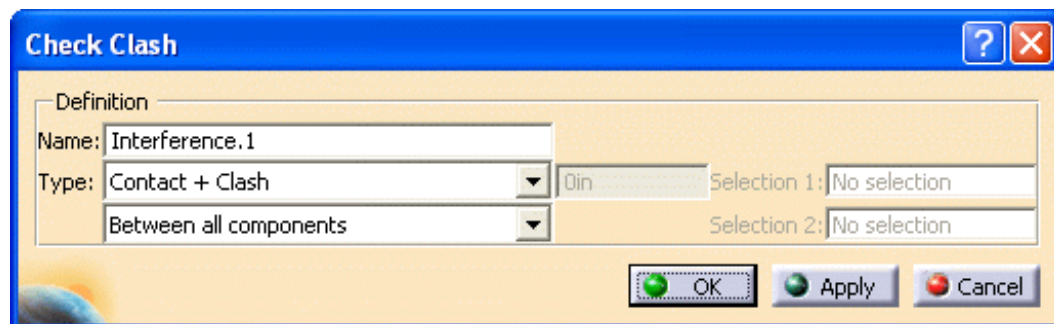
Clash and Distance

Clash detection is used to see if a kinematic simulation interferes with other geometry or itself. You have performed clash analysis before but in this case you will perform a clash analysis while the mechanism is being simulated. In addition to clash detection you can also perform a distance and band analysis while the mechanism is being simulated.

Open the *Clash* document located in the *Clash* directory. You should see a simple mechanism involving a piston. In order to perform a clash detection on the simulation you will want to define the clash analysis.



Select the clash icon.  The *Check Clash* window appears. This is the same window that you should already be familiar with.




Change the mode to *Between two selections* and select the dark blue piston as *Selection 1* and the yellow rotator as *Selection 2*. These are the only two components you are concerned with, in this exercise.

Select **Apply**. Notice that there are no clashes detected.

Select **OK**. The clash analysis appears in your specification tree as an *Interference*.

Select the simulation with commands icon.

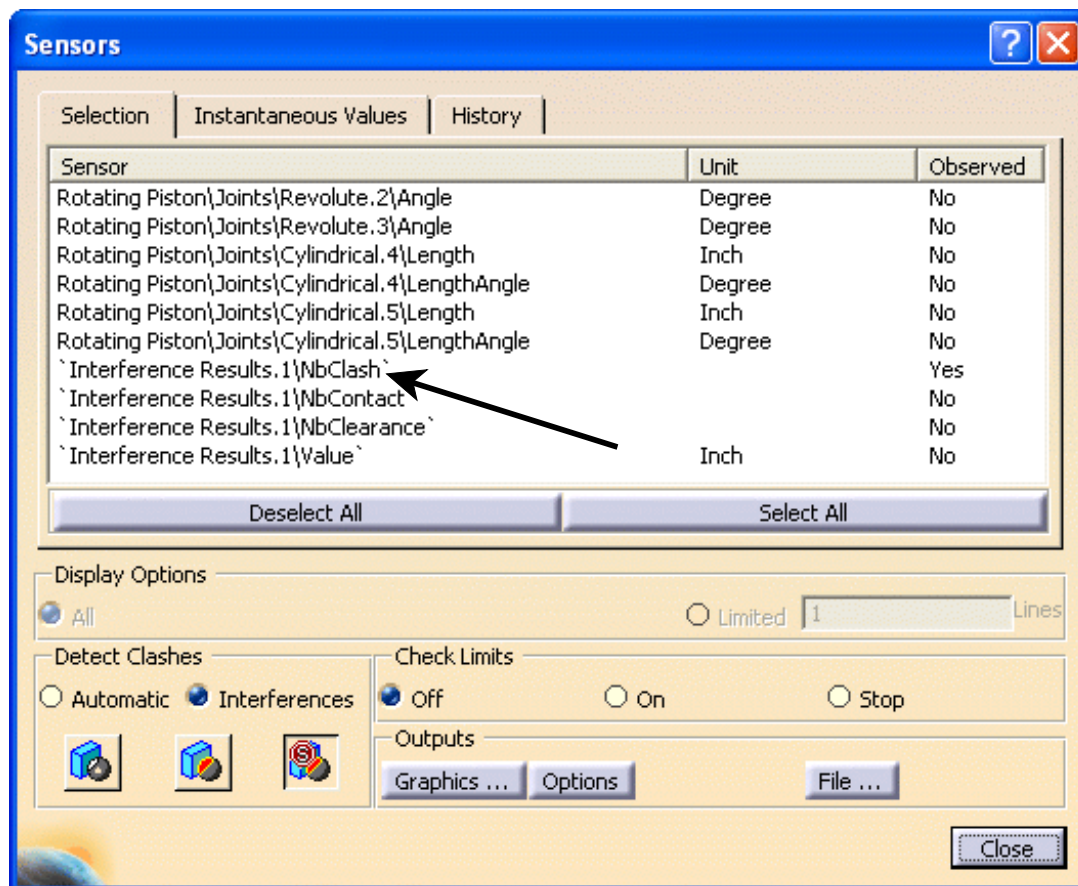
Select the *Activate Sensors* option. The *Sensors* window appears. You should see some interference sensors available.

In the *Sensors* window, under *Detect Clashes*, turn on the *Interferences* option and select the clash stop icon.  This will have the simulation stop if a clash is detected.

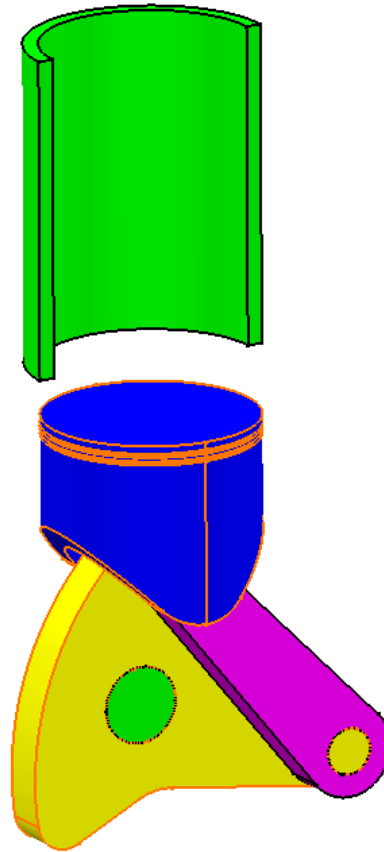
Turn on the *On request* option, drag the slider all the way to the right, change the *Number of steps* to 40 and select the play forward icon. Notice that the simulation never stopped even though the piston collided with the rotator. This is because you did not observe any of the interference sensors.

Select the start icon. This will return the simulation back to the beginning.

In the *Sensors* window, select the *NbClash* sensor. This will have the sensor observed. This sensor keeps track of how many clashes are found.



Drag the slider all the way to the right and select the play forward icon again. The simulation stops when a clash is detected. Notice the value of when it clashes, at 108 degrees.



Select the start icon again. This returns the simulation back to the beginning.

Change the *Number of steps* to 80, drag the slider all the way to the right and select the play forward icon. The simulation stops when a clash is detected. Notice that the value is now 103.5 degrees. It only checks at each step, therefore you need to increase the number of steps in order to get a more accurate limit for your command.

Drag the slider all the way to the left and select the play forward icon. Notice that it collides at around -105 degrees.

Select the *Reset* button to return to 0. You are going to change the limits of the command in order to prevent the mechanism from clashing.

Select the ... button to the right of the command. The *Slider* window appears.

Change the *Lowest value* to be -100 and the *Highest value* to be 100 and select OK. Hopefully this will allow the mechanism to run without those two parts colliding.

Drag the slider all the way to the right, change the *Number of steps* to 100 and select the play forward icon. There were no collisions.

Select the *Reset* button to return to 0. You are going to check the other direction as well.

Drag the slider all the way to the left and select the play forward icon. There were no collisions there either.

Select the *Reset* button to return the mechanism to 0. As you can see, this is a good way to determine the limits of your commands.

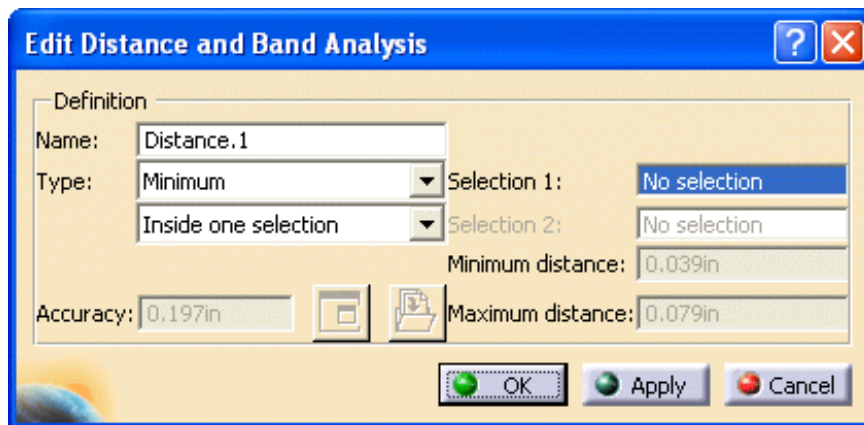
Select the *Analysis...* button in the *Kinematics Simulation* window. An *Edit Analysis* window appears. This will allow you to edit the analysis if you wanted to.

Select *Interference.1* from the window and select the *Browse*. The *Check Clash* window appears for this clash analysis.

Select *Cancel* and *Close* the *Edit Analysis* window.

Close the *Kinematics Simulation* window. You are going to create a distance analysis and observe its value during simulation.

Select the distance and band analysis icon.  The *Edit Distance and Band Analysis* window appears. This is the same window that you should already be familiar with.



Change the mode to *Between two selections* and select the dark blue piston as *Selection 1* and the yellow rotator for *Selection 2* and select *Apply*. A distance of 3.509 is computed.

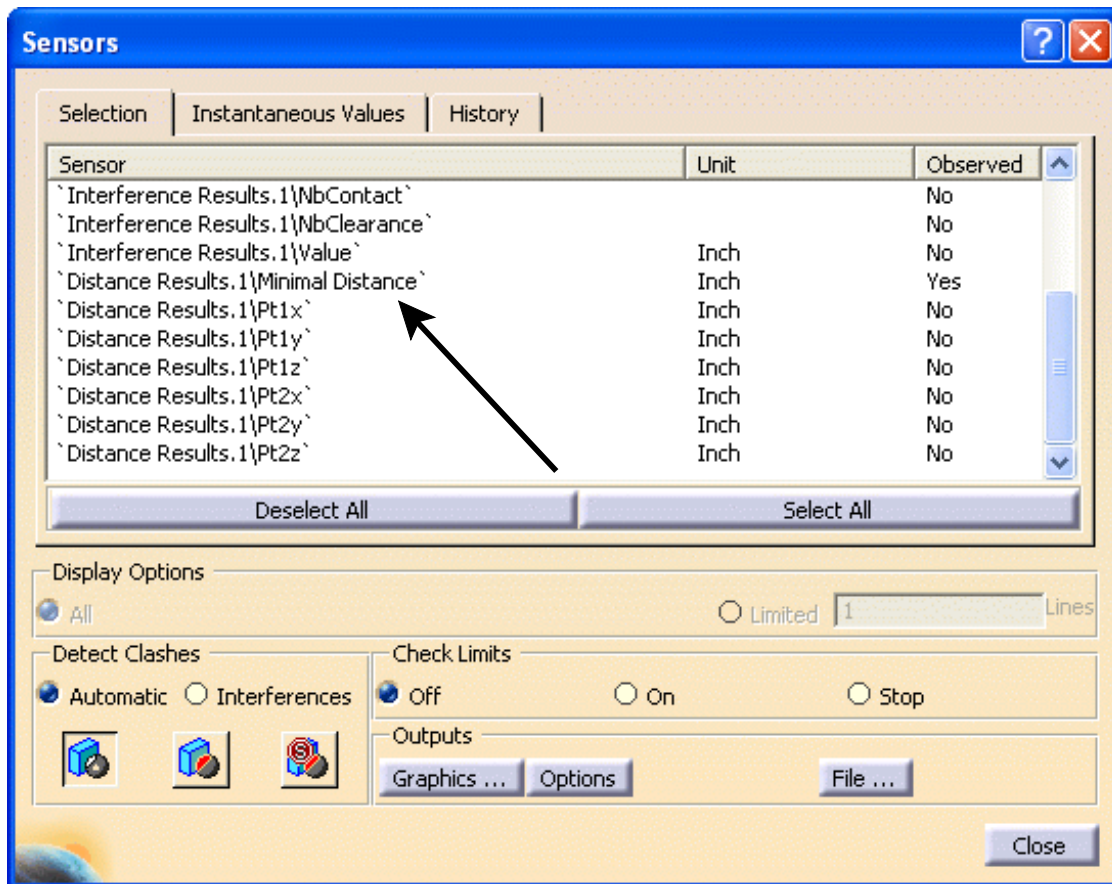
Select *OK*.

Select the simulation with commands icon. You are going to observe the distance and then graph it.

Select the *Immediate* option and drag the slider all the way to the left. This should rotate your mechanism to -100 degrees.

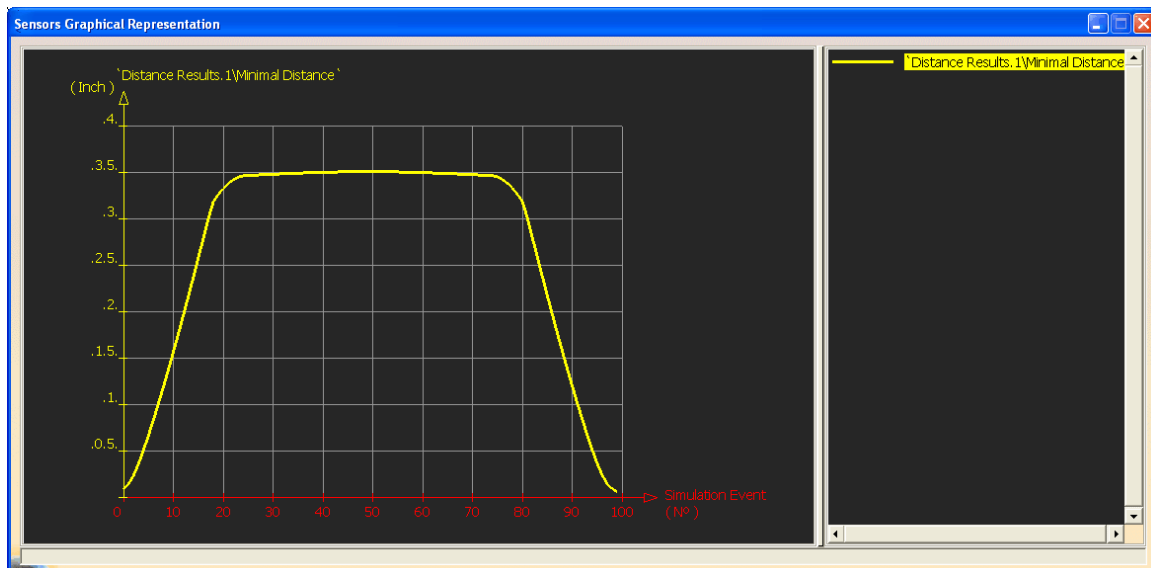
Select the *Activate Sensors* option. The *Sensors* window appears. You should see some distance sensors.

Select the *Minimal Distance* sensor to be observed.



Turn on the *On request* option, drag the slider all the way to the right and select the play forward icon.

Select the *Graphics...* button in the *Sensors* window. A graph of the distance values is shown.



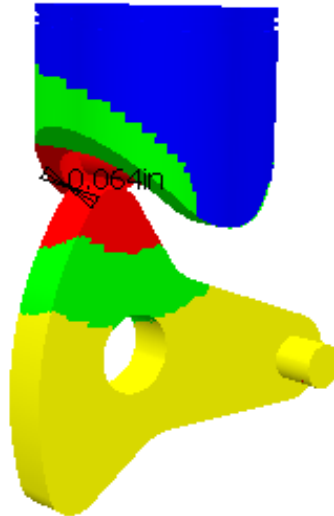
Close all the windows.

Select the distance and band analysis icon again.  The *Edit Distance and Band Analysis* window appears.

Change the type to *Band analysis* and the mode to *Between two selections*.

Select the dark blue piston as *Selection 1* and the yellow rotator as *Selection 2*.

Change the *Minimum distance* to 1 inch and the *Maximum distance* to 2 inches and select *Apply*. The band analysis is performed.



Select *OK*.

Select the simulation with commands icon and select *Activate Sensors*. The *Sensors* window appears.

Turn off the *Minimal Distance* sensor for *Distance.1* and turn on the *Minimal Distance* sensor for *Distance.2*.

Drag the slider all the way to the left and select the play forward icon. You will notice that the simulation runs real slow while the band is updating and then it runs fast when the distance exceeds the band. This is due to the amount of calculation that has to be done in order to color code the band.

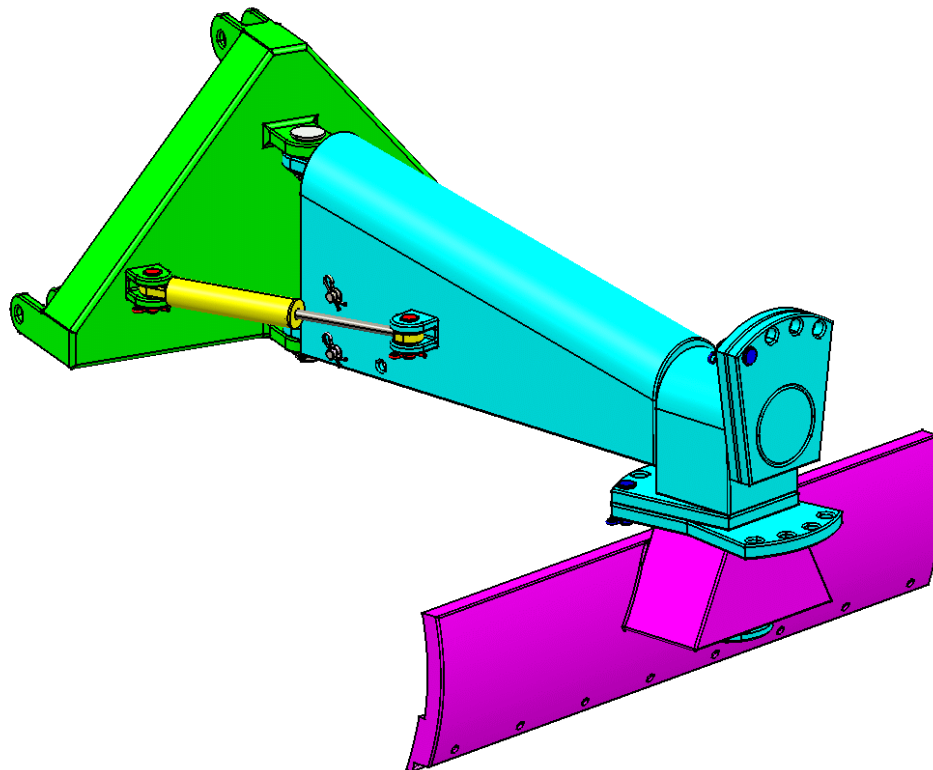
Close all of the windows.

Save and close your document.

Joint Limits

Earlier you set limits on your command. However, there are times when you also need to set limits on the joints themselves. There could be a maximum and minimum value an object is allowed to move as the mechanism is operating. In cases such as these, you need to determine the limits of the command in order for the object to stay within those values.

Open the *Joint Limits* document located in the *Joint Limits* directory. You should see a mechanism with a cylinder attached to it.



Select the simulation with commands icon, select *On request*, drag the slider all the way to the left, change the *Number of steps* to 40 and select play forward. You will notice that the piston leaves the cylinder.

Select the *Reset* button and select *Close*. You are going to put limits on the joint that controls the motion of the piston.

Double select the *Cylindrical.16* joint. The *Joint Edition* window appears.

Under *Joint Limits*, turn on the *1st Lower Limit* and the *1st Upper Limit* options. You can specify values for these limits.

Change the value of the lower limit to -13 and the value of the upper limit to 0 and select *OK*. This will not affect the limits of the revolutes that is driving the mechanism.

Select the simulation with commands icon and select *Activate Sensors*. The *Sensors* window appears.

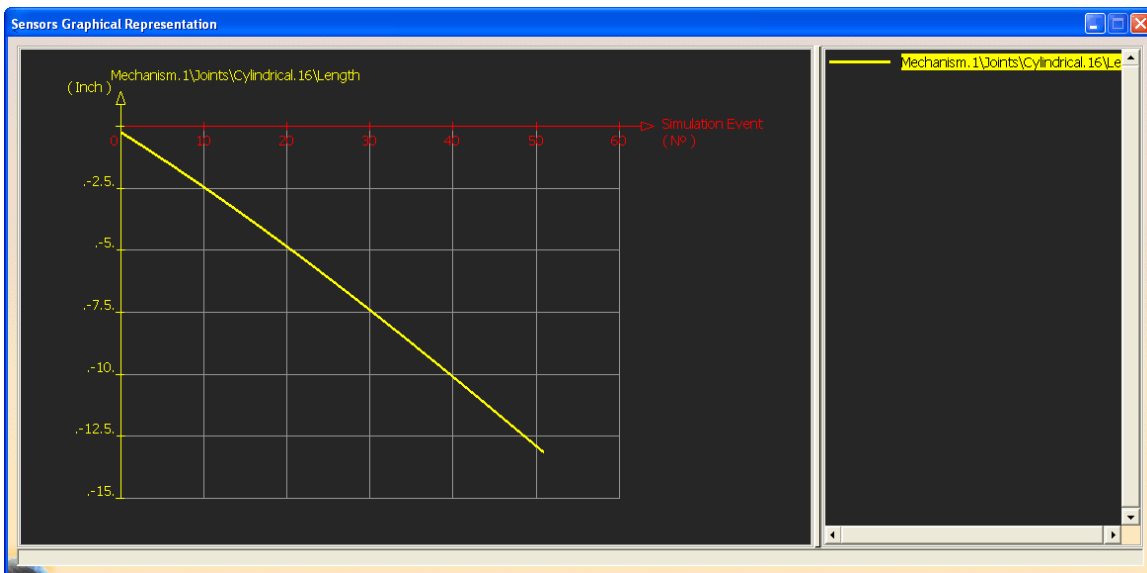
In the *Sensors* window, under *Check Limits*, turn on the *Stop* option. This will cause the simulation to stop when a joint limit is reached.

Turn on the *Cylindrical.16\Length* sensor to be observed.

Drag the slider all the way to the left, change the *Number of steps* to 360 and select the play forward icon. The simulation stops at -52 degrees.

Select the *Instantaneous Values* tab in the *Sensors* window. The value of the joint is just a little over -13. This is fine since the real limit is -13.25 inches and it is within that amount.

Select the *Graphics...* button. A graph of the length of the joint is shown.



Close the *Sensors Graphical Representation* window.

Select the *Reset* button in the *Kinematics Simulation* window. This will reset your mechanism back to 0.

Clear the *History* and select the *On* option under *Check Limits* in the *Sensors* window.

Drag the slider all the way to the left, change the *Number of steps* to 180 and select the play forward icon.

In the *Sensors* window, select the *History* tab and scroll down through the values. You should see an area where it tells you the lower limit has been reached and an area where it tells you the upper limit has been reached.

Close the *Sensors* window and select the *Reset* button in the *Kinematics Simulation* window.

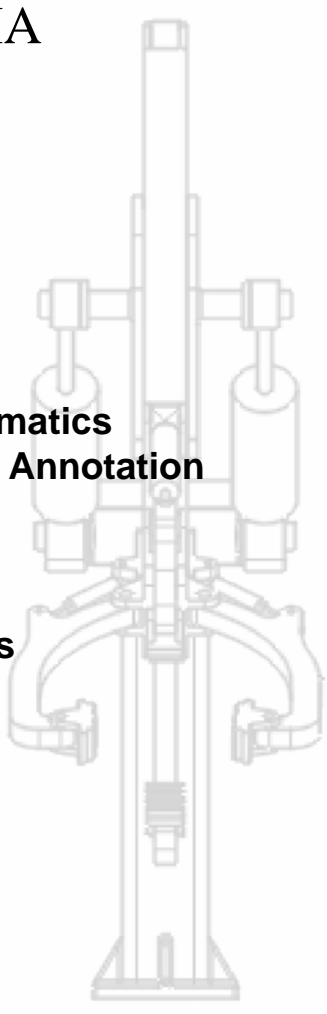
Change the limits of the command so it has a range of -52 to 0 and then select *Close*.

Save and close your document.



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