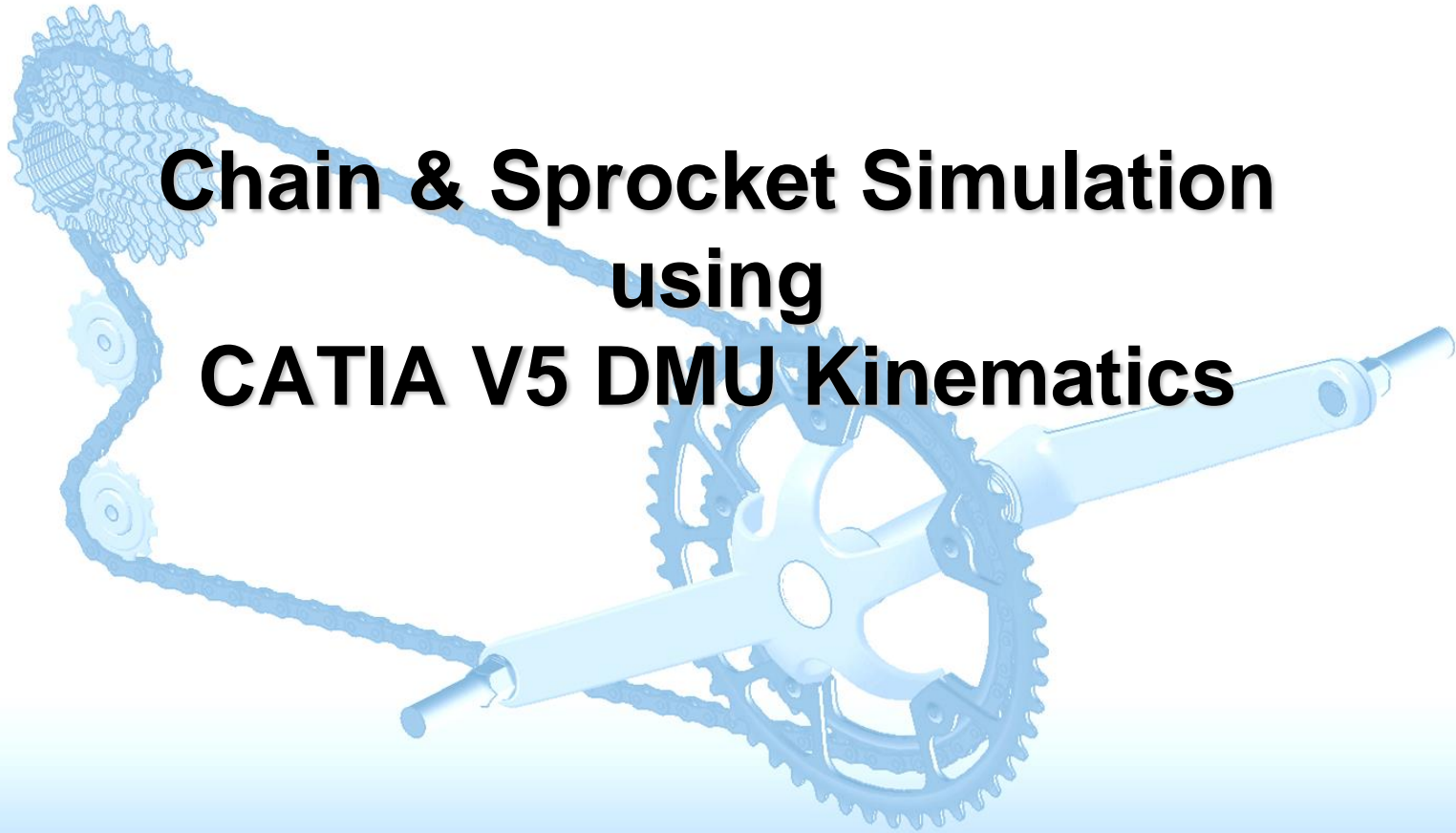
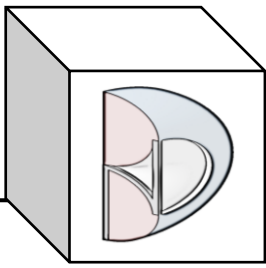


BND TechSource

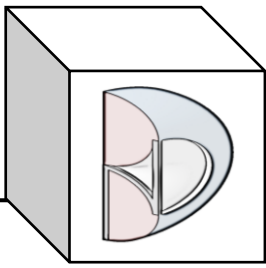


Chain & Sprocket Simulation using CATIA V5 DMU Kinematics

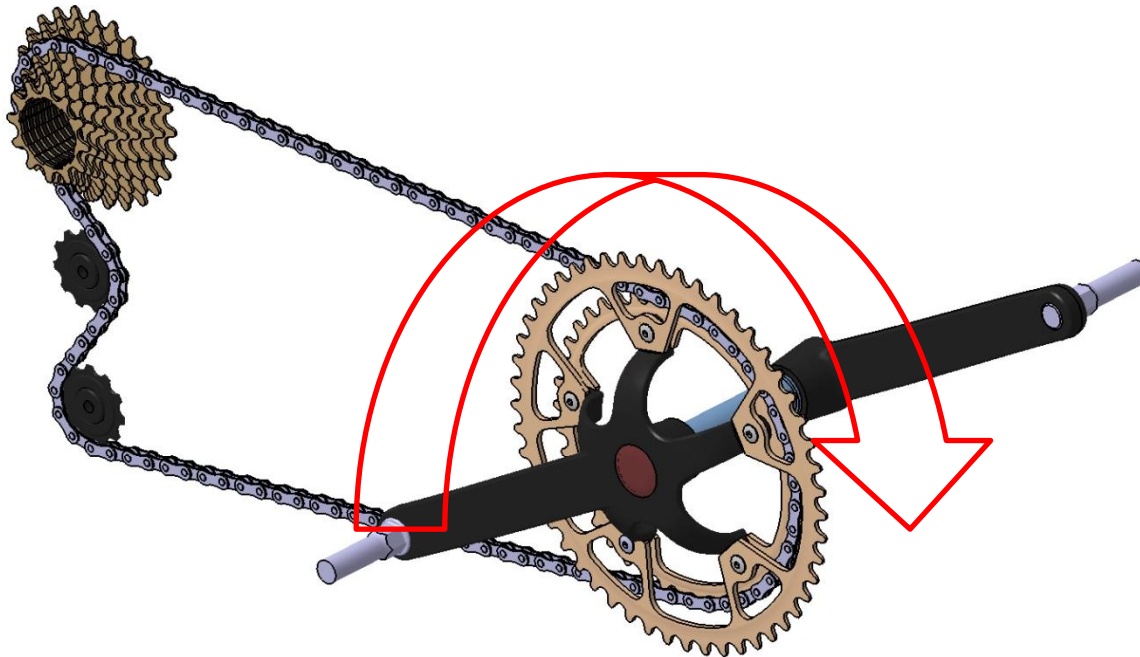


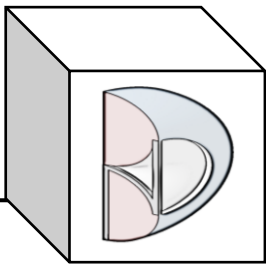


- The following licenses are required to simulate Chain & Sprocket movement with CATIA V5 DMU Kinematics:
 - Digital Mockup + DMU Kinematics
 - Mechanical Design + Part Design
 - Mechanical Design + Assembly Design

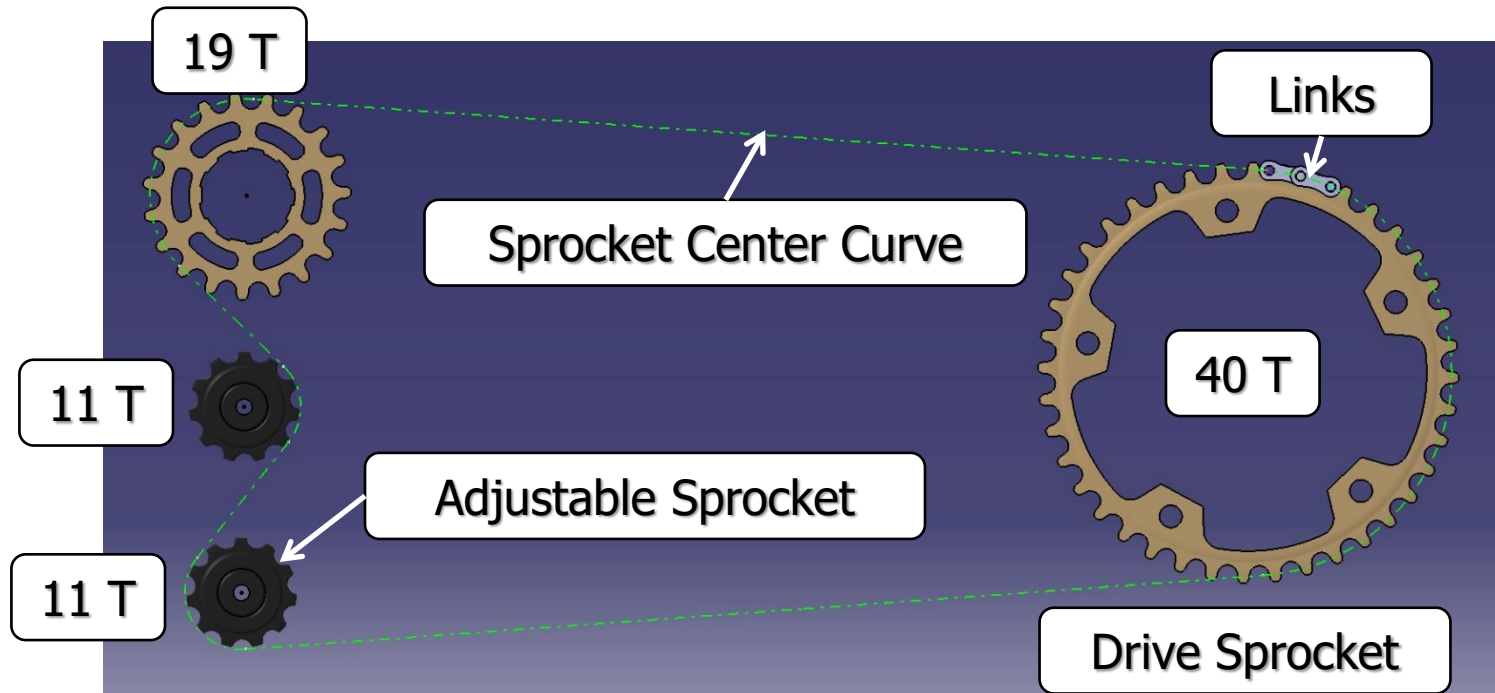


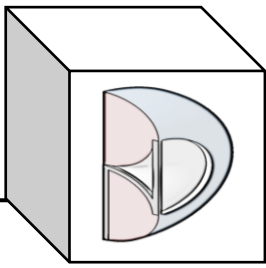
- The end result we are trying to achieve is to simulate the movement of a bicycle chain around the sprockets.



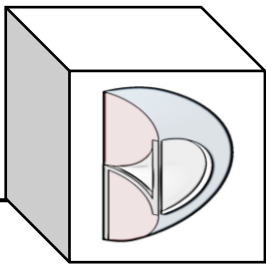


- There are certain known values when you begin your simulation.

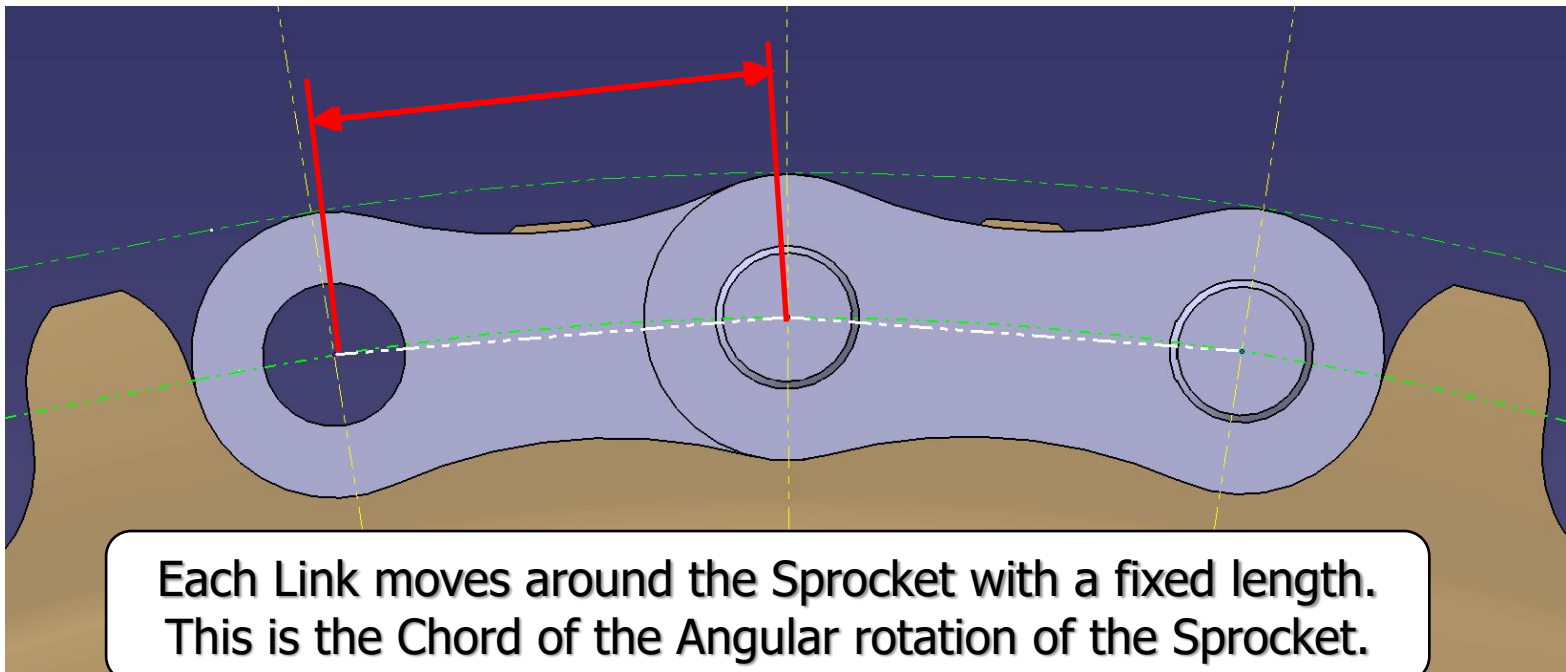


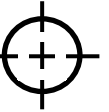
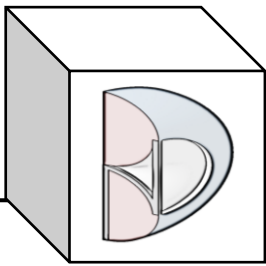


- Known values:
 - Sprocket sizes (number of teeth)
 - Sprocket placement (center to center)
 - Sprocket adjustability (lower derailleur)
 - Link size (12.7mm)
 - Total Number of Links (106)
- These values will help set up the Sprocket Center Curve.

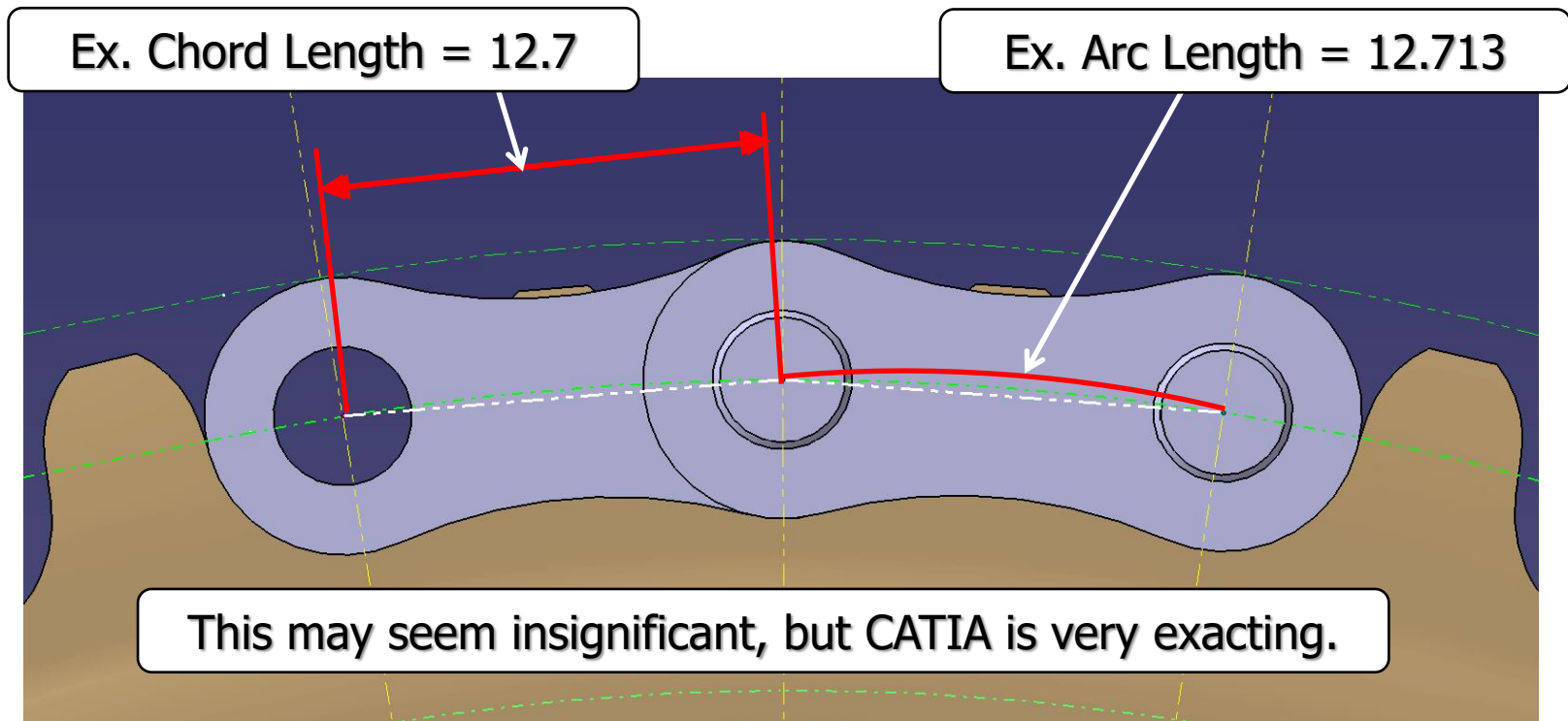


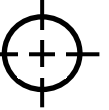
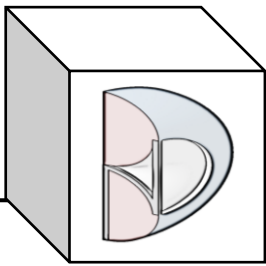
- To accurately simulate the chain movement around the sprockets, you must first understand the chordal relationship of the Link to the Sprocket.



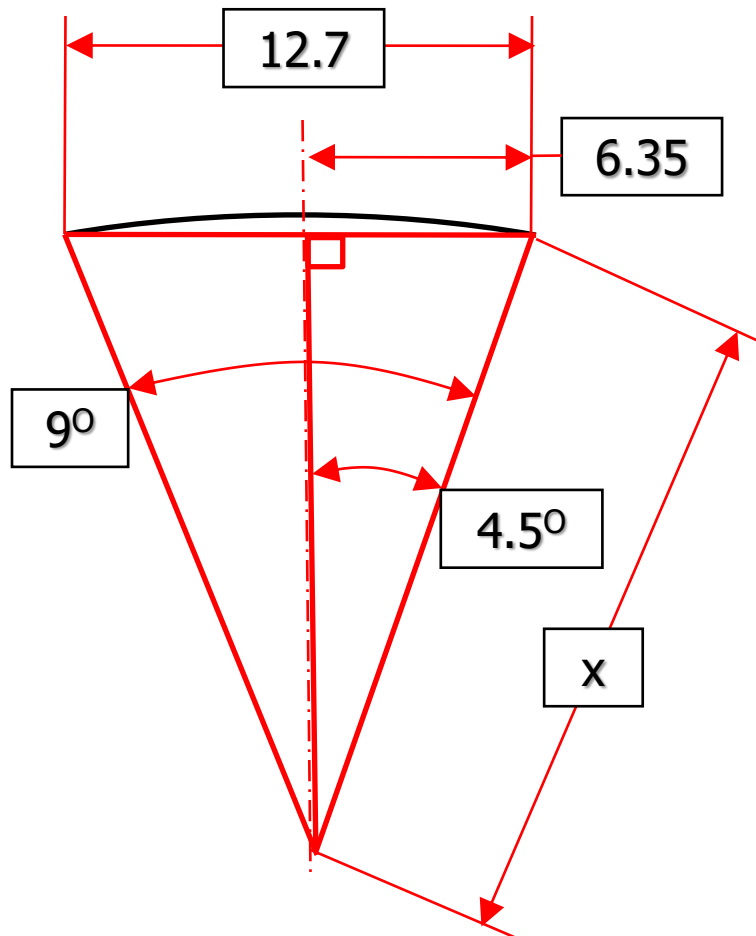


- The Chord length is not the same as the Arc length.





- Time for some trigonometry...



Ex. 40T Drive Sprocket:

$$360^\circ / 40 = 9^\circ$$

Chord Length = 12.7

Radius = x

$$\sin^{-1}(6.35/x) = 4.5^\circ$$

$$x = (6.35/\sin 4.5^\circ)$$

$$x = 80.934\text{mm}$$

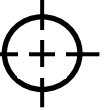
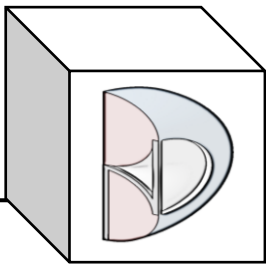
$$\text{Circumference} = 2\pi R = 508.523\text{mm}$$

Arc Length =

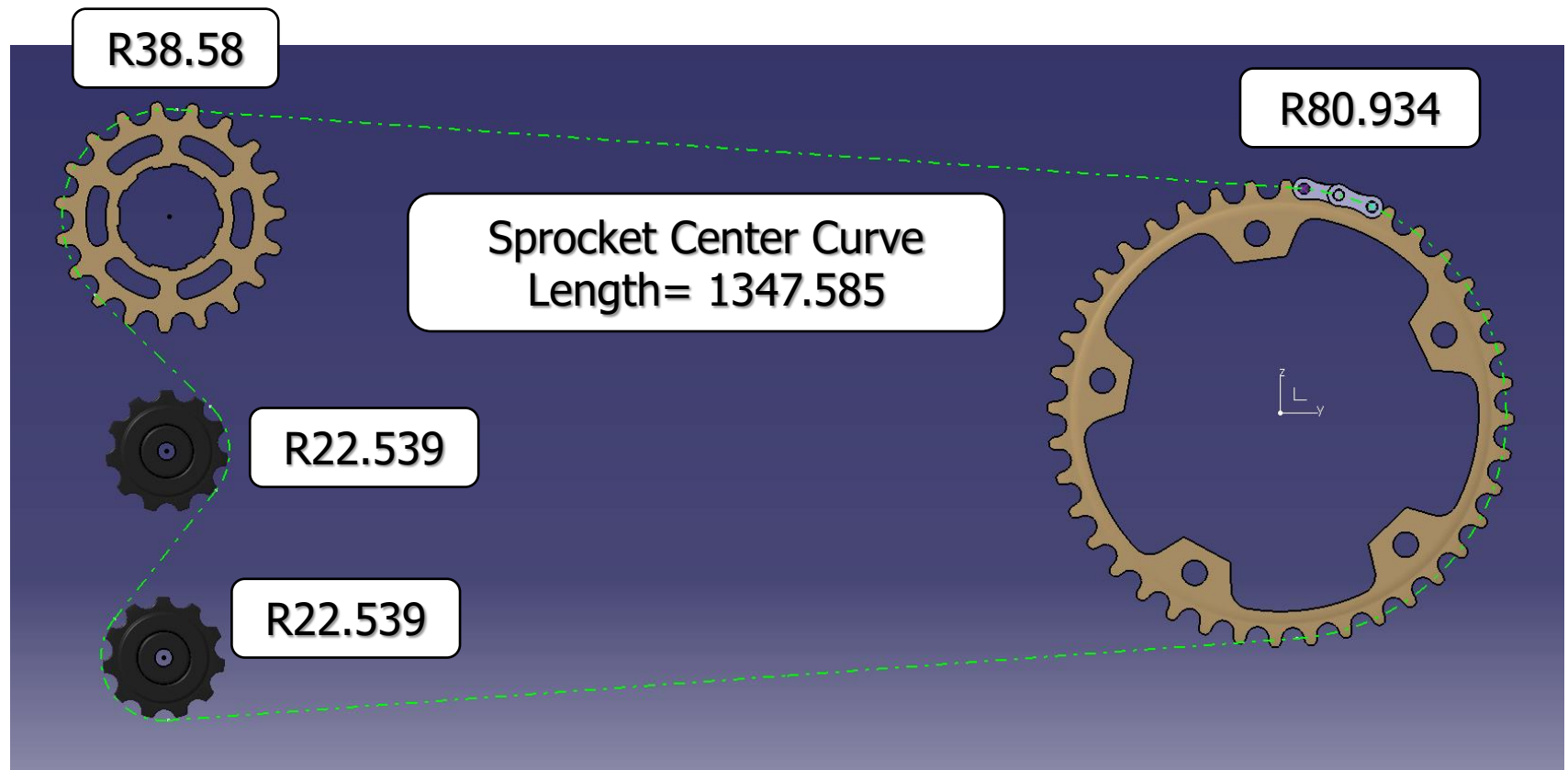
$$508.523/40 = 12.713066$$

Sprocket Center Curve =

$$106 * 12.713066 = 1347.585\text{mm}$$



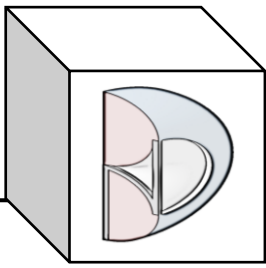
- Now we have the information to proceed.



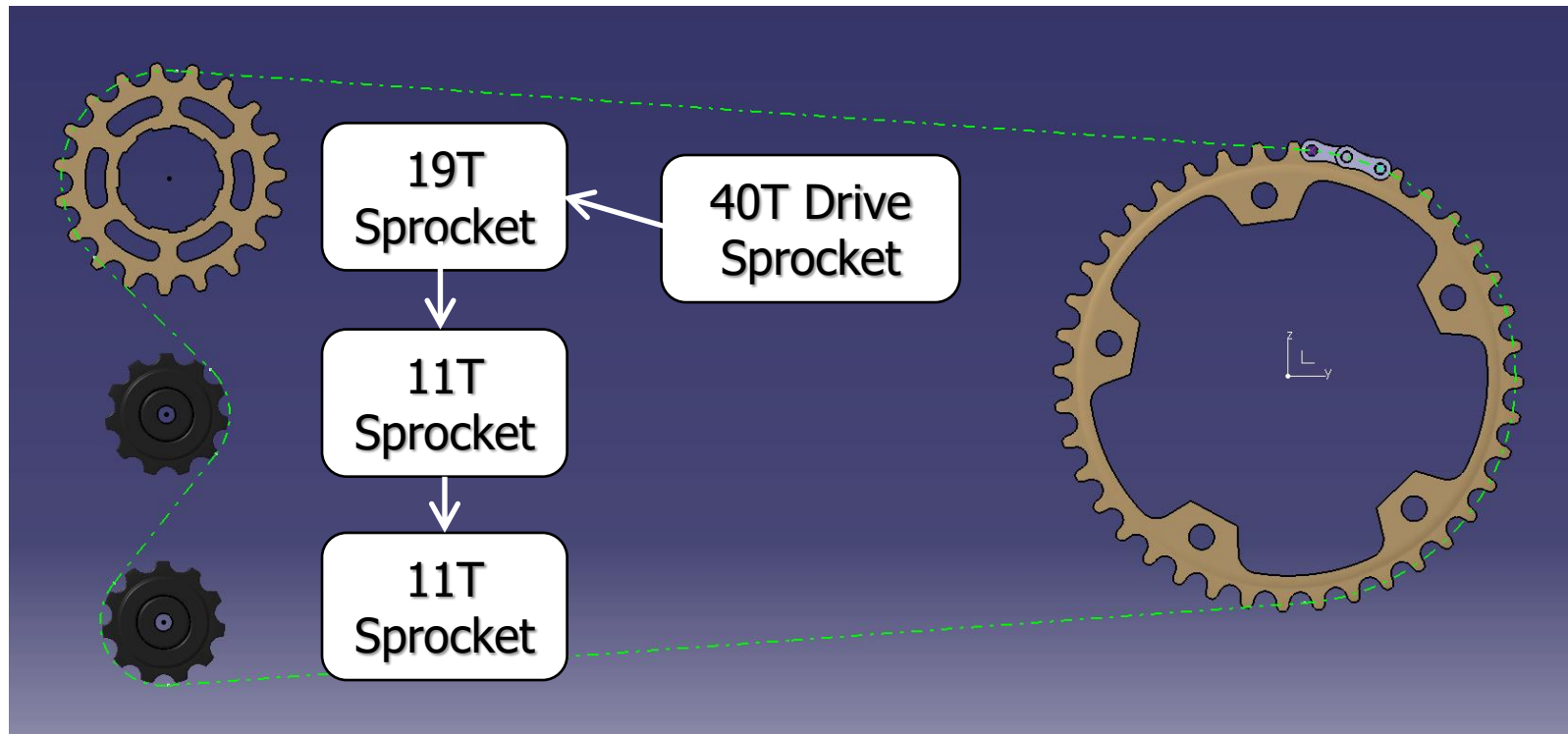


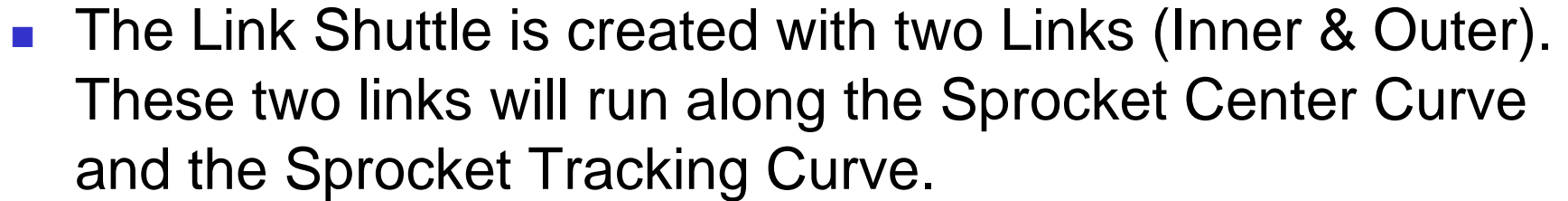
- Here are the Joints and Commands to run the Simulation (Laws come later).

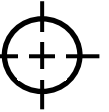
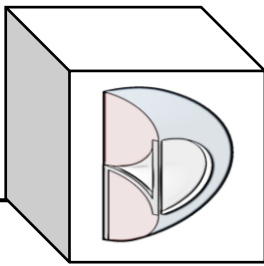




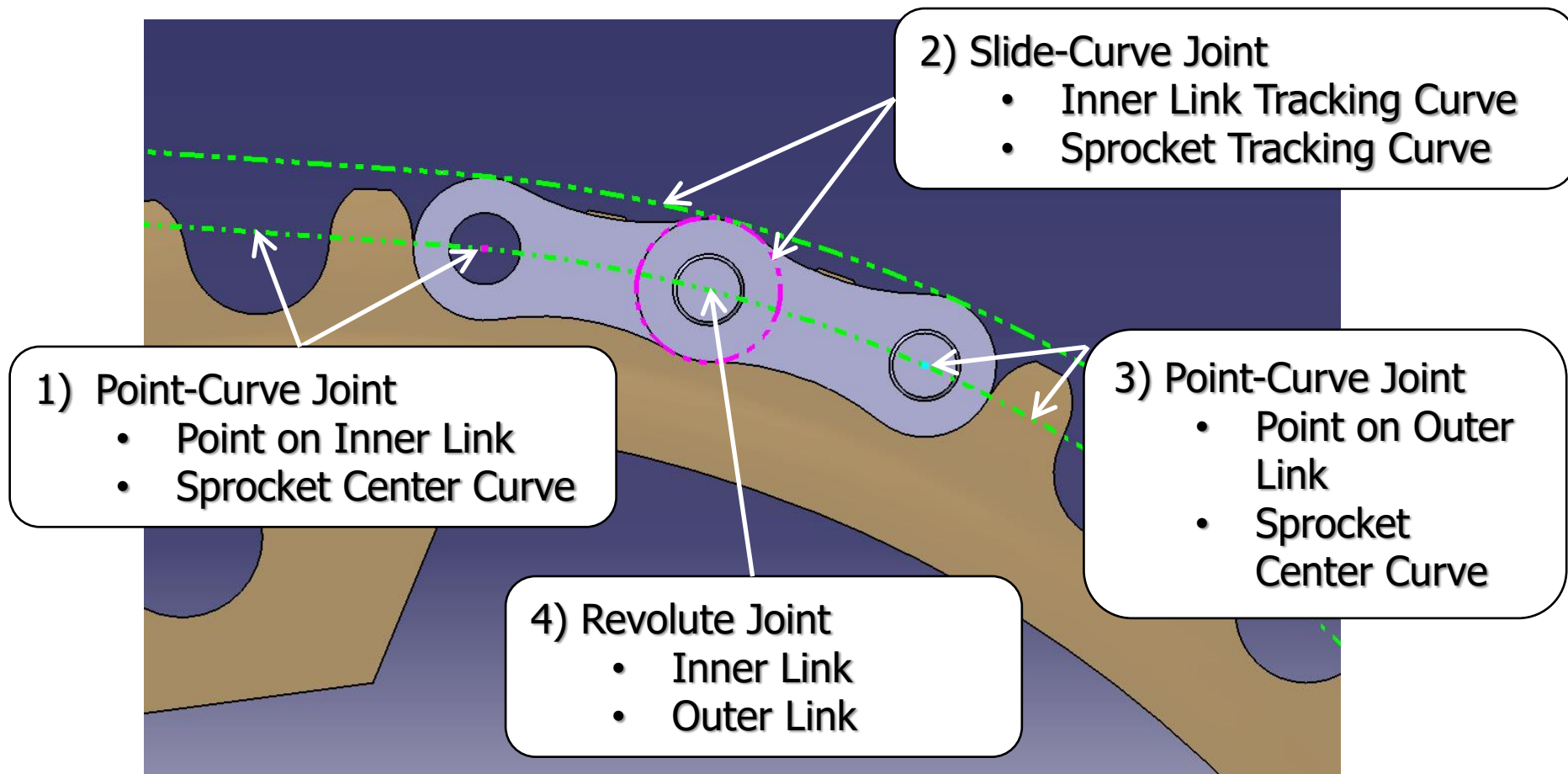
- The Gear Joints for the Sprockets will begin with the normal ratio (ex. $40T/19T=2.105$).

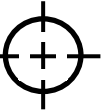
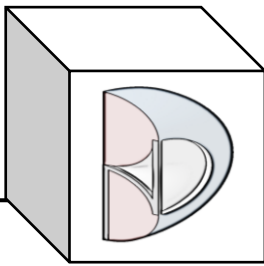




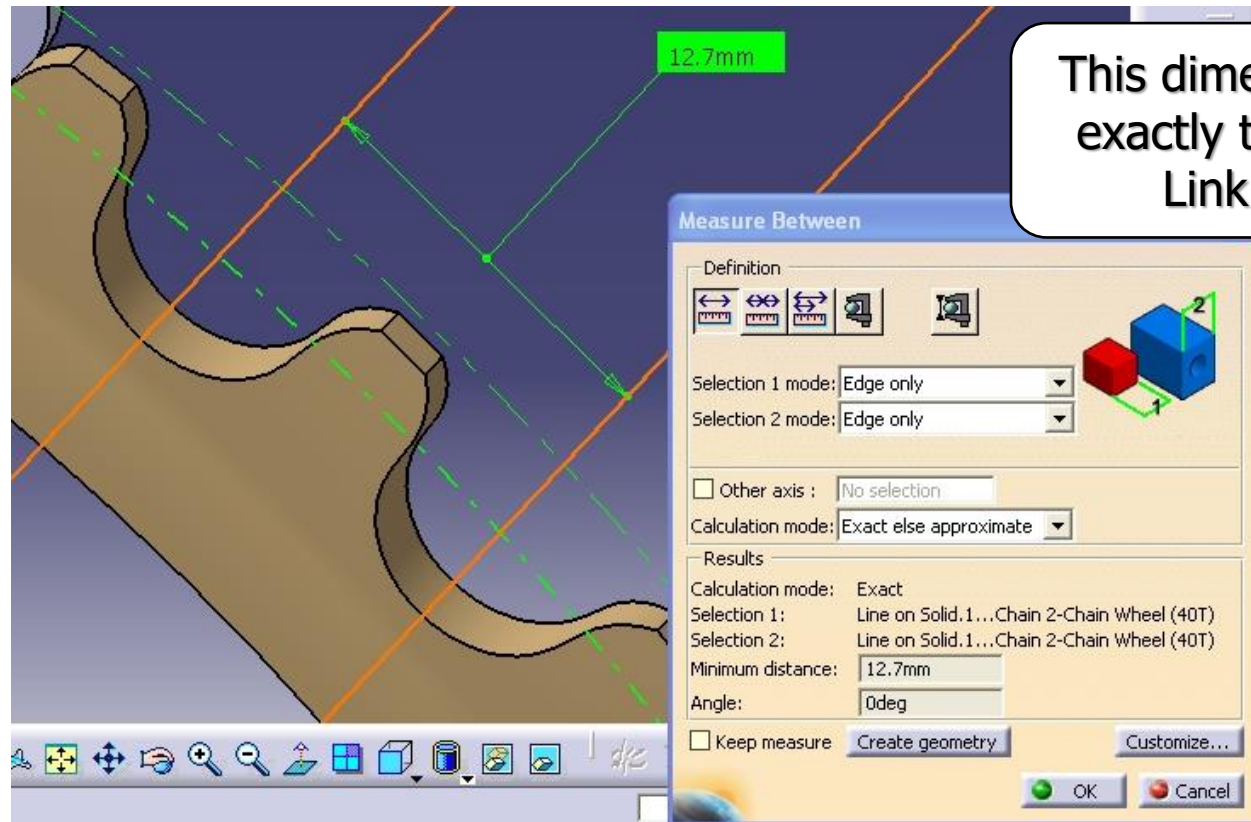


- There will be four Joints in the Link Shuttle .

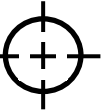
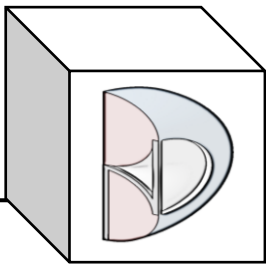




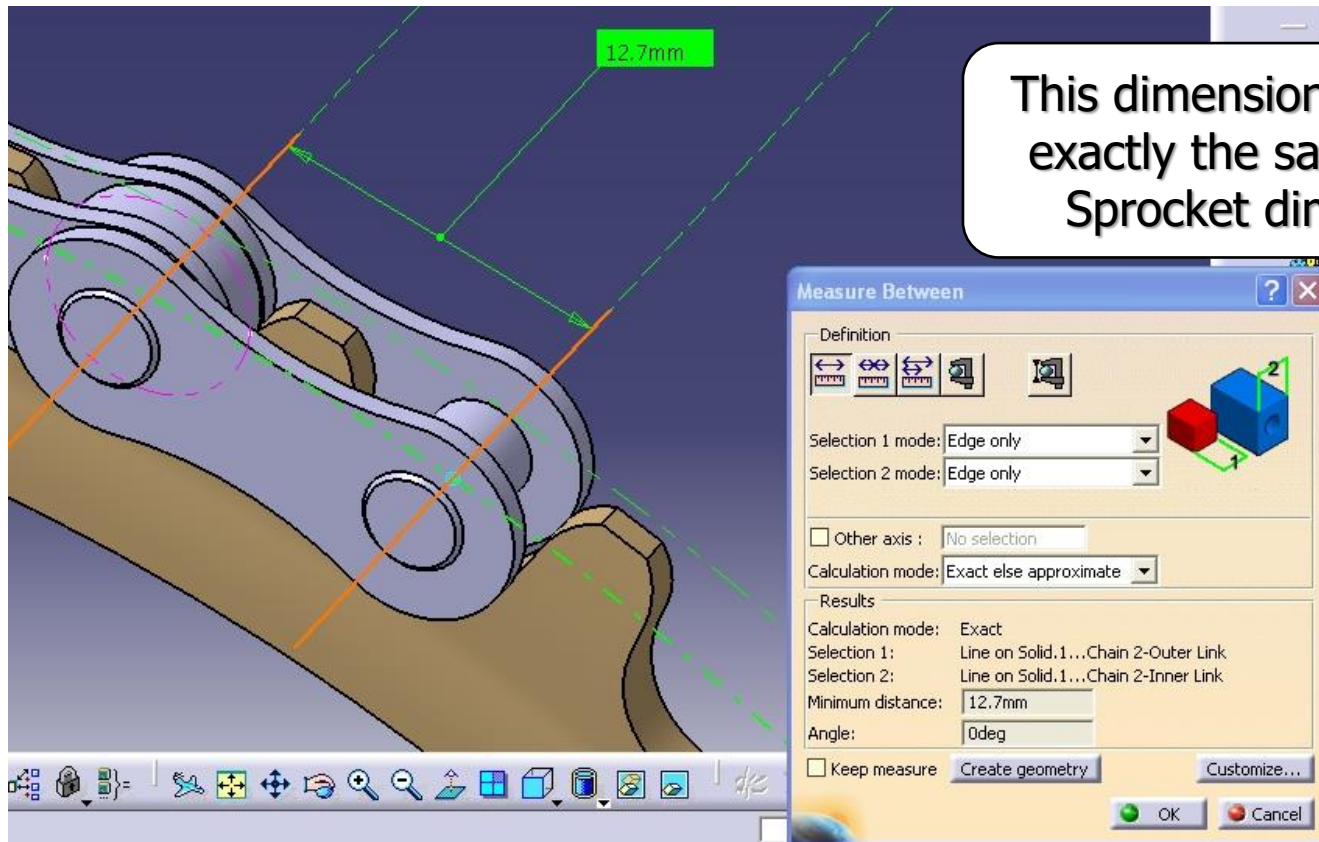
- Check Sprocket tooth-to-tooth centerline dimensions.

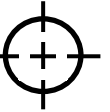
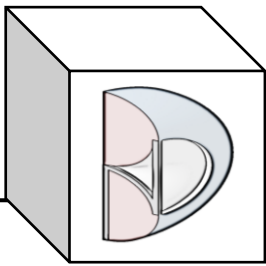


This dimension should be exactly the same as the Link dimension.

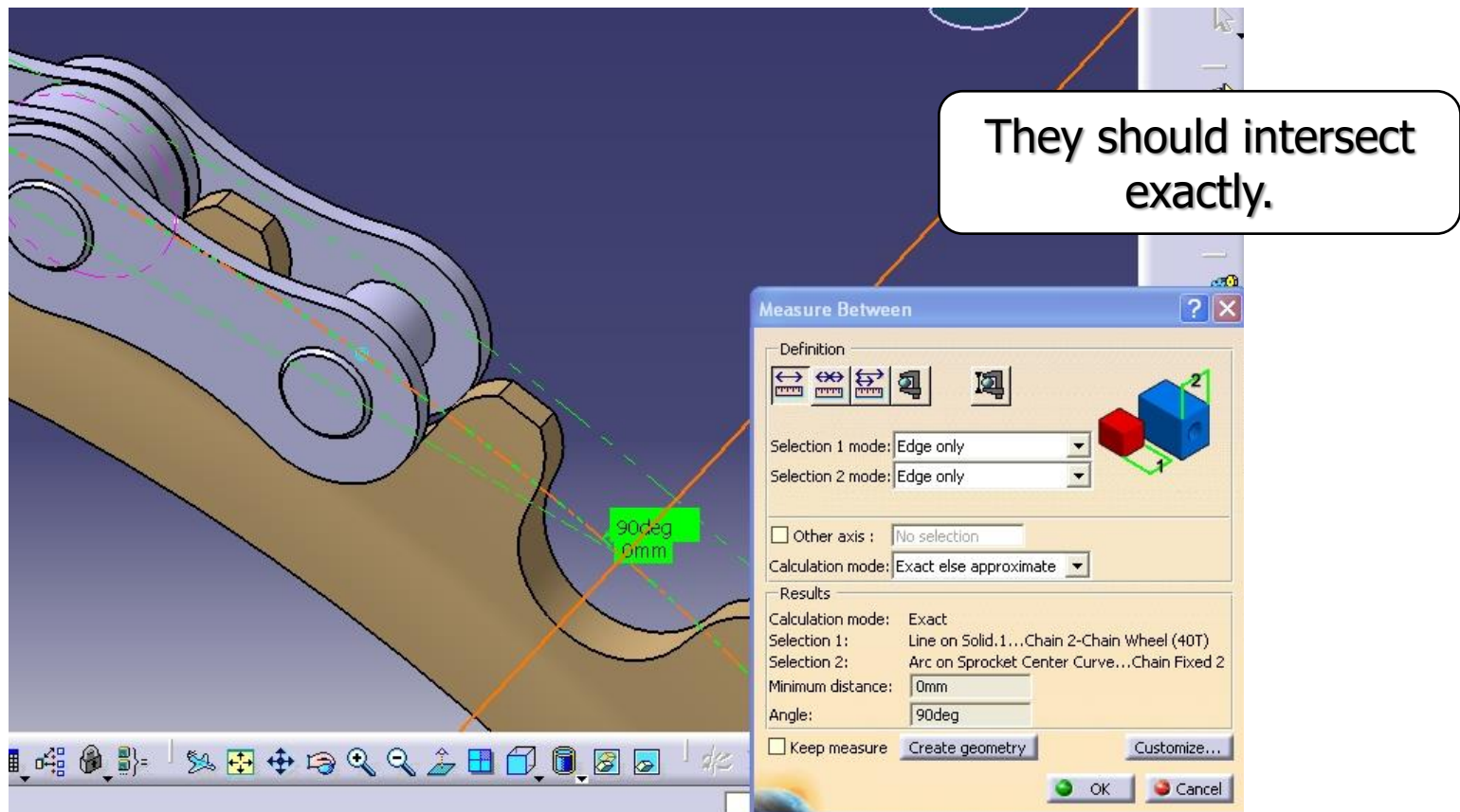


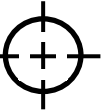
- Check Link roller-to-roller centerline dimensions (for both Links).



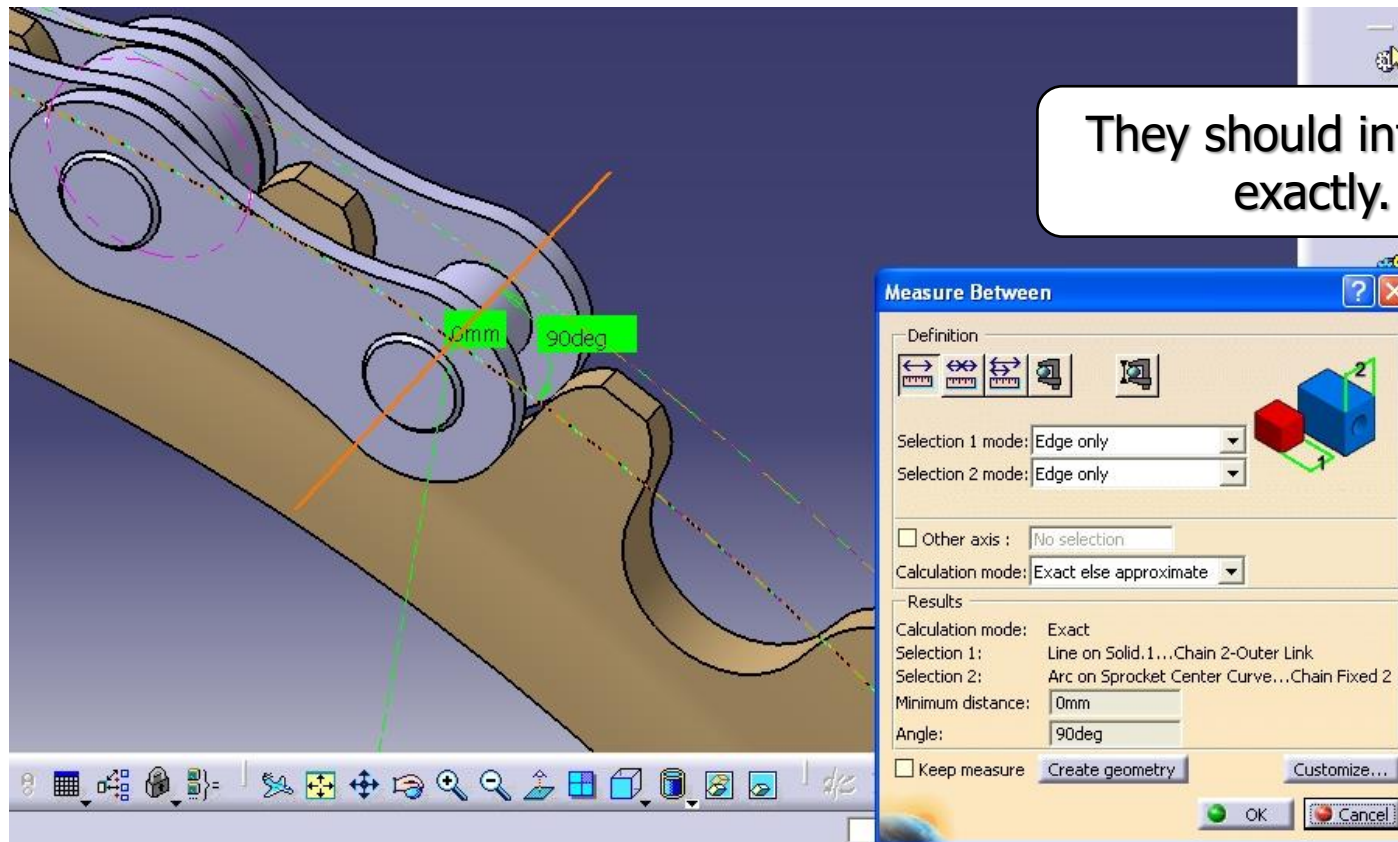


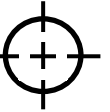
- Check Drive Sprocket tooth centerline to the Sprocket Center Curve.



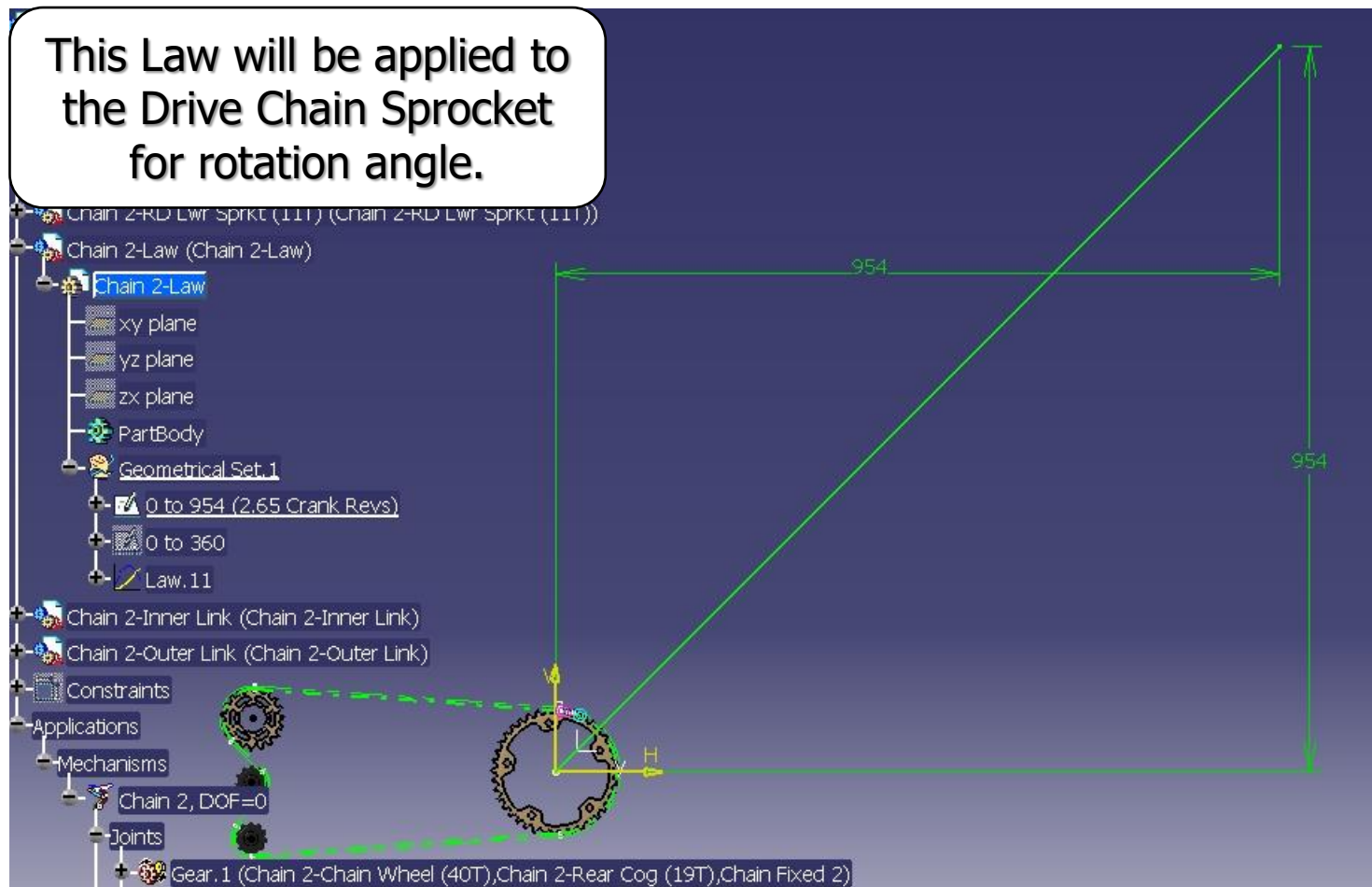


- Check Link roller centerline to the Sprocket Center Curve.





- Create a Law Sketch 954 x 954 (106 x 90°).





■ Apply the Law to the Gear Command.

a) Double pick the Command.

b) Pick Link.

c) Pick the Law Sketch.

d) Pick OK.

Command Edition: Chain Wheel Rotation...

Command name: Chain Wheel Rotation
Command value: 0deg $f(x)$

Reset to Zero

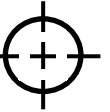
Law Management

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

OK Cancel

Chain Wheel Rotation: 'Chain 2\Commands\Chain Wheel Rotation\Angle1' = 'Chain 2-Law\Geometrical Set.1\Law.11'.Evaluate('Chain 2\KINTime'/10s)*1deg

Formula.14: 'Chain 2\Commands\Link Shuttle\Length' = 1344.896mm + 'Chain 2\Commands\Chain Wheel Rotation\Angle1' * 80.93389225mm



- Apply a Formula to the Shuttle Command.

a) Double pick the Command.

b) Right click inside the Command value box.

c) Hold cursor over Formula.

d) Drop cursor onto Edit.

Command Edition: Link Shuttle (Length)

Command name: Link Shuttle

Command value: 1344.896mm

Edit...
Deactivate
Delete

Formula
Edit Comment...

OK Cancel

Chain 2-Inner Link (Chain 2-Inner Link)
Chain 2-Outer Link (Chain 2-Outer Link)
Constraints
Applications
Mechanisms
Chain 2, DOF=0
Joints
Gear.1 (Chain 2-Inner Link, Chain Fixed 2)
Gear.2 (Chain 2-Inner Link, Chain Fixed 2)
Gear.5 (Chain 2-Inner Link, Chain Fixed 2)
Revolute.4 (Chain 2-Outer Link, Chain 2-Inner Link)
Point Curve.5 (Chain 2-Inner Link, Chain Fixed 2)
Slide Curve.6 (Chain 2-Inner Link, Chain Fixed 2)
Point Curve.7 (Chain 2-Outer Link, Chain Fixed 2)
Commands
Chain Wheel Rotation (Gear.1, Angle 1)
Link Shuttle (Point Curve.5, Length)
Fix Part (Chain Fixed 2)
Laws
Chain Wheel Rotation: 'Chain 2\Commands\Chain Wheel Rotation\Angle1' = 'Chain 2-Law\Geometrical Set.1\Law.11'.Evaluate('Chain 2\KINTime'/10s)*1deg
Formula.14: 'Chain 2\Commands\Link Shuttle\Length' = 1344.896mm + 'Chain 2\Commands\Chain Wheel Rotation\Angle1' * 80.93389225mm



- Apply a Formula to the Shuttle Command (cont'd).

1344.896mm+'Chain 2\Commands\Chain Wheel Rotation\Angle1'*80.93389225mm

The start point of the Sprocket Center Curve is 1344.896 from the Link Shuttle Point.

a) Type this value with mm followed by +

b) Pick the Drive Sprocket Command.

c) Double pick this text to place it into the Formula.

d) Type the Radius value followed by mm.

e) Pick Ok.

Formula Editor: 'Chain 2\Commands\Link Shuttle\Length'

Chain 2\Commands\Link Shuttle\Length = 1344.896mm+'Chain 2\Commands\Chain Wheel Rotation\Angle1'*80.93389225mm

Dictionary: Parameters, Design Table, Operators, Pointer on value function: Point Constructors

Members of Parameters: All, Renamed parameters, Angle

Members of All: Chain 2\Commands\Chain Wheel Rotation\Angle1

Chain Wheel Rotation (Gear.1,Angle.1)

Link Shuttle (Point Curve.5,Length)

Fix Part (Chain Fixed 2)

Chain Wheel Rotation: 'Chain 2\Commands\Chain Wheel Rotation\Angle1' = 'Chain 2\Law\Geometrical Set.1\Law\Time'/10s)*1deg

Formula.14: 'Chain 2\Commands\Link Shuttle\Length' = 1344.896mm+'Chain 2\Commands\Chain Wheel Rotation\Angle1'*80.93389225mm



- Apply a Formula to the Shuttle Command (cont'd).

You will get this Syntax Warning.

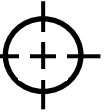
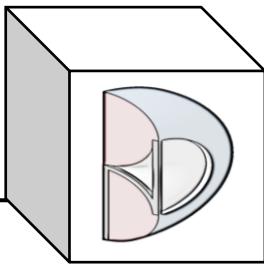
Syntax Warning :

Units are not homogeneous (operator between mrad and m).
We advise you to precise units for constants, otherwise
the International System Units will be the default.
(Ex: 10->10mm or MyRealParameter->MyRealParameter*1mm)

OK

-Do not be alarmed.
-It is telling you that you must be precise when converting angular measurement to length measurement.
-This is why it is important to add the mm to your Formula. Else it will assume meters!

Formula.14: 'Chain 2\Commands\Link Shuttle\Length'=1344.896mm+ 'Chain 2\Commands\Chain Wheel Rotation\Angle1 '*80.93389225mm



■ Run the Kinematic with Laws.

Pick Simulation with Laws Icon.

When you run the simulation, the Links should end exactly where they began.

Kinematics Simulation - Chain 2

Mechanism: Chain 2

Start 0 10 10.000

Number of steps: 40

Analysis...

☐ Activate sensors ☐ Plot vectors

Close

Chain 2, DOF=0

Chain 2-Inner Link (Chain 2-Inner Link)

Chain 2-Outer Link (Chain 2-Outer Link)

Constraints

Applications

Mechanisms

Gear.1 (Chain 2-Chain Wheel (40T),Chain 2-Rear Cog (19T),Chain Fixed 2)

Gear.2 (Chain 2-Rear Cog (19T),Chain 2-RD Upr Sprkt (11T),Chain Fixed 2)

Gear.5 (Chain 2-RD Upr Sprkt (11T),Chain 2-RD Lwr Sprkt (11T),Chain Fixed 2)

Revolute.4 (Chain 2-Outer Link,Chain 2-Inner Link)

Point Curve.5 (Chain 2-Inner Link,Chain Fixed 2)

Slide Curve

Point Curve

Commands

Chain Wheel

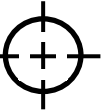
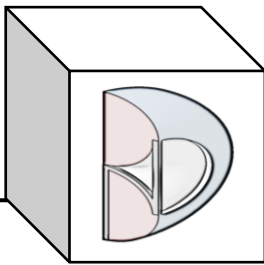
Link Shuttle

Fix Part (Chain Fixed 2)

Laws

Chain Wheel Rotation: 'Chain 2\Commands\Chain Wheel Rotation\Angle1' = 'Chain 2-Law\Geometrical Set.1\Law.11'.Evaluate('Chain 2\KINTime'/10s)*1deg

Formula.14: 'Chain 2\Commands\Link Shuttle\Length' = 1344.896mm + 'Chain 2\Commands\Chain Wheel Rotation\Angle1' * 80.93389225mm



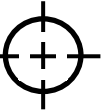
- Return the Kinematic Simulation to the beginning.

0 to 954 (2.65 Crank Revs)
0 to 360
Law.11
Chain 2-Inner Link (Chain 2-Inner Link)
Chain 2-Outer Link (Chain 2-Outer Link)
Constraints
Applications
Mechanisms
Chain 2, DOF=0
Joints
Gear.1 (Chain 2-Chain Wheel (40T),Chain 2-Rear Cog (19T),Chain Fixed 2)
Gear.2 (Chain 2-Rear Cog (19T),Chain 2-RD Upr Sprkt (11T),Chain Fixed 2)
Gear.5 (Chain 2-RD Upr Sprkt (11T),Chain 2-RD Lwr Sprkt (11T),Chain Fixed 2)
Revolute
Point
Slide
Point
Commands
Chain Wheel Rotation (Gear.1,Angle 1)
Link Shuttle (Point Curve.5,Length)
Fix Part (Chain Fixed 2)
Laws
Chain Wheel Rotation: 'Chain 2\Commands\Chain Wheel Rotation\Angle1' = 'Chain 2-Law\Geometrical Set.1\Law.11'.Evaluate('Chain 2\KINTime'/10s)*1deg
Formula.14: 'Chain 2\Commands\Link Shuttle\Length' = 1344.896mm + 'Chain 2\Commands\Chain Wheel Rotation\Angle1' * 80.93389225mm

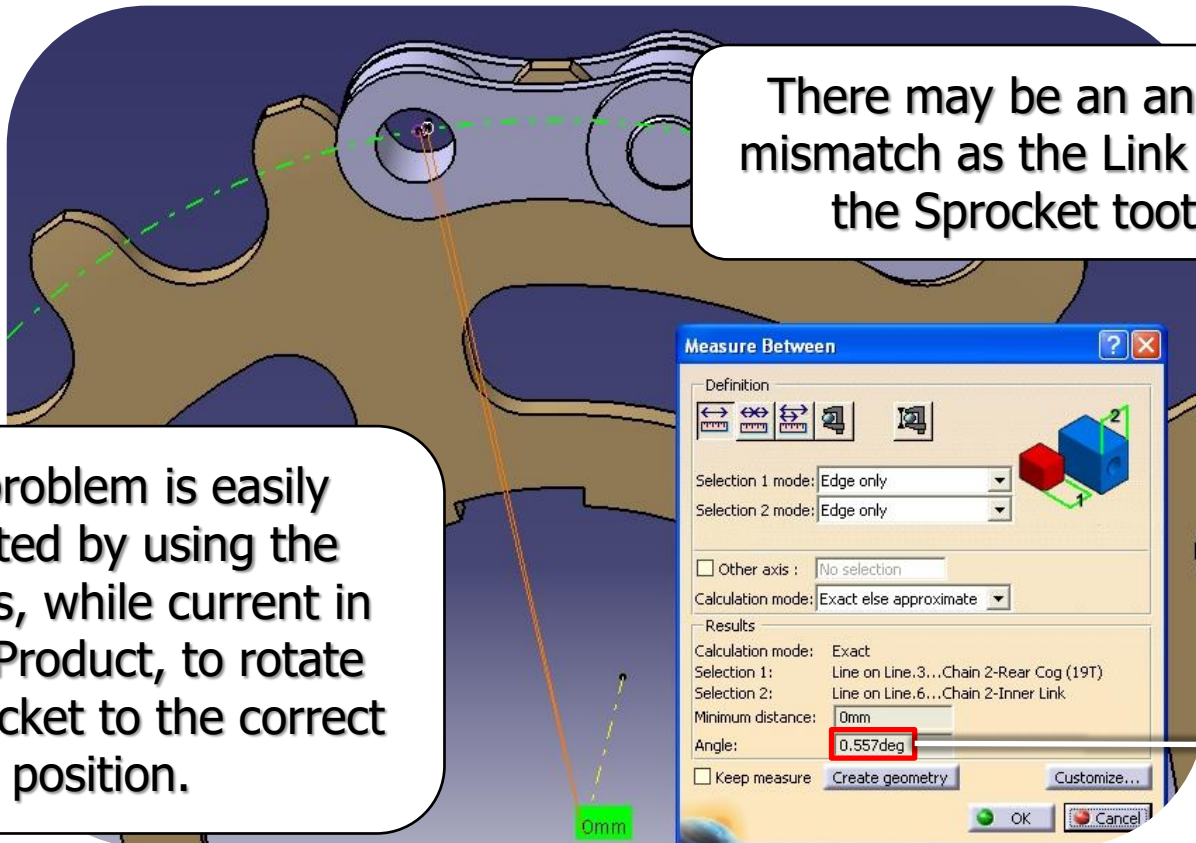
If you toggle between the start and the end, the Links should appear not to move.

Return the Kinematic Simulation to the beginning

Kinematics Simulation - Chain 2
Mechanism: Chain 2
Start: 10 End: 1000
Number of steps: 40
Analysis...
☐ Activate sensors ☐ Plot vectors
Close



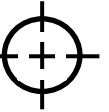
- Check the Links as they travel across the other Sprockets. (19T Sprocket shown)



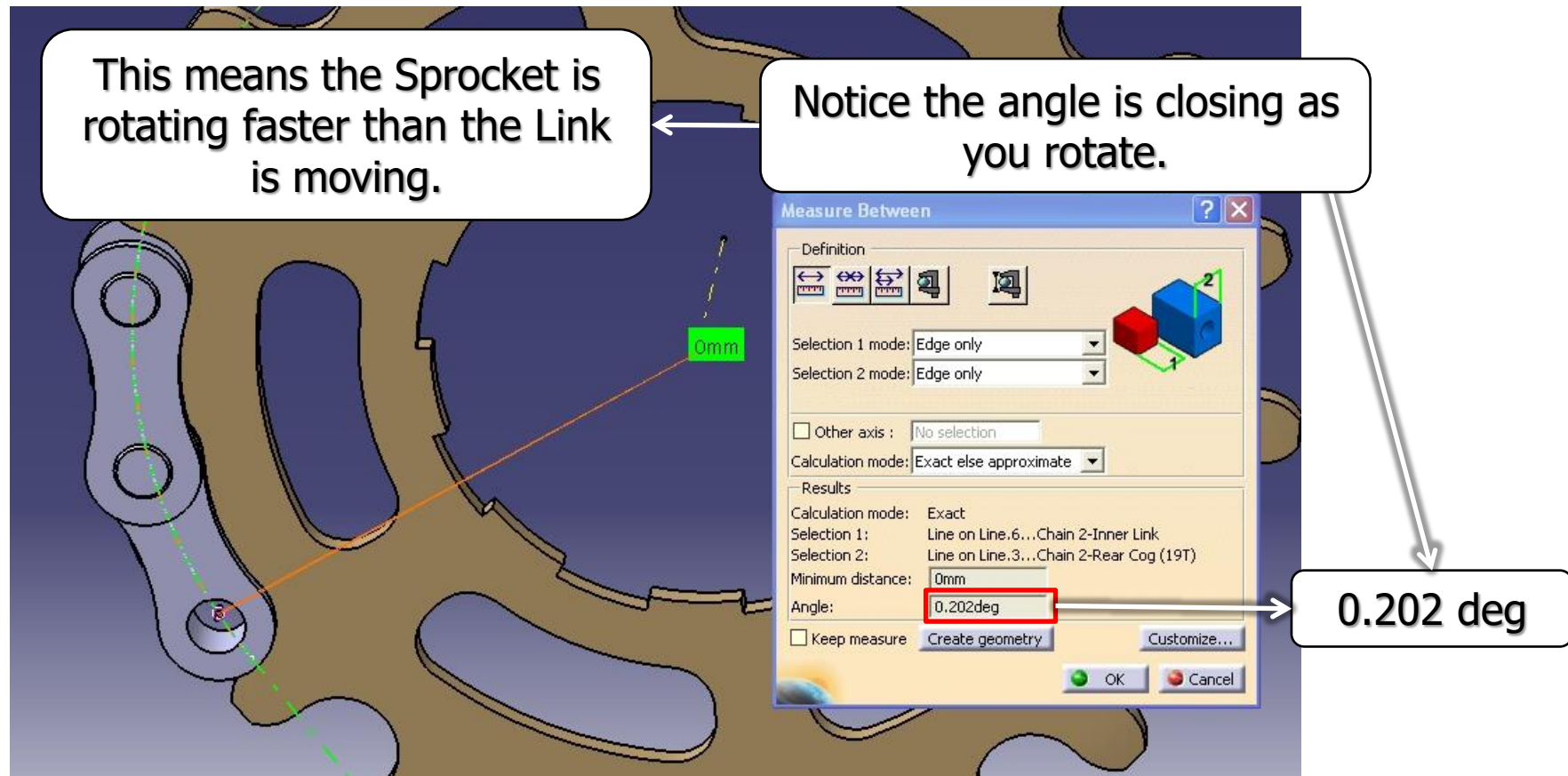
There may be an angular mismatch as the Link meets the Sprocket tooth.

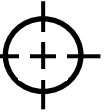
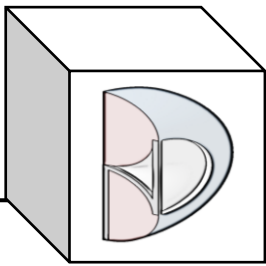
This problem is easily corrected by using the compass, while current in the CatProduct, to rotate the Sprocket to the correct position.

0.557 deg



- A different challenge arises as you rotate the Sprocket further around.





- A different challenge arises as you rotate the Sprocket further around.

The reason for this is the smaller radius on this Sprocket results in a larger Arc Length.

Notice the angle is closing as you rotate.

0mm

0.202 deg

Measure Between

Definition

Selection 1 mode: Edge only

Selection 2 mode: Edge only

☐ Other axis: No selection

Calculation mode: Exact else approximate

Results

Calculation mode: Exact

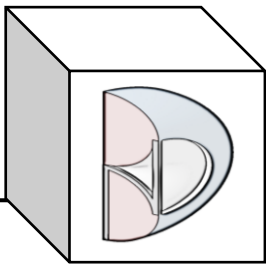
Selection 1: Line on Line.6...Chain 2-Inner Link

Selection 2: Line on Line.3...Chain 2-Rear Cog (19T)

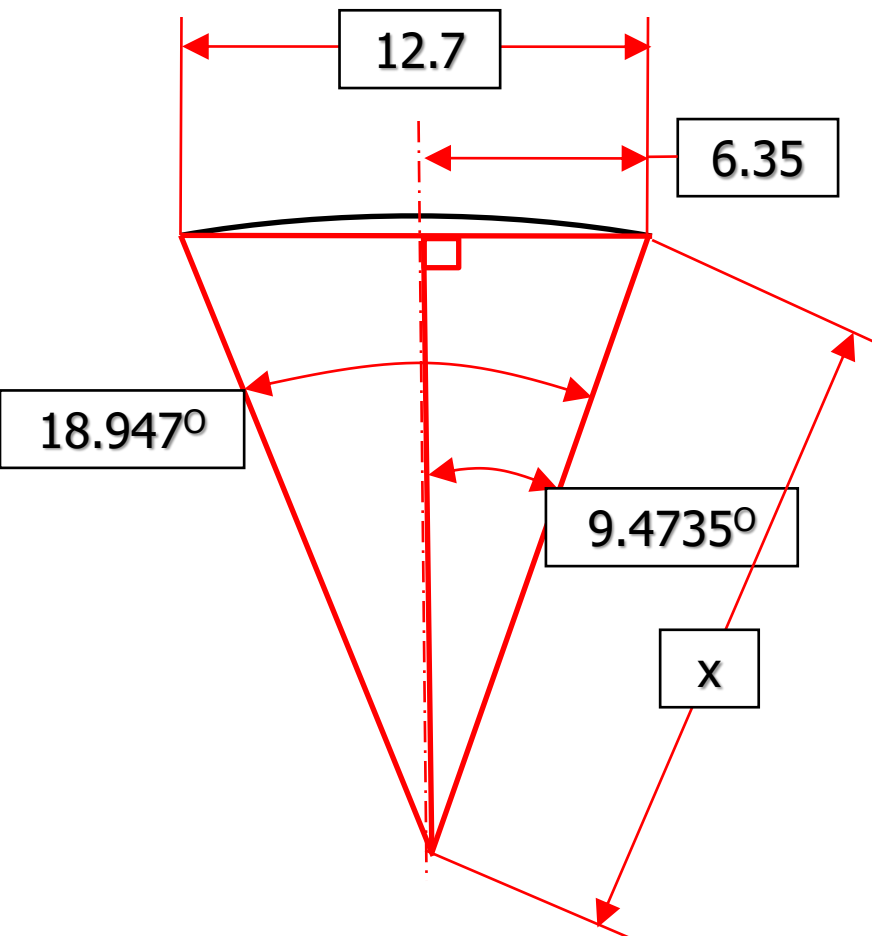
Minimum distance: 0mm

Angle: 0.202deg

☐ Keep measure



- Time for some more trigonometry...



Ex. 19T Drive Sprocket:

$$360^\circ / 19 = 18.947^\circ$$

$$\text{Chord Length} = 12.7$$

$$\text{Radius} = x$$

$$\sin^{-1}(6.35/x) = 9.4735^\circ$$

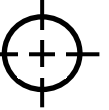
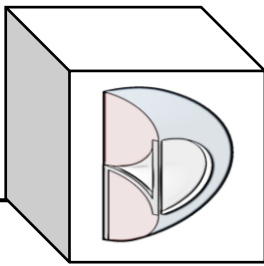
$$x = (6.35 / \sin 9.4735^\circ)$$

$$x = 38.58\text{mm}$$

$$\text{Circumference} = 2\pi R = 242.403\text{mm}$$

$$\text{Arc Length} =$$

$$242.403 / 19 = 12.75805$$



- Adjust the Gear Ratio.

To correct the problem of different Arc Lengths, simply divide the Drive Sprocket Arc Length by the 19T Sprocket Arc length, then multiply the current Gear Ratio by that value.

$$12.713/12.758 = .996472801$$

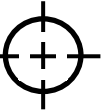
Current Gear Ratio =

$$40/19 = 2.105263158$$

New Gear Ratio =

$$2.105263158 * .996472801 = 2.097837476$$

The same technique can be applied to the 11T gears.



- Adjust the Gear Ratio.

Double pick the Gear Joint to edit the ratio.

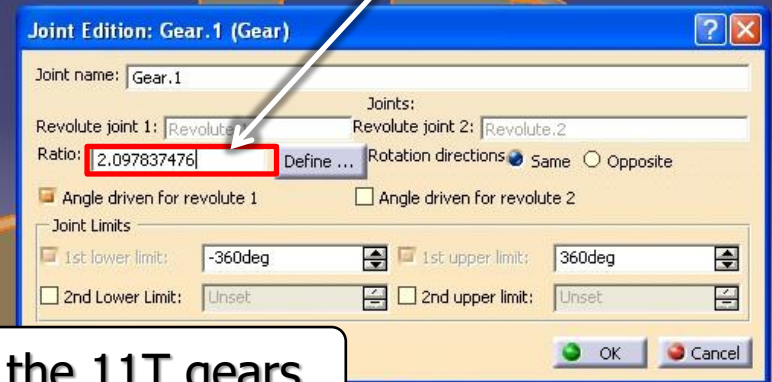
$$12.713/12.758 = .996472801$$

Current Gear Ratio =

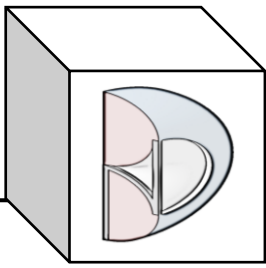
$$40/19 = 2.105263158$$

New Gear Ratio =

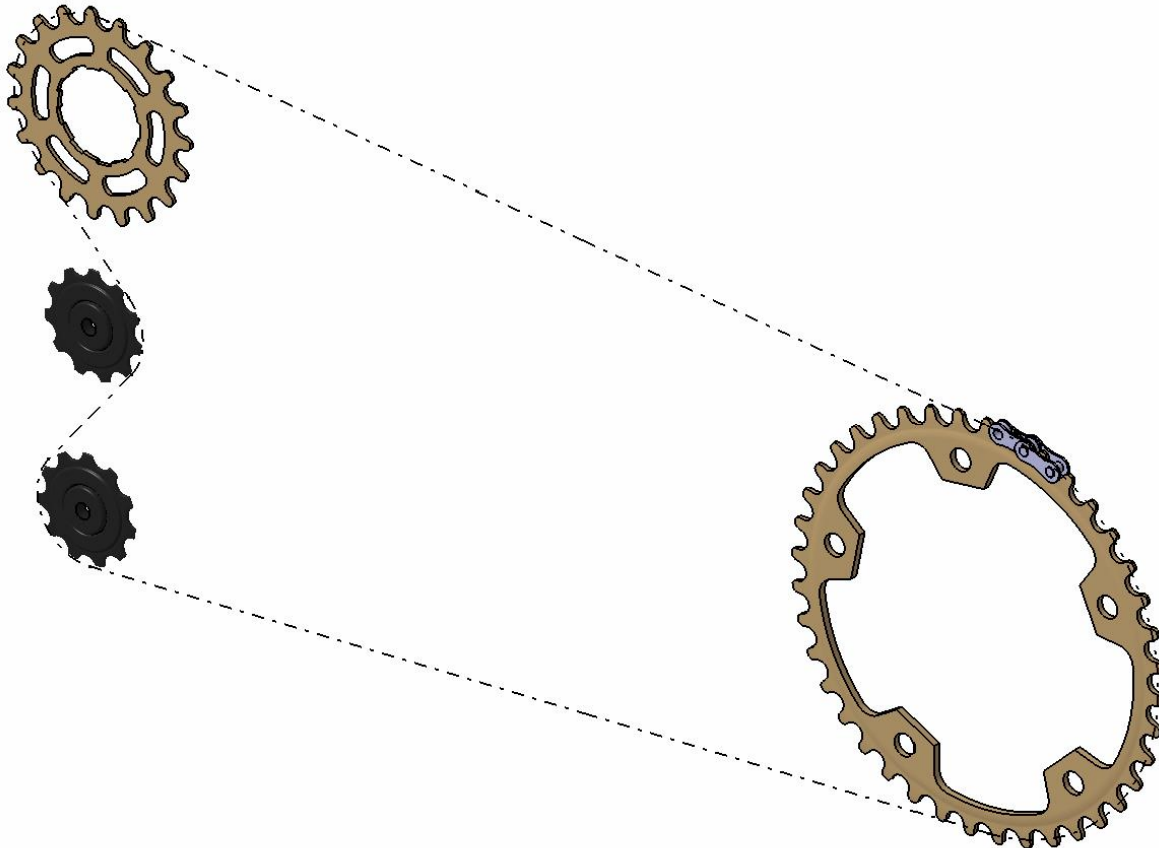
$$2.105263158 * .996472801 = 2.097837476$$

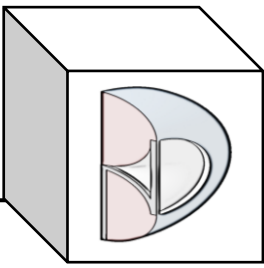


The same technique can be applied to the 11T gears.



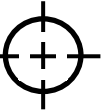
- Congratulations!! Now the real work begins...





- Complete the chain with all 106 Links!





■ Complete the chain with all 106 Links!

Here is where we left off.

Each new Link will have two joints.

- 1) Point-Curve Joint
 - Point on Link
 - Sprocket Center Curve
- 2) Revolute Joint
 - Inner Link
 - Outer Link



■ Complete the chain with all 106 Links!

Point Curve.196 (Chain Link Outer.48,Chain Fixed)

Revolute.197 (Chain Link Inner.49,Chain Link Outer.48)

Point Curve.198 (Chain Link Inner.49,Chain Fixed)

Revolute.199 (Chain Link Inner.49,Chain Link Outer.49)

Point Curve.200 (Chain Link Outer.49,Chain Fixed)

Revolute.201 (Chain Link Inner.50,Chain Link Outer.49)

Point Curve.202 (Chain Link Inner.50,Chain Fixed)

Revolute.203 (Chain Link Inner.50,Chain Link Outer.50)

Point Curve.204 (Chain Link Outer.50,Chain Fixed)

Revolute.205 (Chain Link Inner.51,Chain Link Outer.50)

Point Curve.206 (Chain Link Inner.51,Chain Fixed)

Revolute.207 (Chain Link Inner.51,Chain Link Outer.51)

Point Curve.208 (Chain Link Outer.51,Chain Fixed)

Revolute.209 (Chain Link Inner.52,Chain Link Outer.51)

Point Curve.210 (Chain Link Inner.52,Chain Fixed)

Revolute.211 (Chain Link Inner.52,Chain Link Outer.52)

Point Curve.212 (Chain Link Outer.52,Chain Fixed)

Revolute.213 (Chain Link Inner.53,Chain Link Outer.52)

Point Curve.214 (Chain Link Inner.53,Chain Fixed)

Revolute.215 (Chain Link Inner.53,Chain Link Outer.53)

Point Curve.216 (Chain Link Outer.53,Chain Fixed)

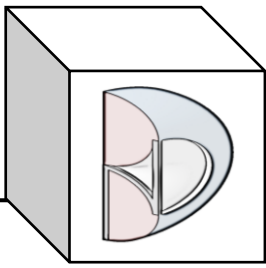
Commands

Fix Part (Chain Fixed)

Laws

Add the remaining 104 Links and Joints...

And here is where you will get to. Good Luck!



- Conclusion:

This tutorial of how we created our bicycle chain simulation put together at the request of our users.

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

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

