Introduction to Hydrodynamic Analysis with Ansys Aqwa

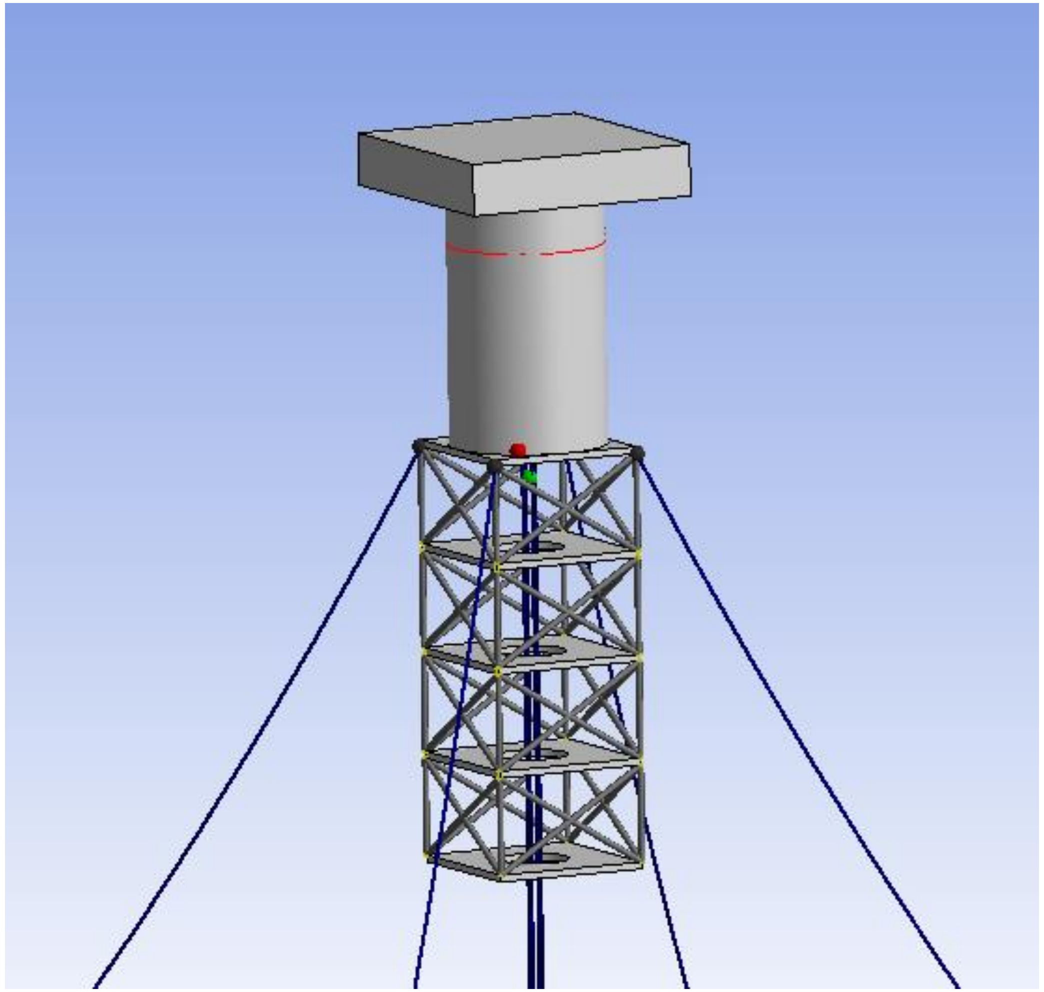
Workshop 08.1: Truss Spar Including Drag Linearization

Release 2021 R2

Truss Spar with Drag Linearization

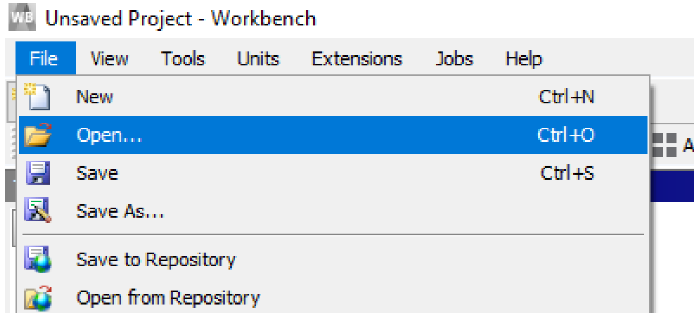
The goal of this workshop is to:

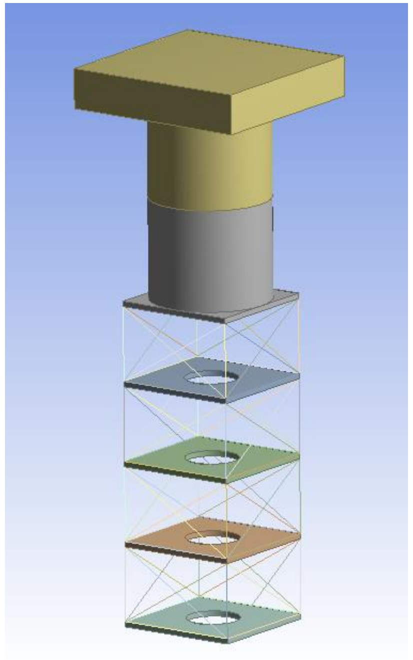
- Create a mixed model comprising diffracting and slender body components
- Investigate the effects of drag linearization
- Compare frequency domain and time domain solutions when including viscous drag

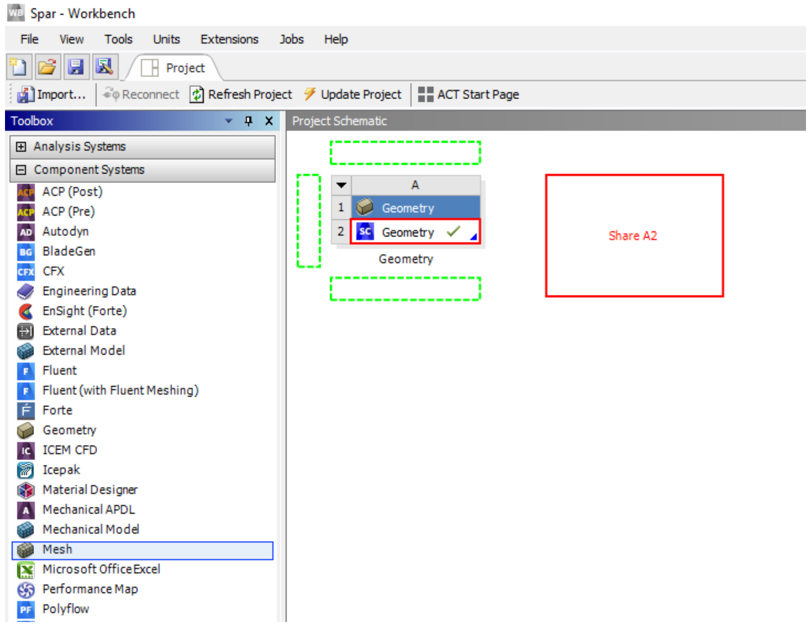


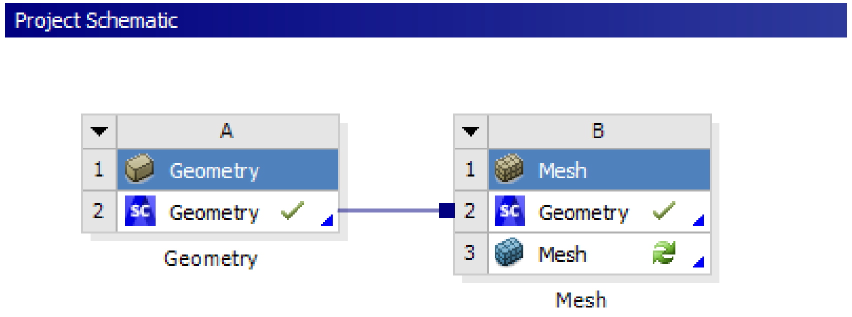
Set Up HD System

- Open Workbench and using File > Open navigate to the Spar.wbpj project file. This project contains a pre-defined Spar geometry
- Add a Mesh system linked to the geometry.





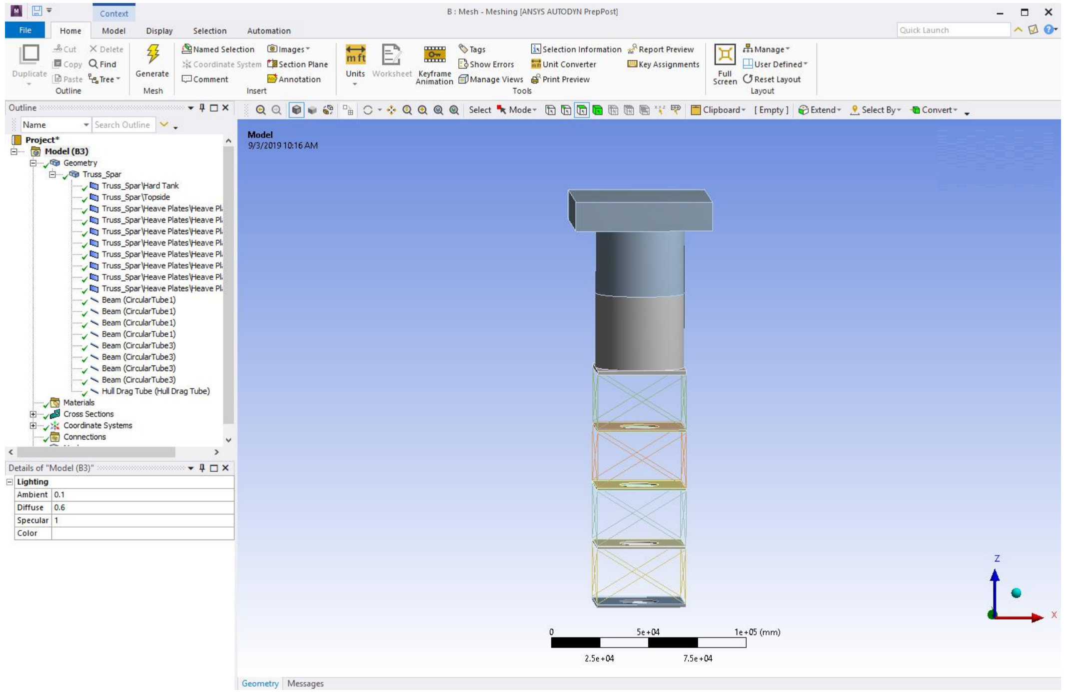




Set Up Mesh

We are going to use the Ansys meshing tool to enable different mesh sizes to be applied to the truss elements and the heave plates. We will take advantage of using the worksheet to prescribe the order of the meshing, which is not possible in the Aqwa meshing tool

- Open the meshing tool by double clicking on the Mesh cell



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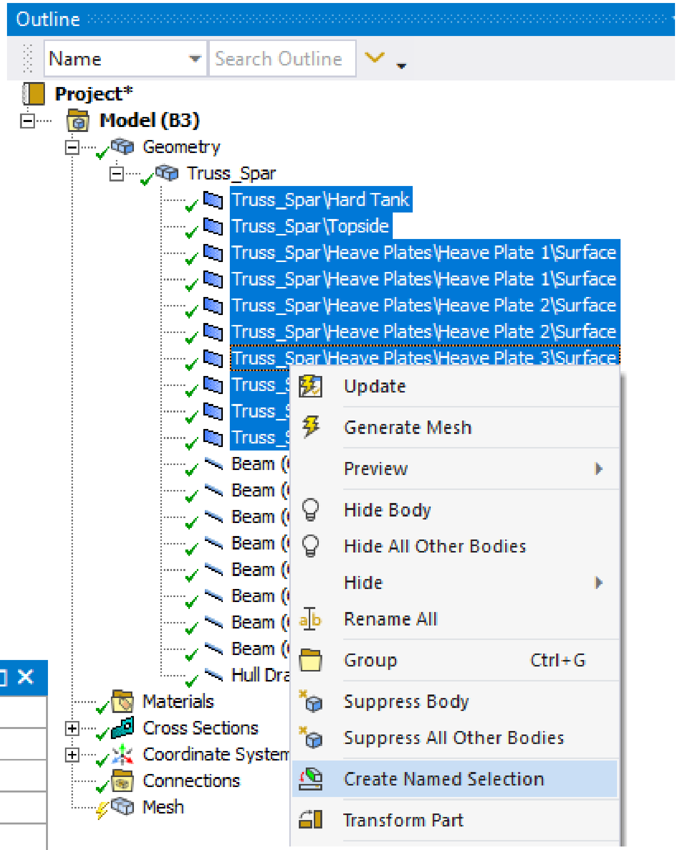
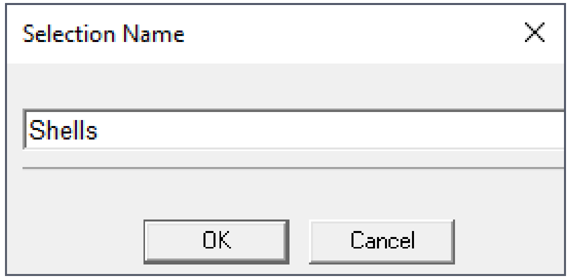
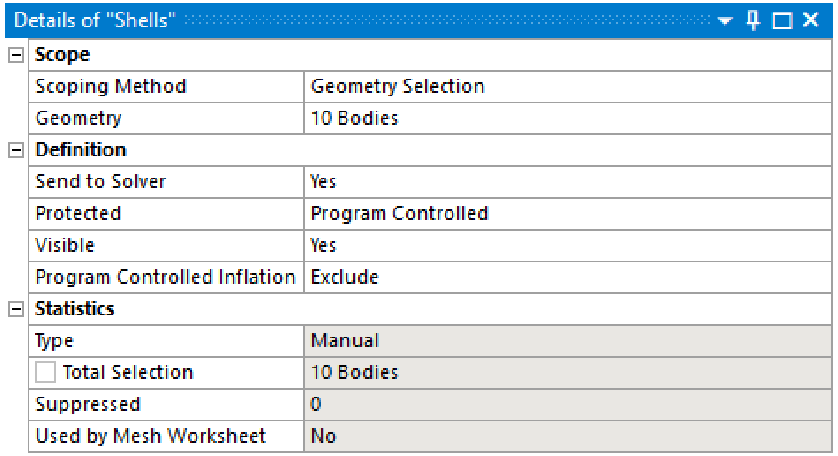
Named Selections

Establish three Named Selections to enable worksheet mesh generation

- Select the Truss_Spar surface bodies in the Outline tree, right-click > Create Named Selection
- Define the Selection Name as Shells



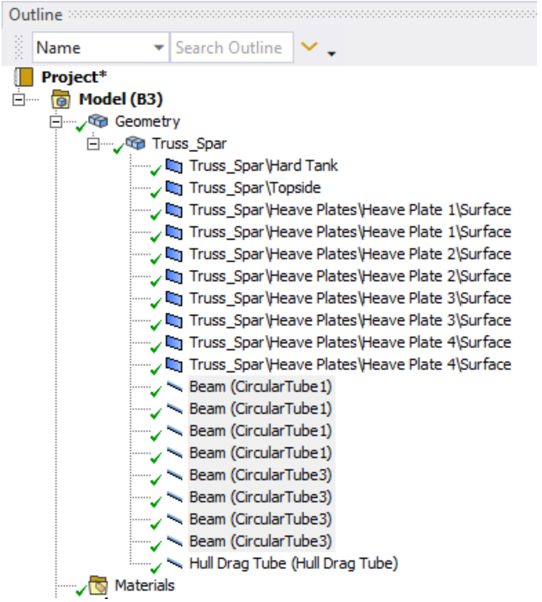


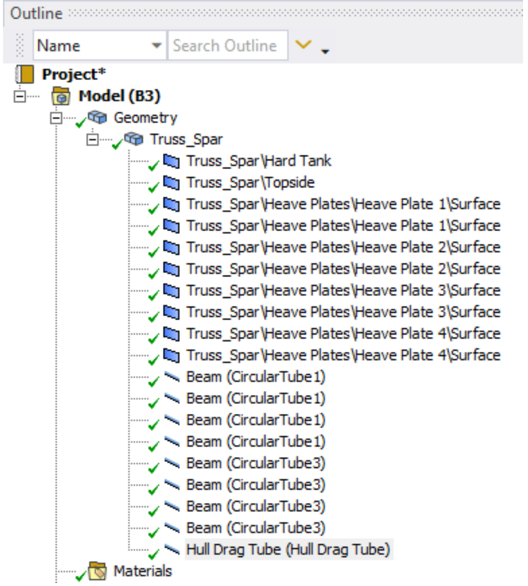


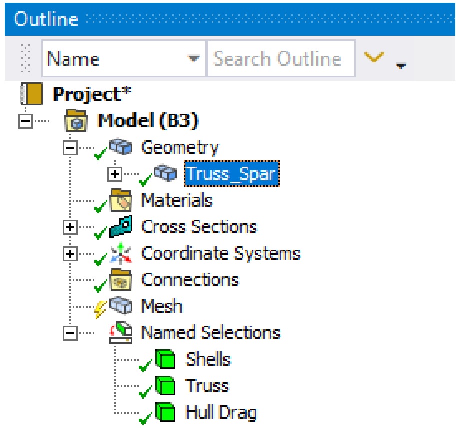
Named Selections

Repeat for the truss beams and hull drag tube

- Select the Truss_Spar_Beams bodies in the Outline tree, right-click > Create Named Selection
- Define the Selection Name as Truss
- Select the Hull Drag Tube body in the Outline tree, right-click > Create Named Selection
- Define the Selection Name as Hull Drag



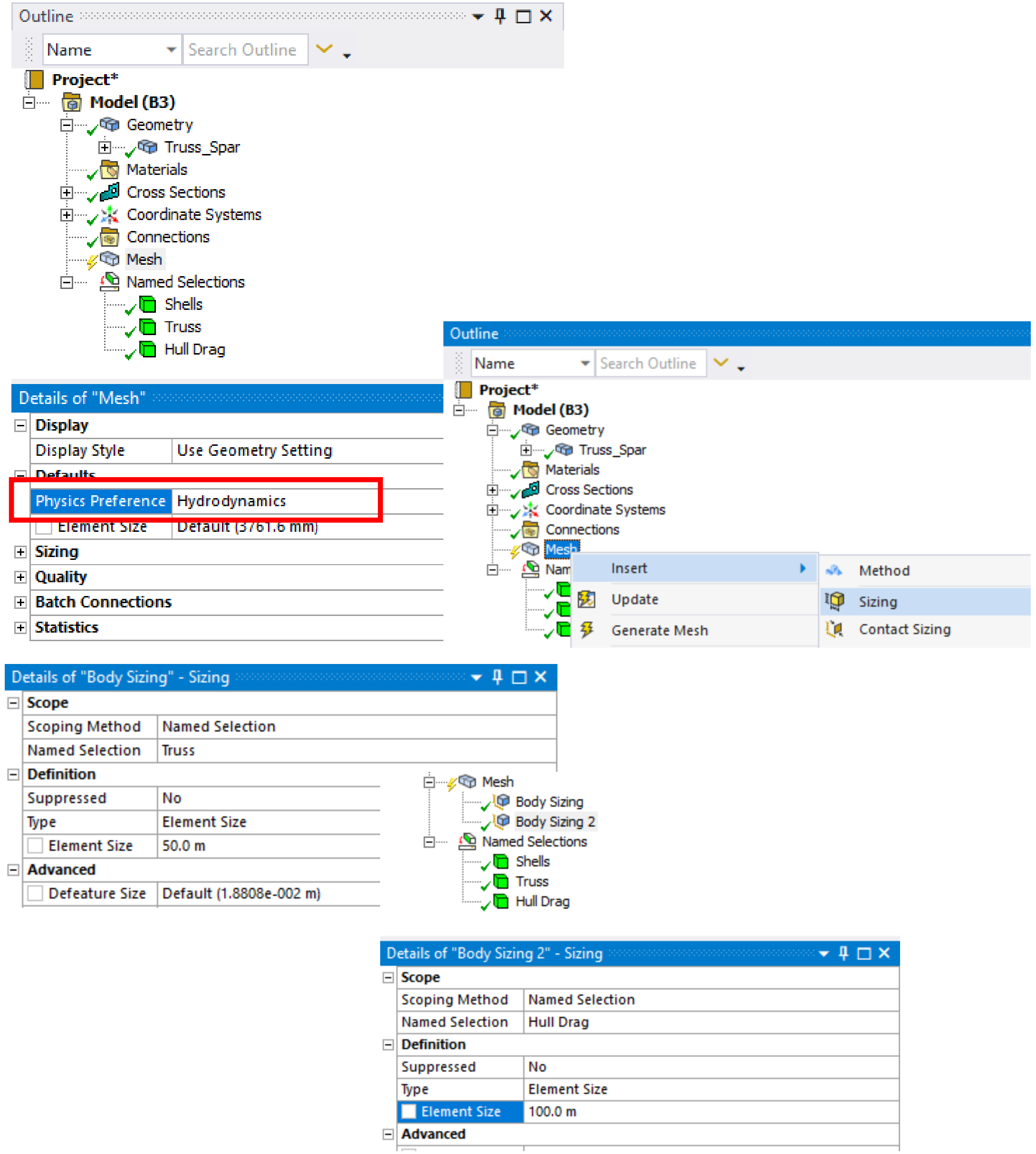




Establish Mesh Settings

Set up mesh parameters for the beam bodies

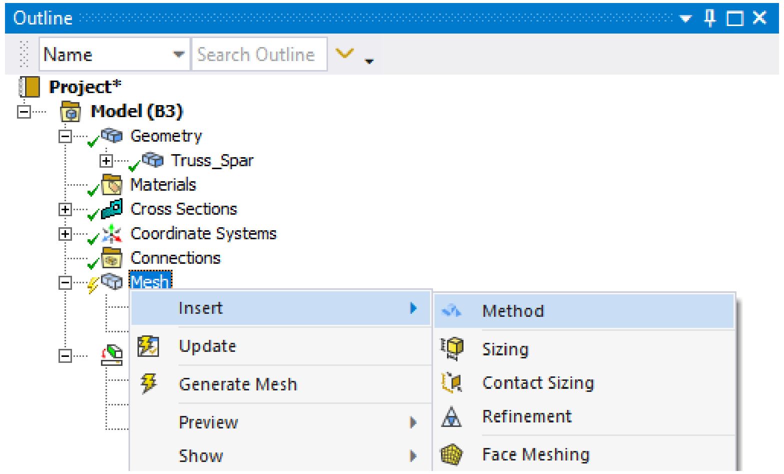
- Click on Mesh in the Outline tree and set Physics Preference to Hydrodynamics
- Right-click > Insert > Sizing
- Set Scoping Method to Named Selection, then choose Truss as the Named Selection. Set Element Size to 50 m
- Repeat for Hull drag Named Selection and set Element Size to 100 m

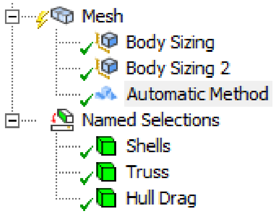


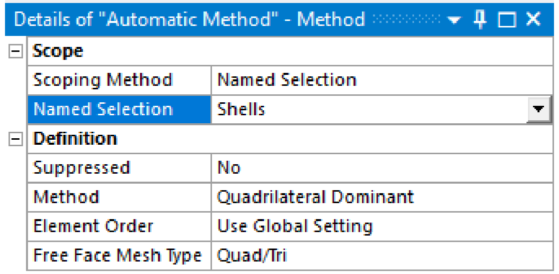
Establish Mesh Settings

Set up mesh parameters for the shells

- Right-click > Insert > Method
- Set Scoping Method to Named Selection, then choose Shells as the Named Selection. Leave other details as defined



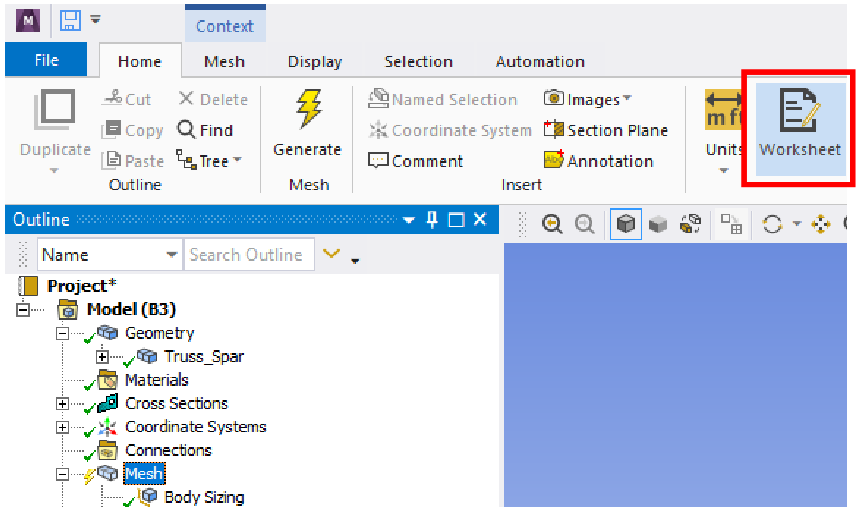


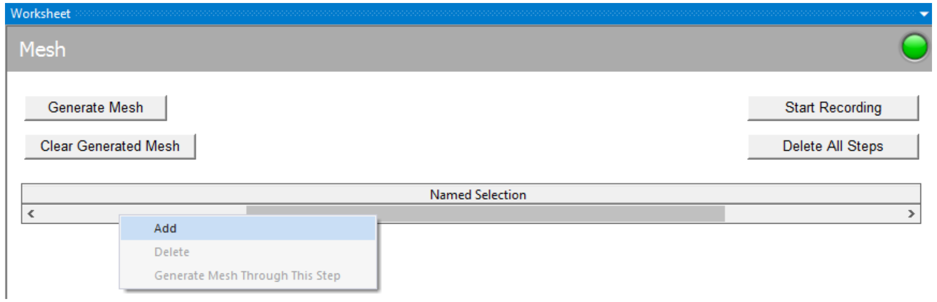


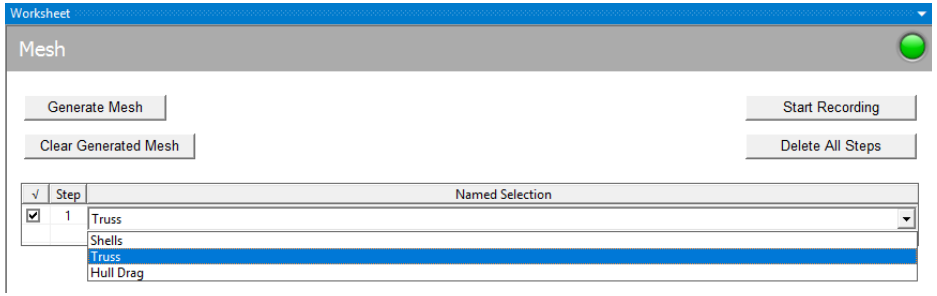
Set up Mesh Worksheet

The Mesh Worksheet enables the order of meshing to be controlled. We want to mesh the beams before the shells to allow a coarser mesh to be established for those bodies

- Click the Mesh object in the Tree Outline
- Click the Worksheet button on the toolbar
- Add a row to the worksheet by right-clicking on the table and selecting Add from the context menu
- In the new row, click on the Named Selection column and select a Truss from the Named Selection drop-down
- Repeat for Hull Drag, and finally Shells Named Selections



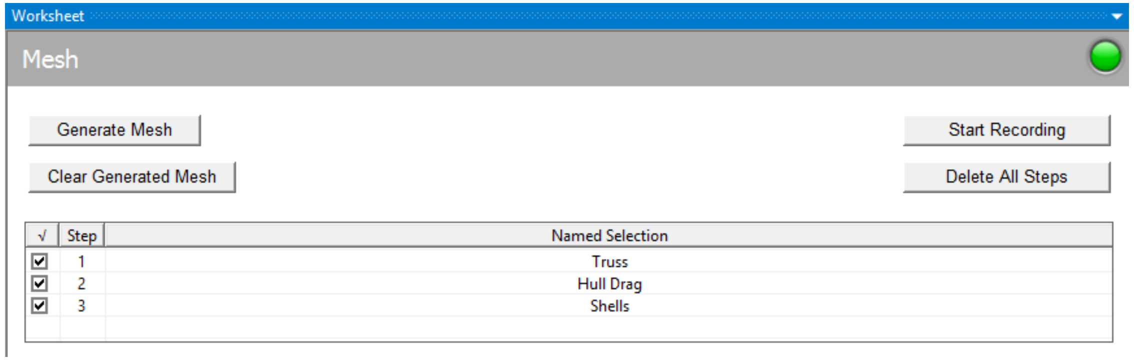


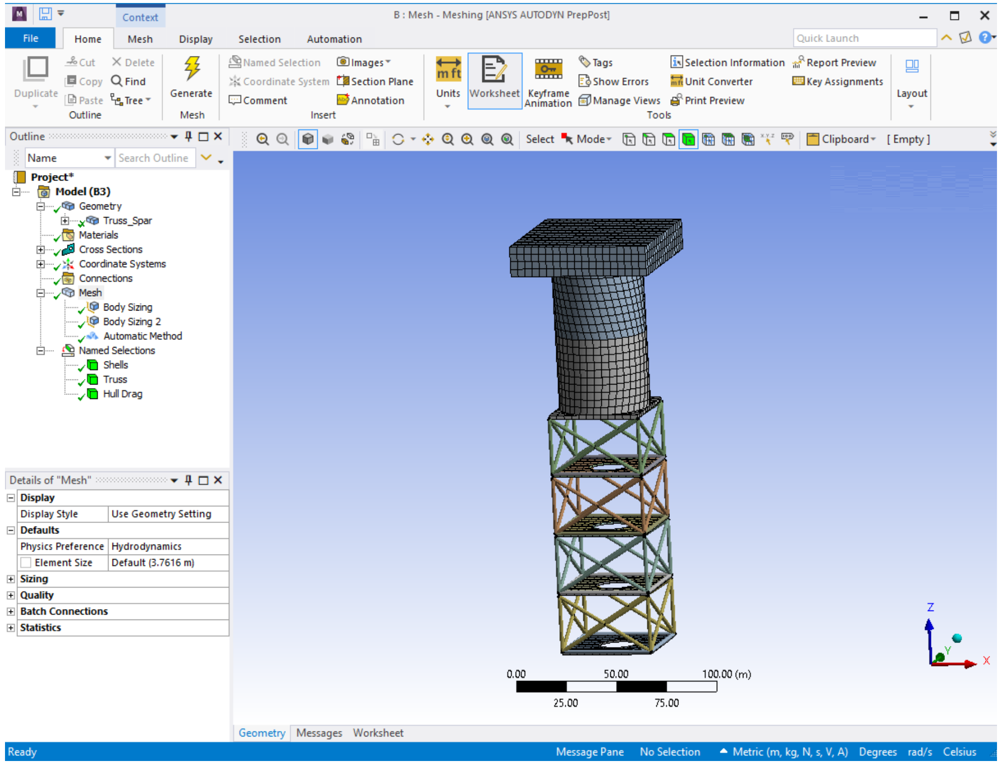


Generate Mesh

The mesh can now be generated

- Either click the Generate Mesh in the Worksheet window, or select Mesh in the Tree Outline, right-click > Generate Mesh
- To view the mesh select Mesh in the Tree Outline and choose the Graphics tab in the visualization window
- Close the Meshing tool

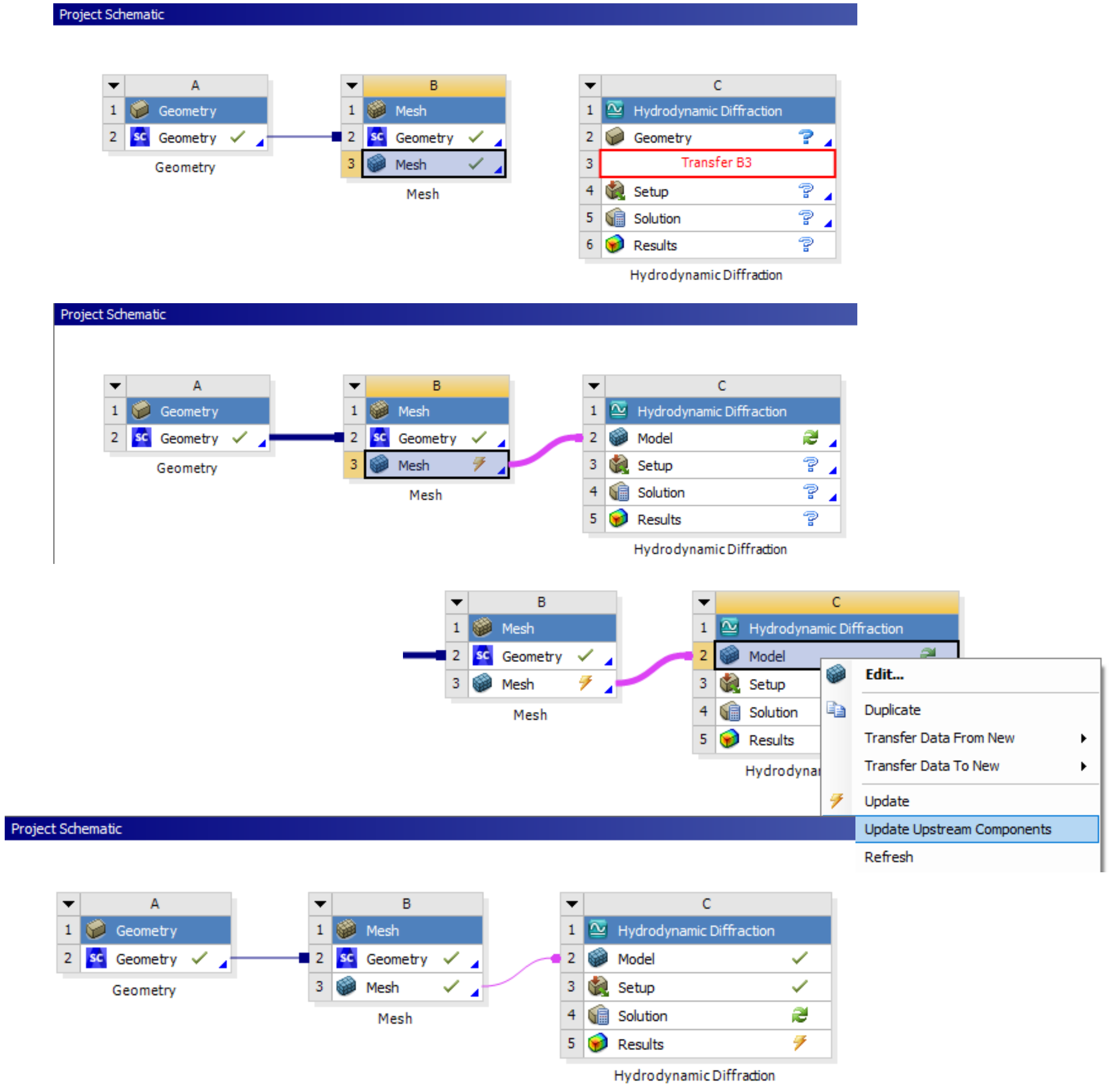




Add Hydrodynamic Diffraction System

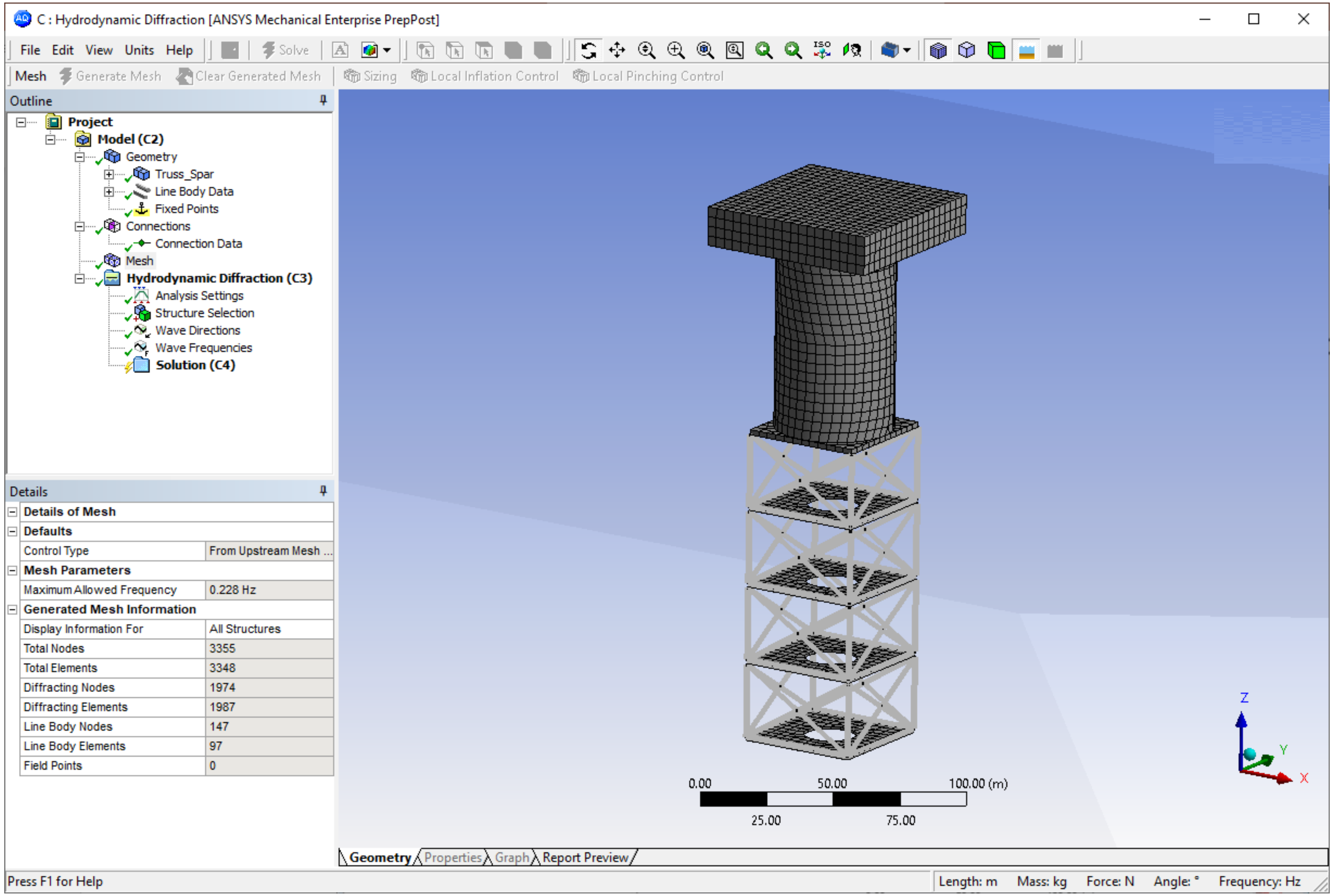
Add a new Hydrodynamic Diffraction system

- The link between the Mesh system and the Hydrodynamic Diffraction system has to be created manually. Click on the Mesh cell and link onto the Model cell of the HD system.
- The HD system will update to reflect the connection
- On the Model cell, right-click > Update Upstream Components
- Double click on any HD cell to open Aqwa



Adding Aqwa Specific Geometry

Note that the mesh information is read only, we cannot modify the mesh directly in Aqwa



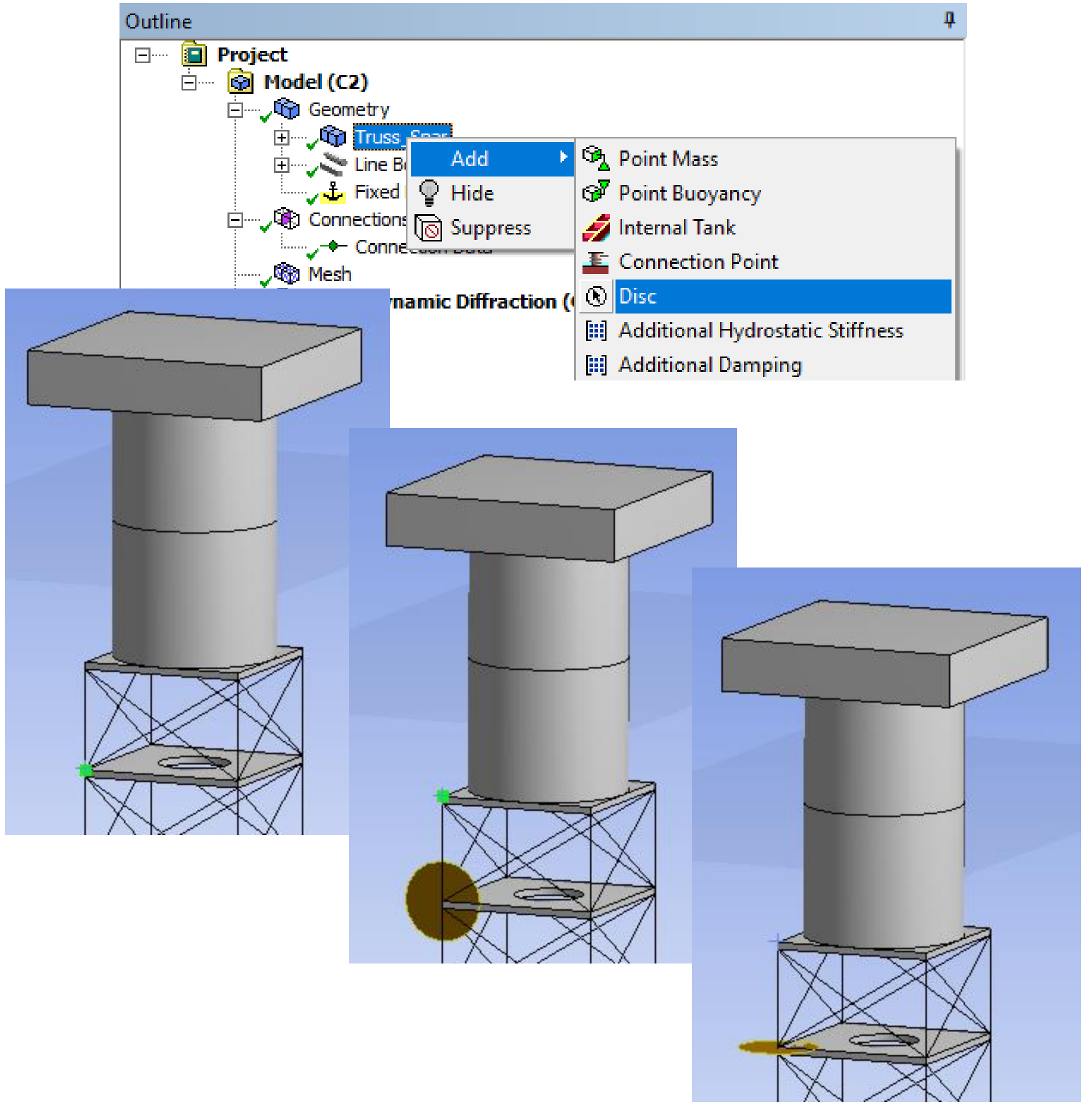
Adding Aqwa Specific Geometry

- Spars typically have natural heave periods in the 20-30 second range and have very low damping. To reduce the effects of resonance, heave plates are normally utilized. Much of the damping effect of heave plates comes from viscous drag, so we are going to add viscous damping elements to supplement the heave plates modelled using diffraction elements
- The geometry already includes Morison Tube elements to model the truss, but we need to add drag elements that only effect the vertical motions of the Spar
- Disc elements are going to be used to provide viscous drag normal to the plane of the heave plates

Adding Discs

We are going to add four discs per heave plate (one on each corner).

- Right-click on Truss_Spar and Add > Disc
- We will assign one quarter of the total area of the heave plate to each disc
  - Set Diameter to 23m
- A disc requires a centroid and a normal definition
  - For the Centroid Definition, click on Select a Single Vertex, then select one of the corners of the topmost heave plate. Apply
  - For the Normal Definition, click on Select a Single Vertex, then select the corner of the plate immediately above that selected for the centroid. Apply. You will see that the disc rotates to be horizontal



Adding Discs

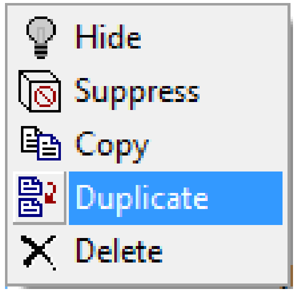
In addition to the disc diameter, an Added Mass and Viscous Drag coefficient needs to be defined

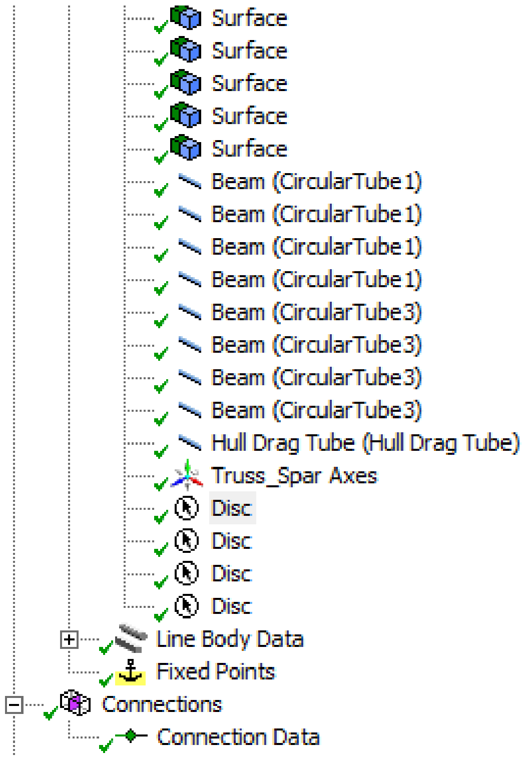
- The Added Mass value should be small, since we have already accounted for this effect by modelling the heave plate using diffraction elements
- We set the Viscous Drag Coefficient to a number that is twice the standard value for a thin disc since the Aqwa solver assumes that discs are used to cap the end of a body, so divides the coefficient by two
    - Set Added Mass Coef to 0.1
    - Set Viscous Drag Coef to 2.28

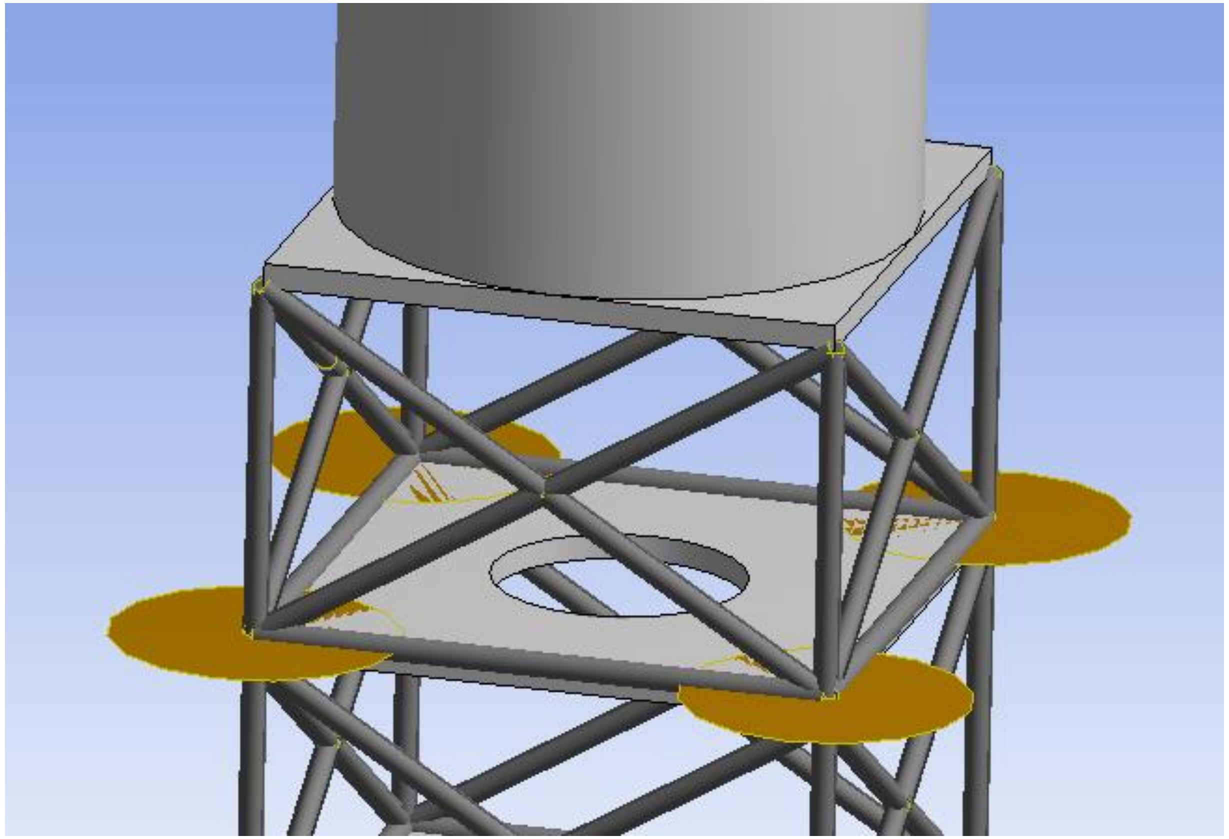
Details	
Details of Disc	
Name	Disc
Visibility	Visible
Activity	Not Suppressed
Disc Size and Position	
Diameter	23 m
Centroid Definition	Vertex Selection
Vertex	Vertex Selected (Truss_Spar)
X	-22.75 m
Y	-22.75 m
Z	-68 m
Disc Normal	
Normal Definition	Vertex Selection
Normal Vertex	Vertex Selected (Truss_Spar)
Normal X	0.0
Normal Y	0.0
Normal Z	1
Physical Properties	
Added Mass Coefficient	0.1
Drag Coefficient	2.28

Adding Discs

- Using right-click on the existing Disc element, Duplicate this three times, and reset the Centroid Vertex and Normal Vertex for the other three corners of the top heave plate







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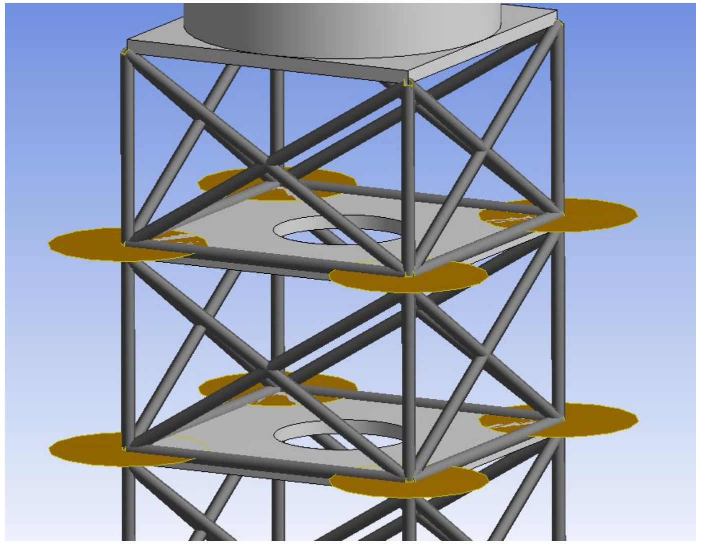
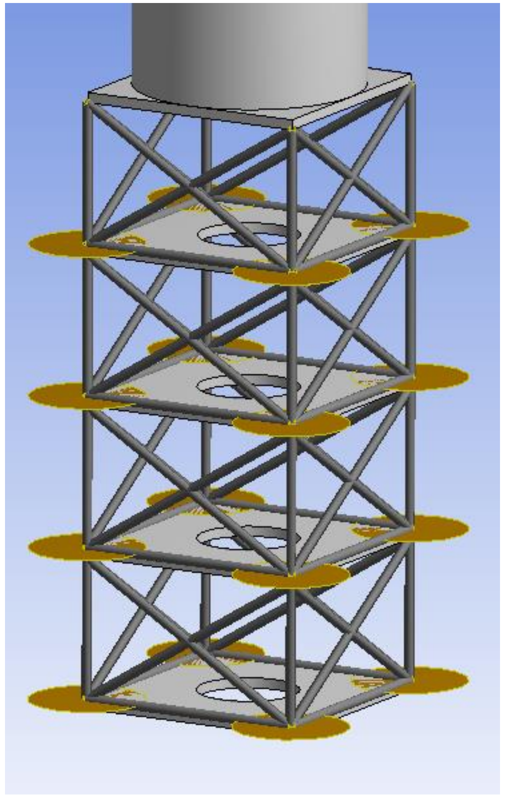
Adding Discs

We now need to repeat this for the remaining three heave plates

- Using right-click on the existing four Disc elements, Duplicate each one, and reset the Centroid Vertex to the corresponding vertex on the heave plate below. The Normal Vertex does not need to be reset in this instance since the direction will already be correct
- Repeat this for the two lower heave plates

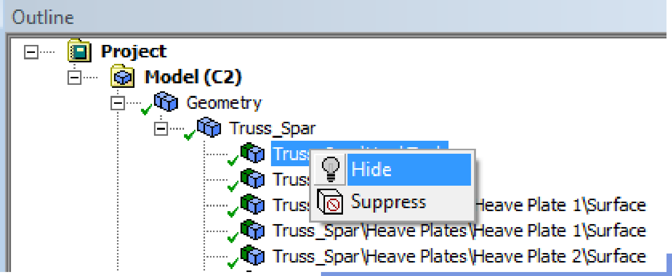


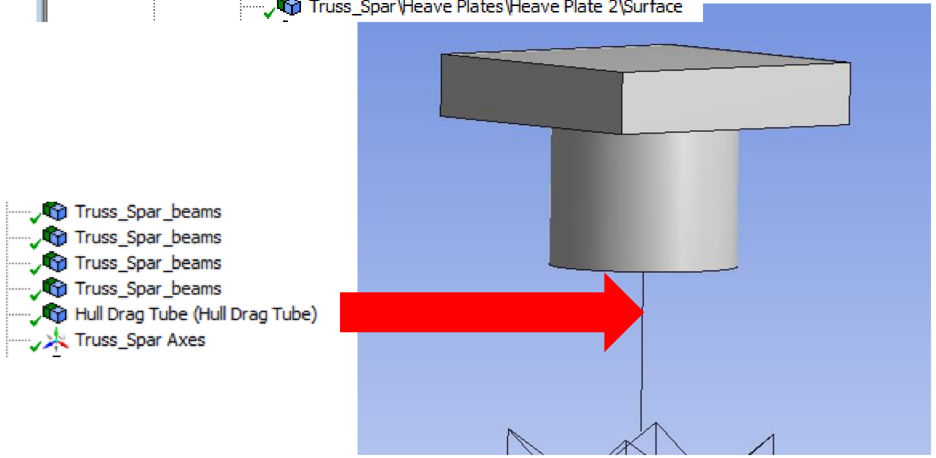


Hull Drag Modelling

In order to include the effects of viscous drag on the hull, there is a dummy Morison tube element that is within the hull model.

- This can be visualized by hiding part of the hull surface ‘Hard Tank’
- The tube element is called Hull Drag Tube in the Truss_Spar geometry. Select the corresponding Beam Section ‘Circular Tube 3’ in the Line Body Data: it can be seen that this tube has a small diameter, 0.01x the real Spar hull diameter of 45.5 m. This is done so that the added mass effect is not doubled up, as this is computed by Aqwa from the diffraction model. To include the viscous effect we therefore multiply the drag coefficient by 100.





Details

Details of Circular Tube 3	
Name	Circular Tube 3
Solver Line Type	Cylindrical (TUBE)
Geometric Properties	
Cross Section Name	Hull Drag Tube
Cross Section Type	Circular Tube
Inner Radius	0.2274 m
Outer Radius	0.2275 m
Cross Section Area	1.42911e-4 m²
Second Moment of Area	3.69664e-6 m⁴
Mass Properties	
Material Density	7850 kg/m³
Inertia/Unit Length	0.02902 (kg.m²)/m
Hydrodynamic Properties	
Displaced Area	0.1626 m²
Transverse Drag Coefficient	75
Axial Drag Coeffcient	0.016
Added Mass Coefficient	1
Inertia Coefficient	2

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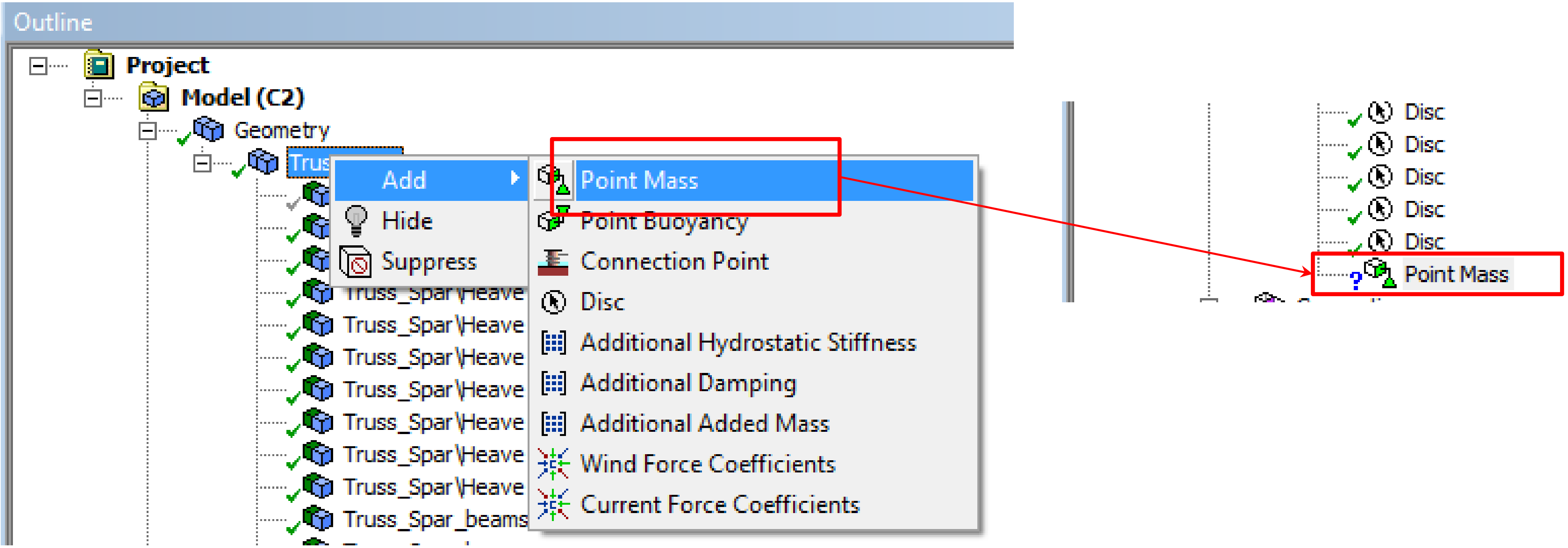
Provide Additional Aqwa Elements

- For the Spar provide a Point Mass element
- Note that the mass of the truss elements is automatically computed, so does not need to be included in the Point Mass definition



Point Mass Input

- Change Mass definition to Manual
- Define Inertia Values by Radius of Gyration
- Set VCG (Z coordinate), Mass and Radius of Gyration as shown

Details

Details of Point Mass	
Name	Point Mass
Visibility	Visible
Activity	Not Suppressed
Mass Properties	
Mass Definition	Manual Definition
X	0.0 m
Y	0.0 m
Z	-68 m
Mass	64646750 kg
Inertia Properties	
Define Inertia Values By	Radius of Gyration
Kxx	70.8 m
Kyy	70.8 m
Kzz	26 m
Ixx	324050884920 kg.m²
Ixy	0.0 kg.m²
Ixz	0.0 kg.m²
Iyy	324050884920 kg.m²
Iyz	0.0 kg.m²
Izz	43701203000 kg.m²

Global Parameters

- Select the Geometry object in the tree. Set the Water Depth to 600m.

Details

Details of Geometry	
Name	Geometry
Attached Assembly Path	C:\backedup\ANSYS\Aqwa_Training_18\Aqwa...
Sea Geometry	
Water Depth	600 m
Water Density	1025 kg/m³
Water Size X	810 m
Water Size Y	560 m
Stability/Time Response-Specific Options	
Tube Drag Coefficients	Defined in Line Body Details
Seabed Inline Friction Coeffic...	0.0
Seabed Lateral Friction Coeff...	0.0
Composite Cable Seabed Definition	
Seabed Type	No Composite Cable Seabed
Import Preferences	
Import Solid Bodies	No
Import Surface Bodies	Yes
Import Line Bodies	Yes

Analysis Settings

- To reduce computational time we are going to switch off the wave grid pressure feature.
  - Set Generate Wave Grid Pressures to No
- By default viscous effects on slender body elements is ignored in a Hydrodynamic Diffraction analysis. To include this effect set Linearized Morison Drag to Yes
- Set Ignore Modelling Rule Violations to Yes

Details	
Details of Analysis Settings	
Name	Analysis Settings
External Operation before Solving	None
External Operation after Solving	None
Parallel Processing	Program Controlled
Generate Wave Grid Pressures	No
Common Analysis Options	
Ignore Modelling Rule Violations	Yes
Calculate Extreme Low/High Fre...	Yes
Include Multi-Directional Wave Int...	Yes
Near Field Solution	Program Controlled
Linearized Morison Drag	Yes
QTF Options	
Calculate Full QTF Matrix	Yes
Output File Options	
Source Strengths	No
Potentials	No
Centroid Pressures	No
Element Properties	No
ASCII Hydrodynamic Database	No
Example of Hydrodynamic Datab...	No
Generate AHD Pressure Output	No

Wave Directions and Frequencies

Leave the Wave Directions as Program Controlled

For the Wave Frequencies we want to investigate the region where the natural heave period is located. From simple hand calculations this is estimated to be around 23 seconds.

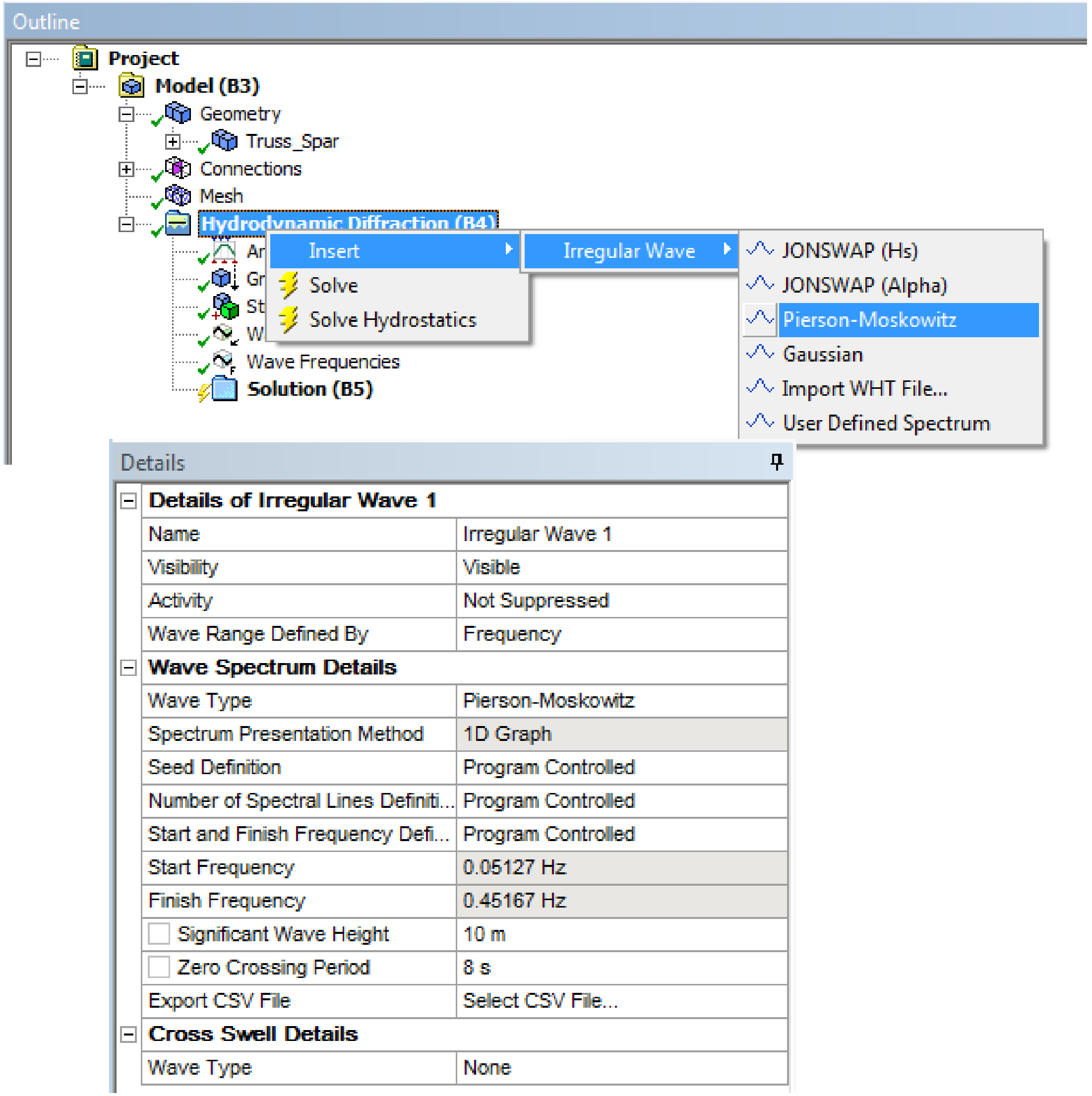
- Set Intervals Based Upon Period
- Set Frequency/Period Definition in the Details of Wave Frequencies to Manual Definition.
- Set Lowest/Highest Frequency Definitions to Manual Definition.
    - Set Longest Period to 60 seconds
    - Shortest Period to 5 seconds.
    - Set Number of Intermediate Values to 21.
- Define a manual single Additional Frequency with a period of 23 seconds

Details

Details of Wave Frequencies	
Name	Wave Frequencies
Intervals Based Upon	Period
Incident Wave Frequency/Period Definition	
Range	Manual Definition
Definition Type	Range
Lowest Frequency Definition	Manual Definition
Lowest Frequency	0.01667 Hz
Longest Period	60 s
Highest Frequency Definition	Manual Definition
Highest Frequency	0.2 Hz
Shortest Period	5 s
Number of Intermediate Values	21
Interval Period	2.5 s
Additional Frequencies A	
Additional Range	Single
Lowest Frequency Definition	Manual Definition
Lowest Frequency	0.04348 Hz
Longest Period	23 s
Additional Frequencies B	
Additional Range	None

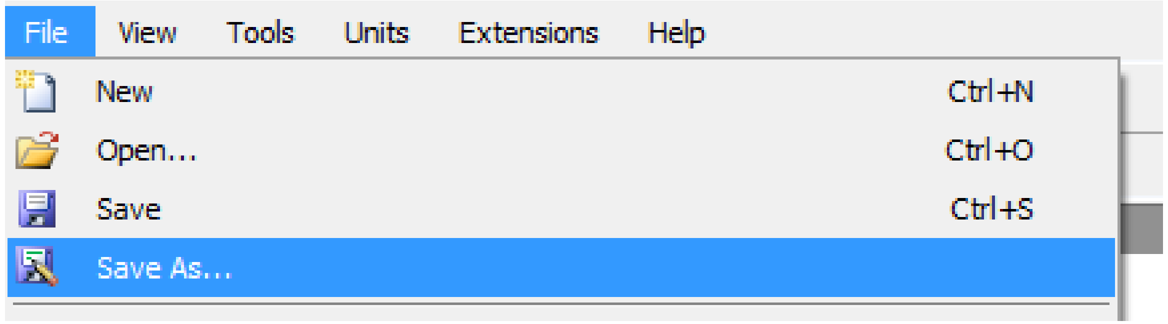
Define Wave Spectrum

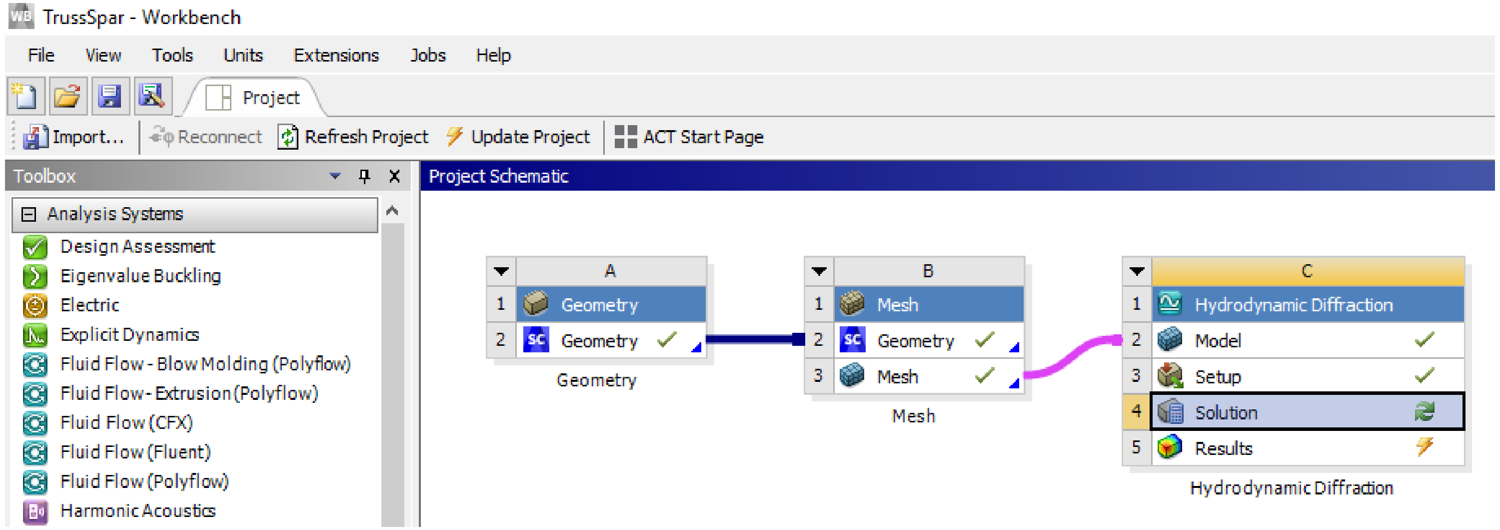
- In order to undertake drag linearization for the Morison elements, we need to define a wave spectrum upon which the linearization will be undertaken. Provided the Linearized Morison Drag is set to Yes in the Analysis settings, you will be able to add a spectrum to the HD system
    - Right-click on Hydrodynamic Diffraction and Insert > Irregular Wave > Pierson-Moskowitz
    - Set Significant Wave Height to 10m and Zero Crossing Period to 8 seconds



Save Project

- Save the project from the Workbench Project Page, File > Save As
- Browse to the training working directory and save the project as TrussSpar.wbpj.

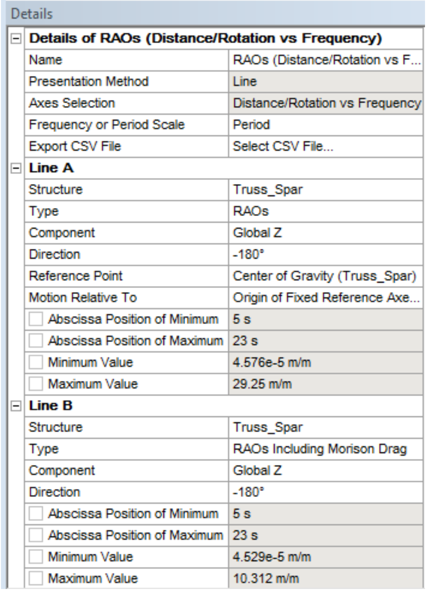




Solve

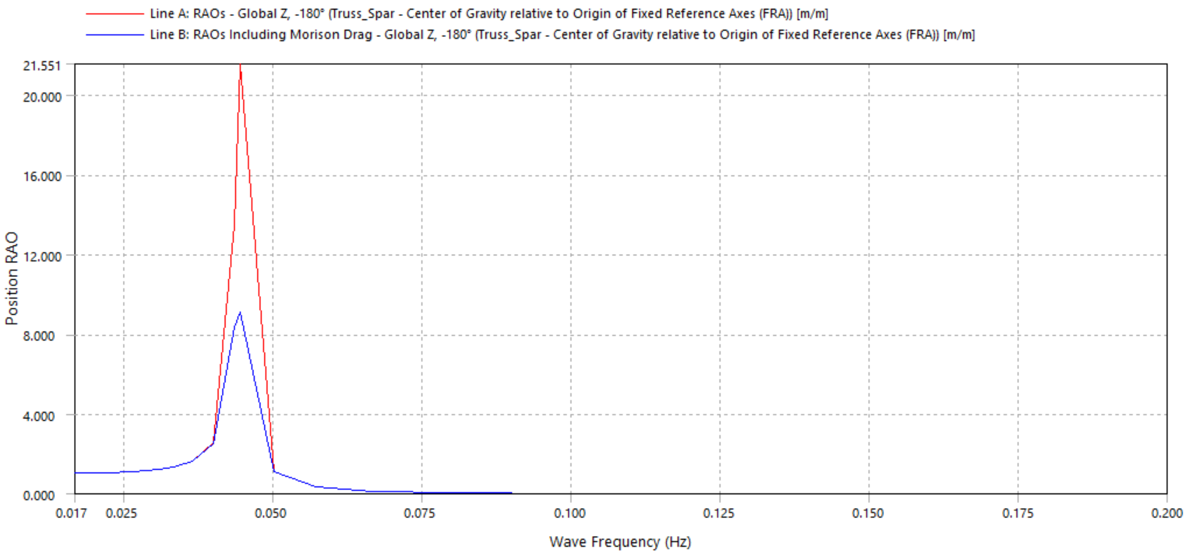
Undertake a full hydrodynamic solve. This will take a few minutes.

- Add the following results
  - Hydrostatics (check displacement values)
  - RAOs
    - Can plot these with and without Linearized Drag on the same graph. Choose the heave response (Global Z), for a -180° wave direction



Details

Details of RAOs (Distance/Rotation vs Frequency)	
Name	RAOs (Distance/Rotation vs F...
Presentation Method	Line
Axes Selection	Distance/Rotation vs Frequency
Frequency or Period Scale	Period
Export CSV File	Select CSV File...
Line A	
Structure	Truss_Spar
Type	RAOs
Component	Global Z
Direction	-180°
Reference Point	Center of Gravity (Truss_Spar)
Motion Relative To	Origin of Fixed Reference Axe...
Abscissa Position of Minimum	5 s
Abscissa Position of Maximum	23 s
Minimum Value	4.576e-5 m/m
Maximum Value	29.25 m/m
Line B	
Structure	Truss_Spar
Type	RAOs Including Morison Drag
Component	Global Z
Direction	-180°
Abscissa Position of Minimum	5 s
Abscissa Position of Maximum	23 s
Minimum Value	4.529e-5 m/m
Maximum Value	10.312 m/m

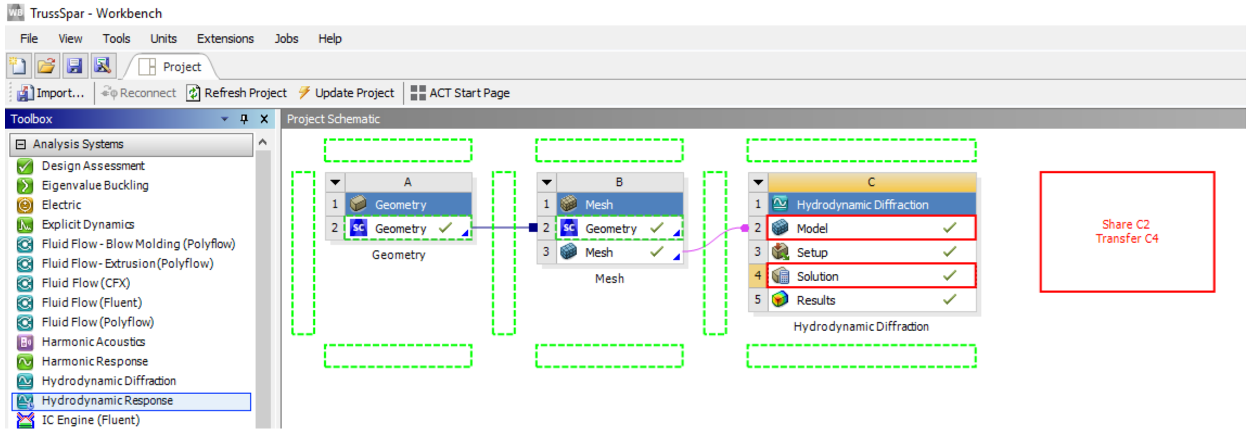


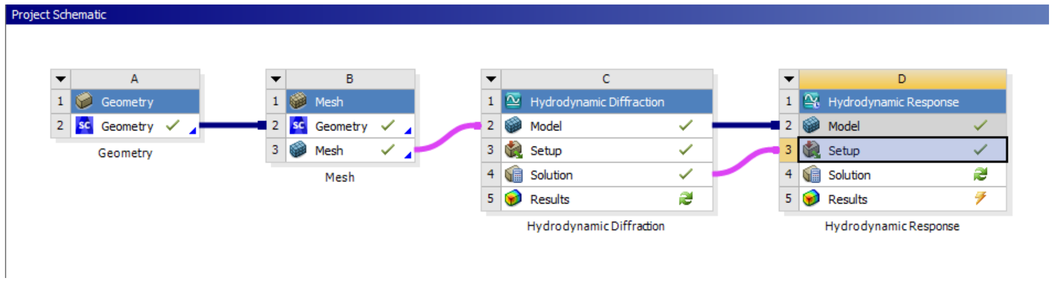
Adding the HR Systems

We are going to include four separate HR systems

- An initial static Stability Analysis
- Two Frequency Statistical Analyses, one including drag linearization and one without
- A Time Response Analysis

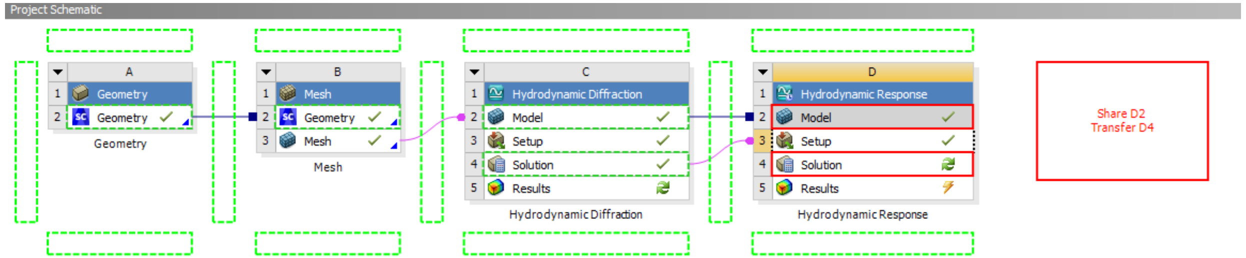
Drag and drop a Hydrodynamic Response to the WB Project Schematic while sharing the solution from Hydrodynamic Diffraction.

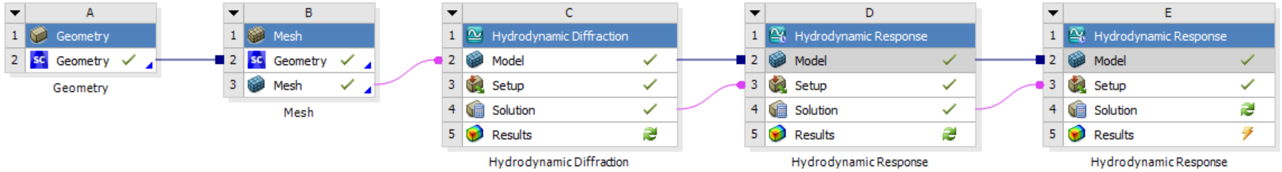


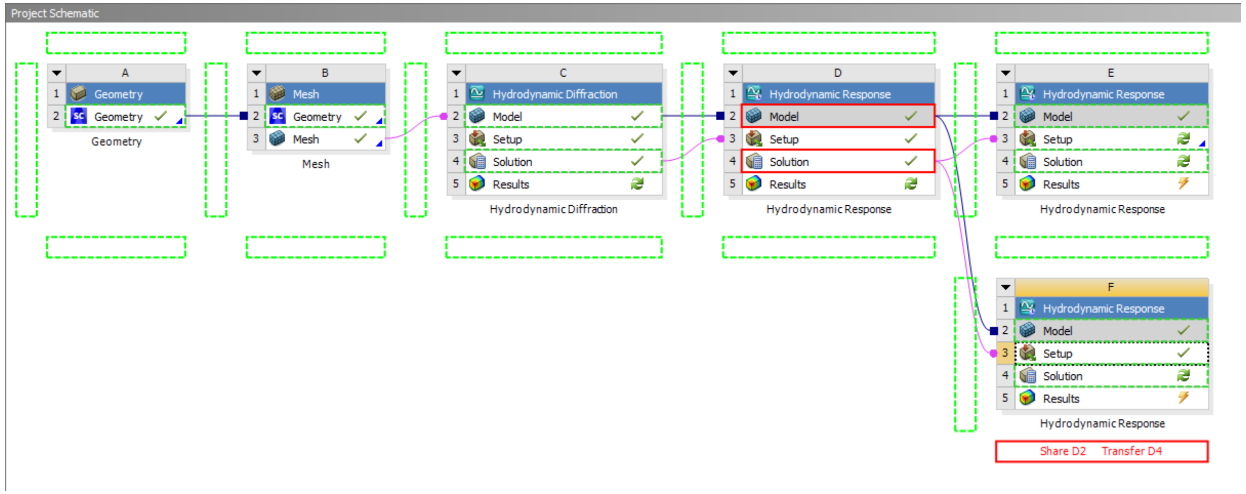


Adding the HR Systems

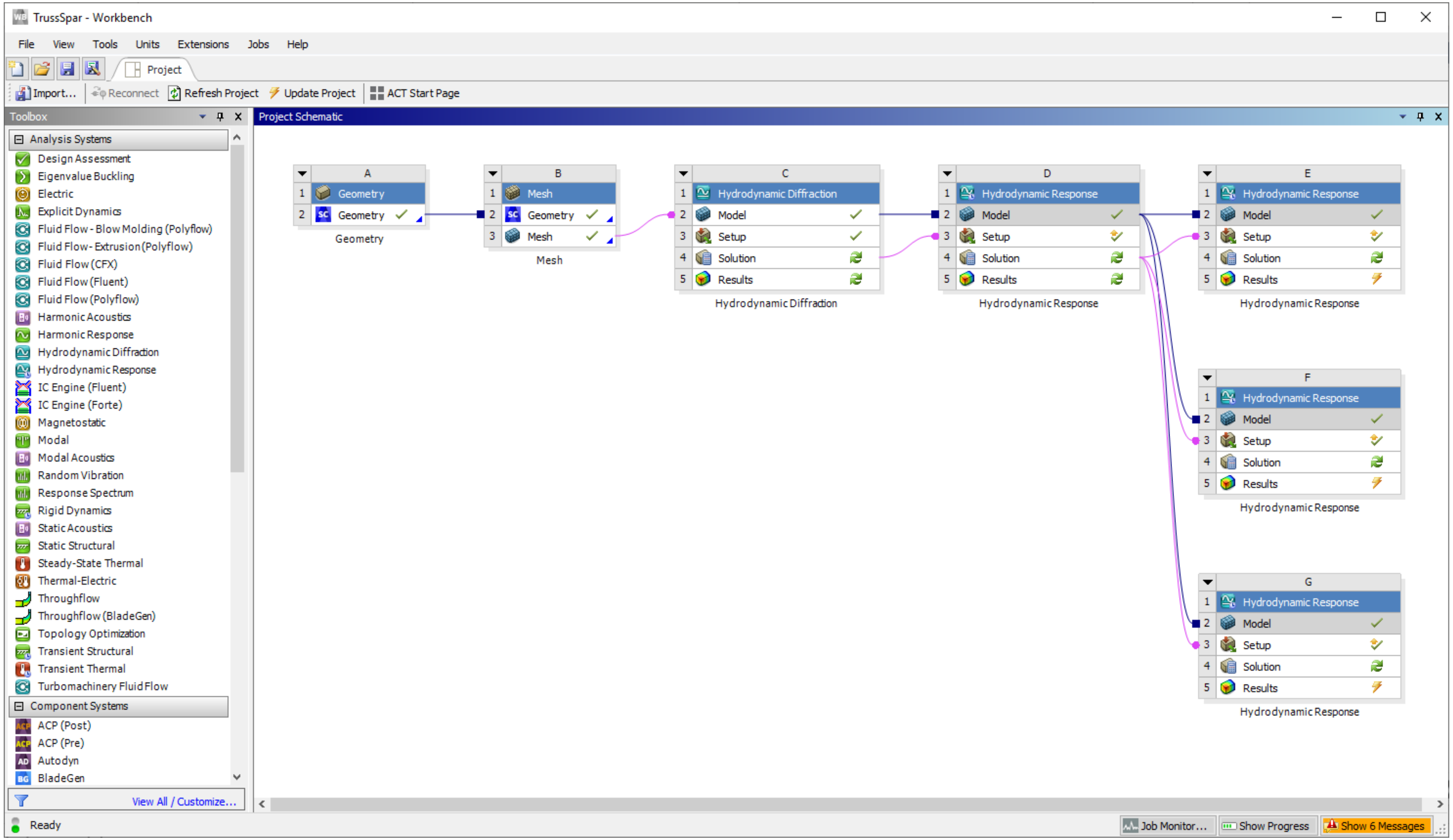
- Add a further three HR systems, but this time link each one with the solution from the first HR system (which is going to be the Stability Analysis)







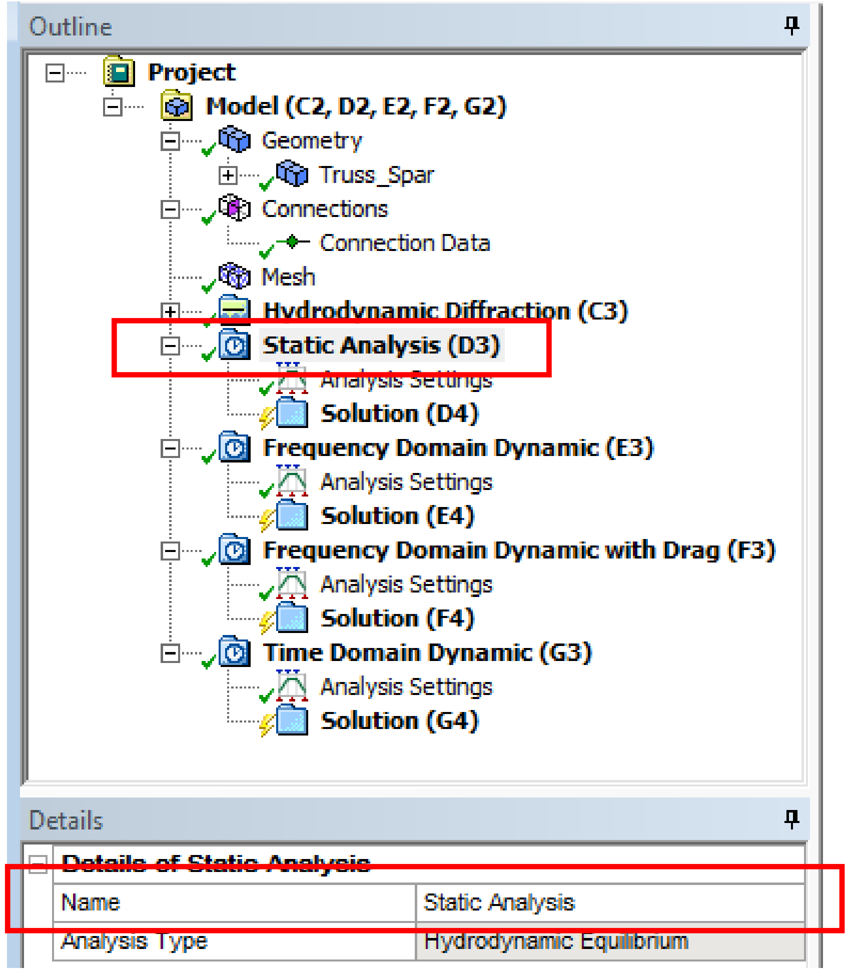
Completed Project Workflow



Identify Response Systems

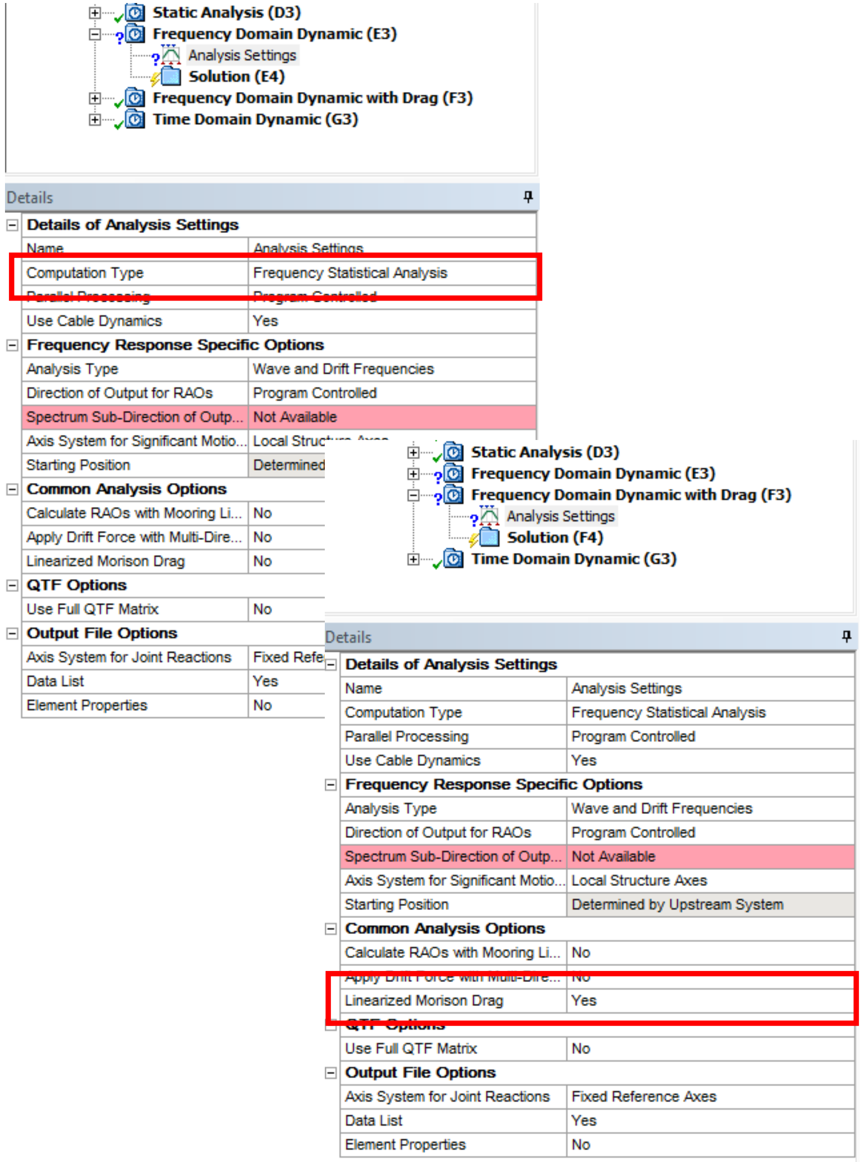
- In the project tree, click on the first Hydrodynamic Response (D3), rename this Analysis system to Static Analysis.

- Repeat for the other three HR systems as shown



Set up Response Systems

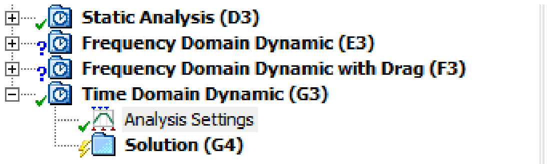
- By default, the first system linked to a HD system will become a static Stability Analysis, so this can be left as defined.
- For any HR system linked to a Stability Analysis, the default is to have a Computation Type of Time Response Analysis.
  - For the Frequency Domain Dynamic set Computation Type to Frequency Statistical Analysis. Leave other settings as they are.
  - For the Frequency Domain Dynamic with Drag, again set Computation Type to Frequency Statistical Analysis, but this time set the Linearized Morison Drag Analysis Option to Yes.



Set up Response Systems

For the Time Response Analysis

- Set the Analysis Type to Irregular Wave Response with Slow Drift
- Set the simulation Duration to 600 seconds



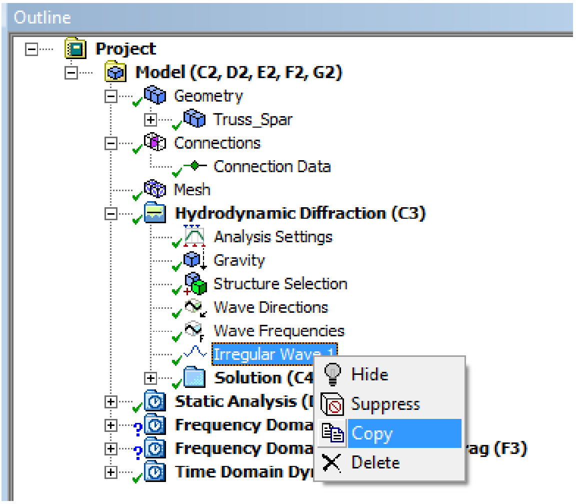
Details

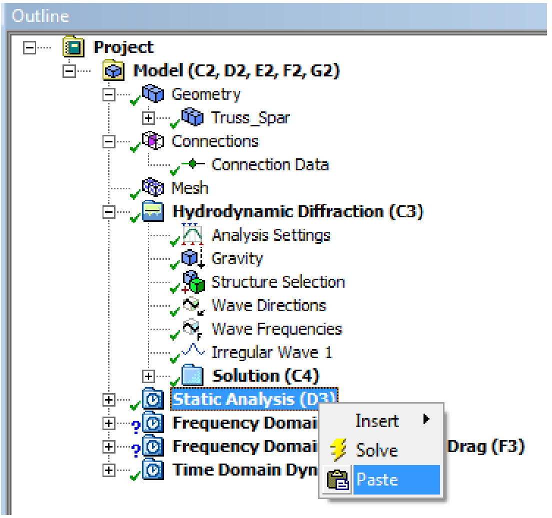
Details of Analysis Settings	
Name	Analysis Settings
Computation Type	Time Response Analysis
Parallel Processing	Program Controlled
Use Cable Dynamics	Yes
Time Response Specific Options	
Analysis Type	Irregular Wave Response with Slow Drift
Start Time	0.0 s
Time Step	0.1 s
Duration	600 s
Number of Steps	6001
Finish Time	600 s
Starting Position	Determined by Upstream System
X-Position for Wave Surface Ele...	0.0 m
Y-Position for Wave Surface Ele...	0.0 m
Common Analysis Options	
Convolution	Yes
Call Routine "user_force"	No
Calculate Motions Using RAOs ...	No
Account for Current Phase Shift	Yes
Apply Drift Force with Multi-Dire...	No
Calculate Wave Drift Damping	Yes
Include Yaw Wave Drift Damping	Yes
Use Slow Velocity for Hull Drag ...	No
QTF Options	
Use Full QTF Matrix	No
Use Sum Frequency QTFs	No
Output File Options	
Axis System for Joint Reactions	Fixed Reference Axes
Data List	Yes
Element Properties	No

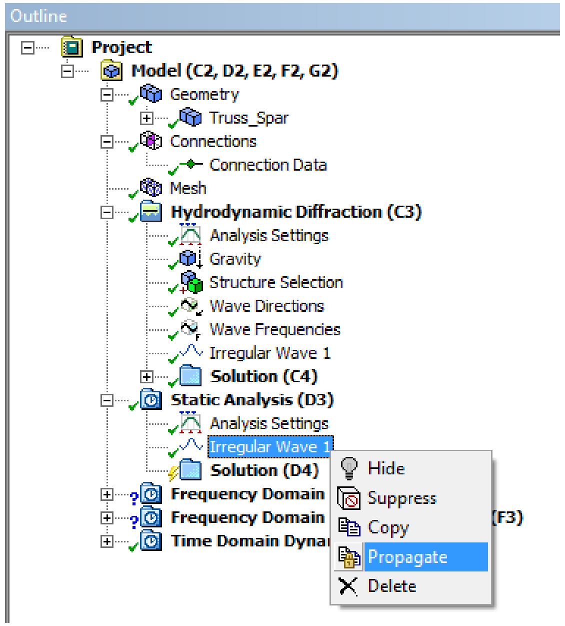
Define Environment

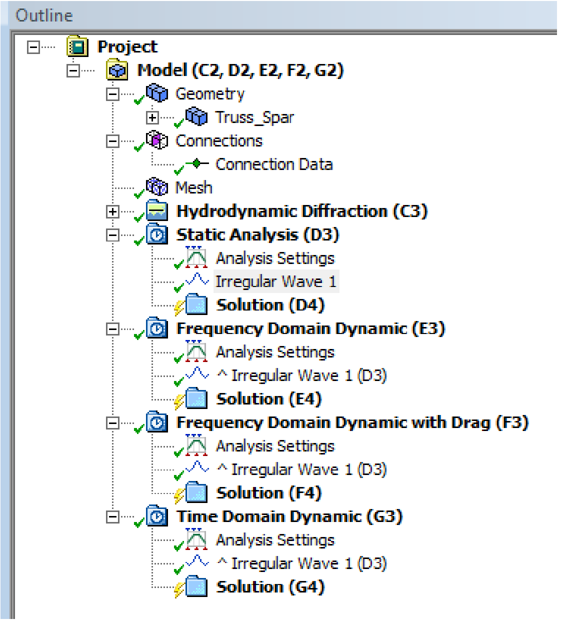
Since the drag linearization is based upon a given spectrum, we are going to use the same spectrum for all of the analyses.

- Right-click on Irregular Wave under the HD system, select Copy.
- Right-click on Static Analysis, select Paste
- Right-click on the new Irregular Wave under the Static Analysis, select Propagate



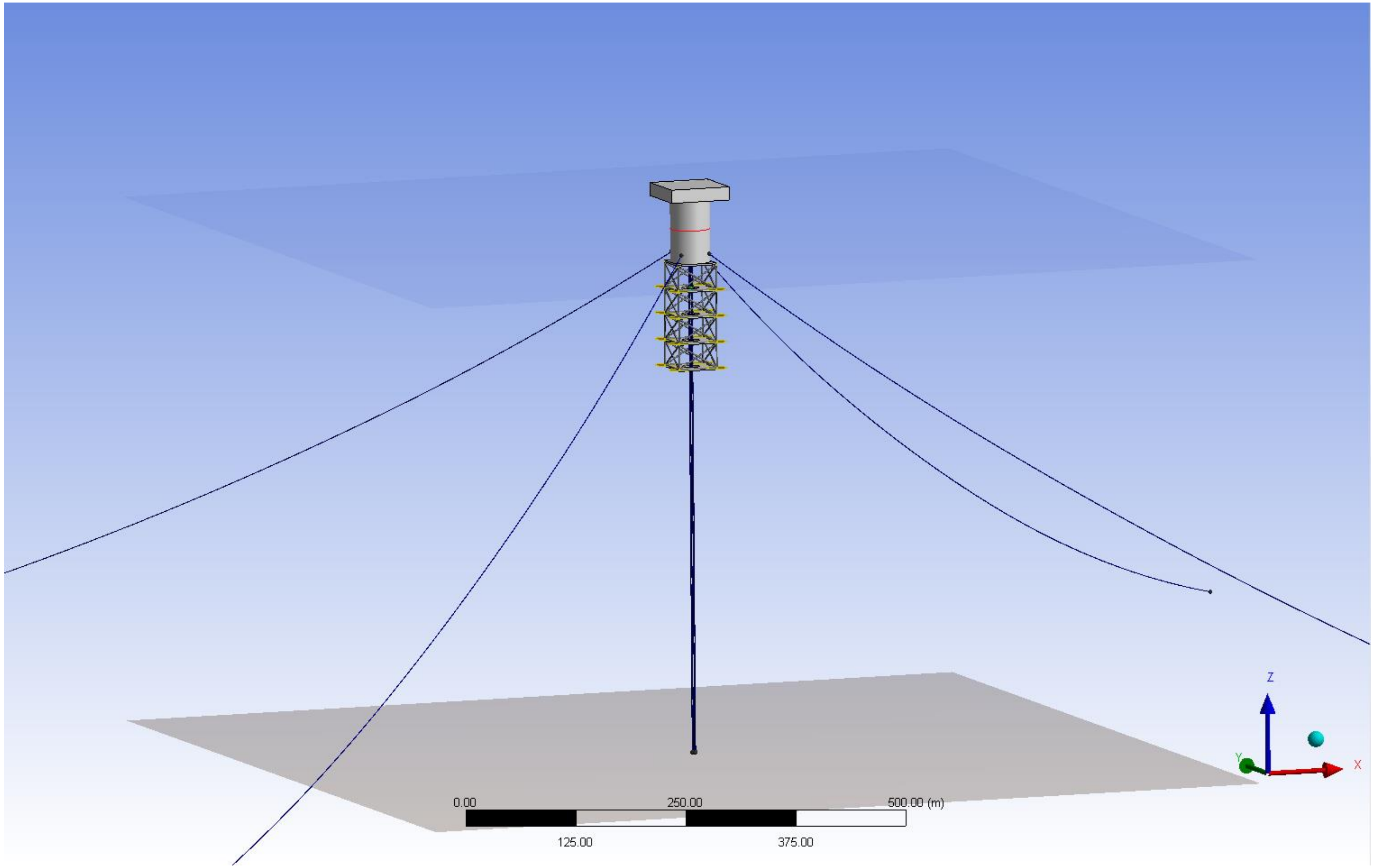






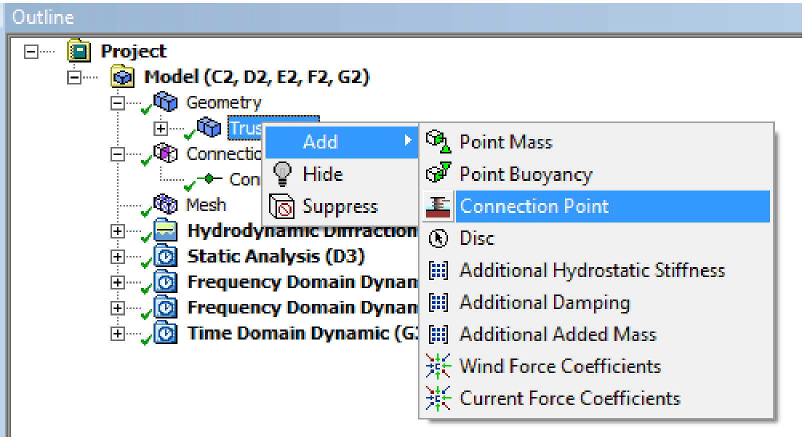
Set up Mooring Configuration

- The mooring configuration will consist of four conventional semi-taut lines, and four “rigid risers”



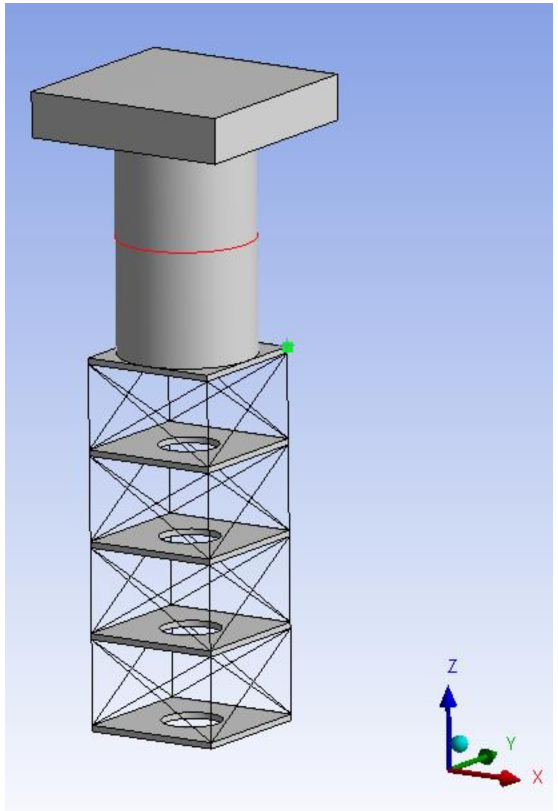
Create Connection Points on Spar

- Add four locations for the mooring system on the spar
- Select Geometry > Truss_Spar > Add > Connection Point
- Set Definition of Position to Vertex Selection and select the vertex on the corner at the top of the Spar hull base, in the positive X/Y quadrant. Set the X/Y/Z Offsets as shown.



Details

Details of Connection Point 1	
Name	Connection Point 1
Visibility	Visible
Point Definition	
Type	Attached to Structure
Structure	Truss_Spar
Definition of Position	Vertex Selection
Vertex	Vertex Selected (Truss_Spar)
Vertex X	22.75 m
Vertex Y	22.75 m
Vertex Z	-38 m
Position Coordinates	
X	16.75 m
Y	16.75 m
Z	-28 m
X Offset	-6 m
Y Offset	-6 m
Z Offset	10 m
Hydrodynamic Response Nodal Motions Output	
Include in Results	Yes



Create Connection Points on Spar

Repeat for the three other corners on the Spar hull base. Define the offsets such that the connection points lie adjacent to the Spar hull

- Assuming that the connection points are defined in a clock-wise manner when looking from above, the offset data is as follows

Details

Details of Connection Point 2	
Name	Connection Point 2
Visibility	Visible
Point Definition	
Type	Attached to Structure
Structure	Truss_Spar
Definition of Position	Vertex Selection
Vertex	Vertex Selected (Truss_Spar)
Vertex X	22.75 m
Vertex Y	-22.75 m
Vertex Z	-38 m
Position Coordinates	
X	16.75 m
Y	-16.75 m
Z	-28 m
X Offset	-6 m
Y Offset	6 m
Z Offset	10 m
Hydrodynamic Response Nodal Motions Output	
Include in Results	Yes

Details

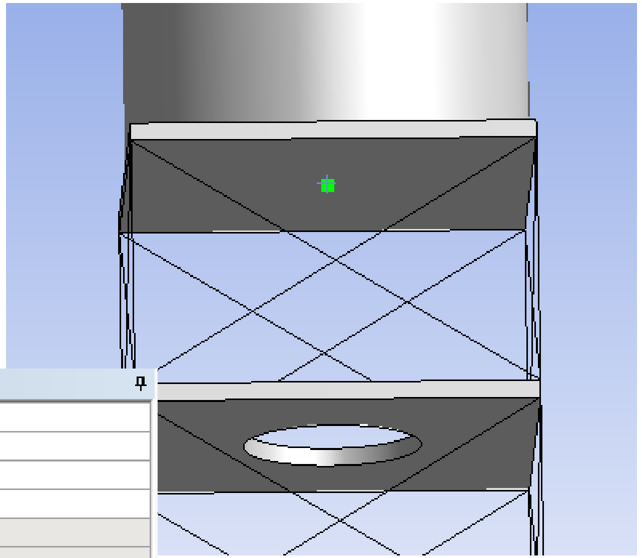
Details of Connection Point 3	
Name	Connection Point 3
Visibility	Visible
Point Definition	
Type	Attached to Structure
Structure	Truss_Spar
Definition of Position	Vertex Selection
Vertex	Vertex Selected (Truss_Spar)
Vertex X	-22.75 m
Vertex Y	-22.75 m
Vertex Z	-38 m
Position Coordinates	
X	-16.75 m
Y	-16.75 m
Z	-28 m
X Offset	6 m
Y Offset	6 m
Z Offset	10 m
Hydrodynamic Response Nodal Motions Output	
Include in Results	Yes

Details

Details of Connection Point 4	
Name	Connection Point 4
Visibility	Visible
Point Definition	
Type	Attached to Structure
Structure	Truss_Spar
Definition of Position	Vertex Selection
Vertex	Vertex Selected (Truss_Spar)
Vertex X	-22.75 m
Vertex Y	22.75 m
Vertex Z	-38 m
Position Coordinates	
X	-16.75 m
Y	16.75 m
Z	-28 m
X Offset	6 m
Y Offset	-6 m
Z Offset	10 m
Hydrodynamic Response Nodal Motions Output	
Include in Results	Yes

Create Connection Points on Spar

- Add four locations for the riser system on the spar
- Select Geometry > Truss_Spar > Add > Connection Point
- Set Definition of Position to Vertex Selection and select the vertex on the bottom of the Hull Drag Tube. Set the X/Y/Z Offsets as shown.



Details

Details of Connection Point 5	
Name	Connection Point 5
Visibility	Visible
Point Definition	
Type	Attached to Structure
Structure	Truss_Spar
Definition of Position	Vertex Selection
Vertex	Vertex Selected (Truss_Spar)
Vertex X	0.0 m
Vertex Y	0.0 m
Vertex Z	-40 m
Position Coordinates	
X	2 m
Y	0.0 m
Z	-40 m
X Offset	2 m
Y Offset	0.0 m
Z Offset	0.0 m
Hydrodynamic Response Nodal Motions Output	
Include in Results	Yes

Create Connection Points on Spar

Repeat three times for the remaining risers. Use the same vertex as a reference point, but just change the offset. Use Duplicate to re-use the existing vertex selection

- Assuming that the connection points are defined in a clock-wise manner when looking from above, the offset data is as follows

Details

Details of Connection Point 6	
Name	Connection Point 6
Visibility	Visible
Point Definition	
Type	Attached to Structure
Structure	Truss_Spar
Definition of Position	Vertex Selection
Vertex	Vertex Selected (Truss_Spar)
Vertex X	0.0 m
Vertex Y	0.0 m
Vertex Z	-40 m
Position Coordinates	
X	0.0 m
Y	-2 m
Z	-40 m
X Offset	0.0 m
Y Offset	-2 m
Z Offset	0.0 m
Hydrodynamic Response Nodal Motions Output	
Include in Results	Yes

Details

Details of Connection Point 7	
Name	Connection Point 7
Visibility	Visible
Point Definition	
Type	Attached to Structure
Structure	Truss_Spar
Definition of Position	Vertex Selection
Vertex	Vertex Selected (Truss_Spar)
Vertex X	0.0 m
Vertex Y	0.0 m
Vertex Z	-40 m
Position Coordinates	
X	-2 m
Y	0.0 m
Z	-40 m
X Offset	-2 m
Y Offset	0.0 m
Z Offset	0.0 m
Hydrodynamic Response Nodal Motions Output	
Include in Results	Yes

Details

Details of Connection Point 8	
Name	Connection Point 8
Visibility	Visible
Point Definition	
Type	Attached to Structure
Structure	Truss_Spar
Definition of Position	Vertex Selection
Vertex	Vertex Selected (Truss_Spar)
Vertex X	0.0 m
Vertex Y	0.0 m
Vertex Z	-40 m
Position Coordinates	
X	0.0 m
Y	2 m
Z	-40 m
X Offset	0.0 m
Y Offset	2 m
Z Offset	0.0 m
Hydrodynamic Response Nodal Motions Output	
Include in Results	Yes

Define Anchor Locations

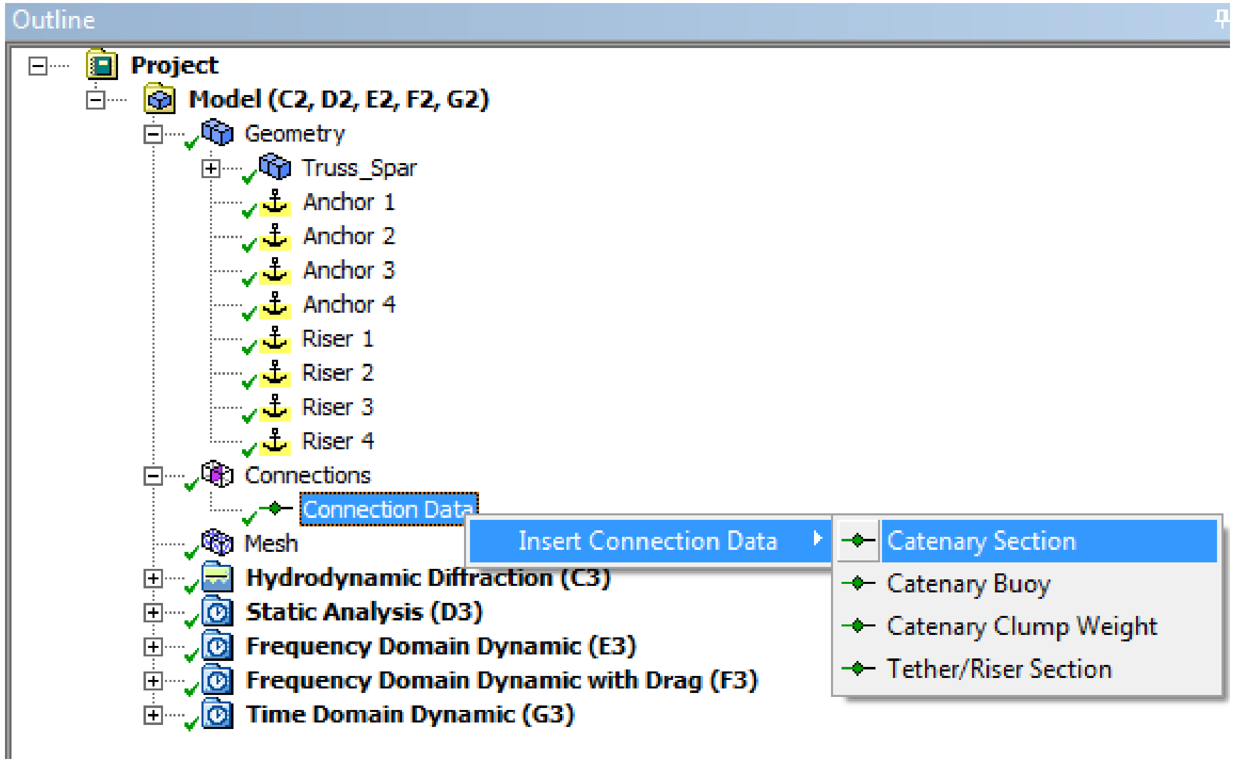
- Add four anchors for the mooring lines, and four connections for the rigid risers

Mooring Anchors			
	X	Y	Z
Anchor 1	1000	1000	-600
Anchor 2	1000	-1000	-600
Anchor 3	-1000	-1000	-600
Anchor 4	-1000	1000	-600

Riser Connectors			
	X	Y	Z
Riser 1	2	0	-600
Riser 2	0	-2	-600
Riser 3	-2	0	-600
Riser 4	0	2	-600

Set Up Mooring Line Properties

- We are going to use composite catenary lines for the mooring system. These are lines made up of one or more segments (or sections) with varying properties e.g. chain/wire/chain
- Select Connections > Connection Data > Insert Connection Data > Catenary Section.



Mooring Line Properties

- Provide data for Mass/Unit Length, Equivalent Cross-Sectional Area, Stiffness, Maximum Tension and Equivalent Diameter as below. Note that stiffness value is 6e8, and maximum tension is 7.5e6.
- Repeat for two additional sections

Details

Details of Catenary Section 1	
Name	Catenary Section 1
Section Properties	
Mass/Unit Length	150 kg/m
Equivalent Cross-Sectional A...	0.01 m²
Stiffness, EA	600000000 N
Maximum Tension	7500000 N
Bending Stiffness, EI	0.0 N.m²
Axial Stiffness Coefficient k1	0.0
Axial Stiffness Coefficient k2	0.0
Axial Stiffness Coefficient k3	0.0
Section Hydrodynamic Properties	
Added Mass Coefficient	1
Transverse Drag Coefficient	1
Equivalent Diameter	0.1 m
Longitudinal Drag Coefficient	0.025

Details

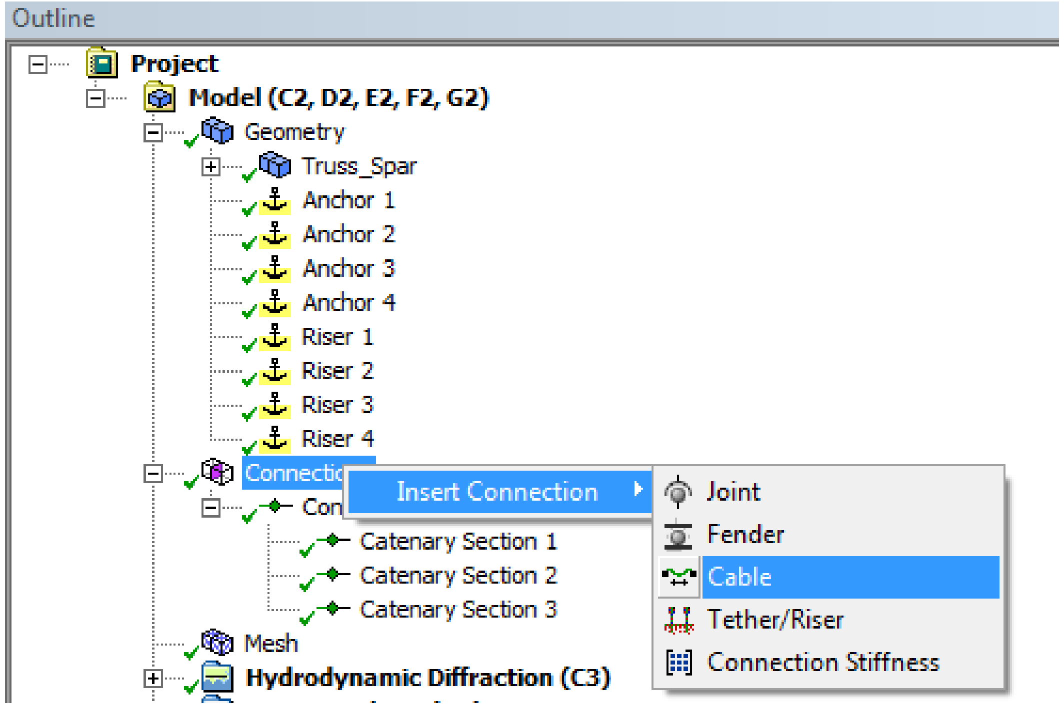
Details of Catenary Section 2	
Name	Catenary Section 2
Section Properties	
Mass/Unit Length	120 kg/m
Equivalent Cross-Sectional A...	0.01 m²
Stiffness, EA	900000000 N
Maximum Tension	7500000 N
Bending Stiffness, EI	0.0 N.m²
Axial Stiffness Coefficient k1	0.0
Axial Stiffness Coefficient k2	0.0
Axial Stiffness Coefficient k3	0.0
Section Hydrodynamic Properties	
Added Mass Coefficient	1
Transverse Drag Coefficient	1
Equivalent Diameter	0.1 m
Longitudinal Drag Coefficient	0.025

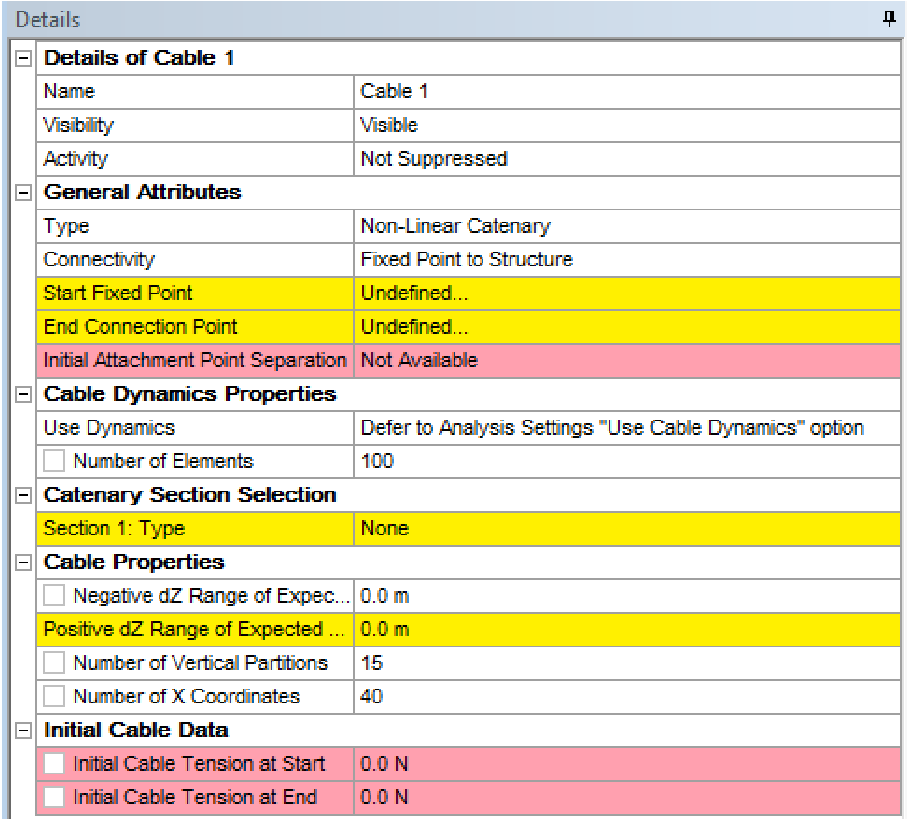
Details

Details of Catenary Section 3	
Name	Catenary Section 3
Section Properties	
Mass/Unit Length	170 kg/m
Equivalent Cross-Sectional A...	0.01 m²
Stiffness, EA	600000000 N
Maximum Tension	7500000 N
Bending Stiffness, EI	0.0 N.m²
Axial Stiffness Coefficient k1	0.0
Axial Stiffness Coefficient k2	0.0
Axial Stiffness Coefficient k3	0.0
Section Hydrodynamic Properties	
Added Mass Coefficient	1
Transverse Drag Coefficient	1
Equivalent Diameter	0.1 m
Longitudinal Drag Coefficient	0.025

Mooring Line Connections

- To add a line select Connections > Insert Connection > Cable
- Rename mooring line as Mooring 1
- Choose Non-Linear Catenary for Type and Fixed Point to Structure for Connectivity





Ansys

Mooring Line Connections

- We need to define end connection points and the segments along the line, plus some data defining the possible dZ range of the fairlead (will be explained in a later lecture).
- Click on cell adjacent to Start Fixed Point and select Anchor 1 (Fixed) from drop down menu.
- Click on cell adjacent to End Connection Point and select Connection Point 1 (Truss_Spar) from drop down menu.

Details

Details of Cable 1	
Name	Cable 1
Visibility	Visible
Activity	Not Suppressed
General Attributes	
Type	Non-Linear Catenary
Connectivity	Fixed Point to Structure
Start Fixed Point	Anchor 1 (Fixed)
End Connection Point	Connection Point 1 (Truss_Spar)
Initial Attachment Point Separation	1503.57744230219 m (Point to Point)

Ansys

Mooring Line Configuration

- The composition of the line is now defined
  - Section allocation
  - Line length
- Sections are defined from the *anchor* location up to the *fairlead*
- Section 1 type should be set to Catenary Section 1, length 600 m
- Repeat for sections 2 and 3 as shown
- Finally set the dZ Ranges under Cable Properties to 10m

Details

Details of Mooring 1	
Name	Mooring 1
Visibility	Visible
Activity	Not Suppressed
General Attributes	
Type	Non-Linear Catenary
Connectivity	Fixed Point to Structure
Start Fixed Point	Anchor 1 (Fixed)
End Connection Point	Connection Point 1 (Truss_Spar)
Initial Attachment Point Separation	1503.57744230219 m (Point to Point)
Cable Dynamics Properties	
Use Dynamics	Defer to Analysis Settings "Use Cable Dynamics" option
Number of Elements	100
Catenary Section Selection	
Section 1: Type	Catenary Section 1
Section 1: Length	600 m
Joint 1/2: Mass/Buoyancy	None
Section 2: Type	Catenary Section 2
Section 2: Length	500 m
Joint 2/3: Mass/Buoyancy	None
Section 3: Type	Catenary Section 3
Section 3: Length	400 m
Section 4: Type	None
Cable Properties	
Negative dZ Range of Expec...	10 m
Positive dZ Range of Expect...	10 m
Number of Vertical Partitions	15
Number of X Coordinates	40

Mooring Line Configuration

- Set up the remaining 3 mooring lines with identical properties but different connection points
- Use the Duplicate option to reduce data repetition

Details

Details of Mooring 2	
Name	Mooring 2
Visibility	Visible
Activity	Not Suppressed
General Attributes	
Type	Non-Linear Catenary
Connectivity	Fixed Point to Structure
Start Fixed Point	Anchor 2 (Fixed)
End Connection Point	Connection Point 2 (Truss_Spar)
Initial Attachment Point Separation	1503.57744230219 m (Point to Point)

Details

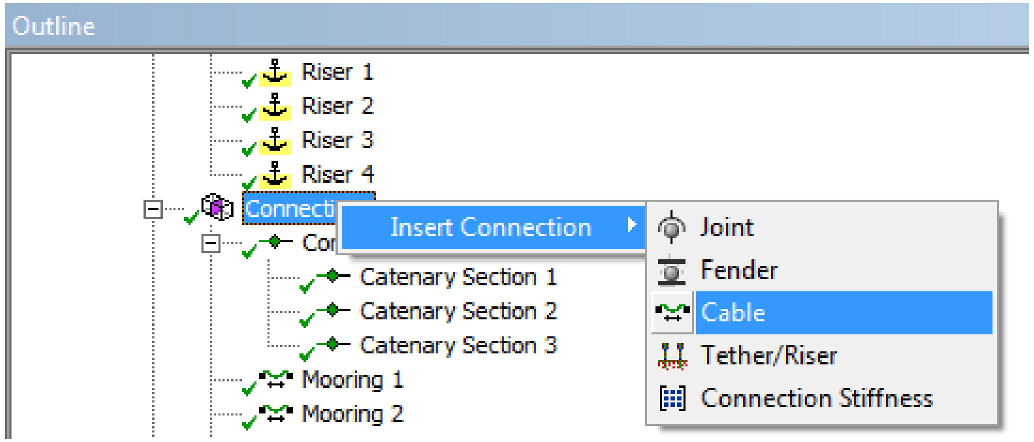
Details of Mooring 3	
Name	Mooring 3
Visibility	Visible
Activity	Not Suppressed
General Attributes	
Type	Non-Linear Catenary
Connectivity	Fixed Point to Structure
Start Fixed Point	Anchor 3 (Fixed)
End Connection Point	Connection Point 3 (Truss_Spar)
Initial Attachment Point Separation	1503.57744230219 m (Point to Point)

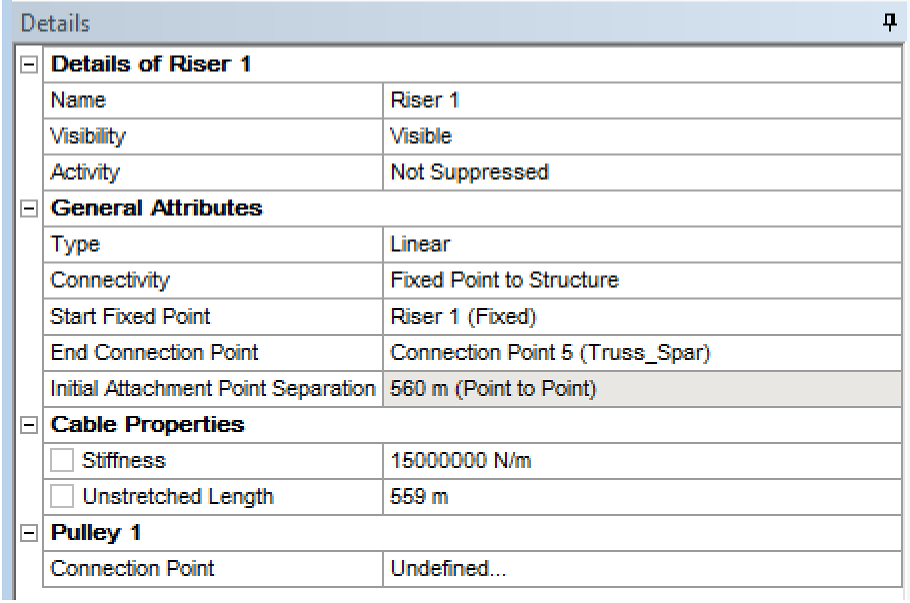
Details

Details of Mooring 4	
Name	Mooring 4
Visibility	Visible
Activity	Not Suppressed
General Attributes	
Type	Non-Linear Catenary
Connectivity	Fixed Point to Structure
Start Fixed Point	Anchor 4 (Fixed)
End Connection Point	Connection Point 4 (Truss_Spar)
Initial Attachment Point Separation	1503.57744230219 m (Point to Point)

Riser Connections

- These are added in the same way as the mooring lines, except now we are going to use a simplified model for the riser (we could have used the Tether/Riser connection, but this is not available in the solver for dynamic frequency domain analyses)
- Choose Fixed Point & Structure for Connectivity and Linear for Type
- Set Stiffness to 1.5E7 N/m and Unstretched Length to 559 m
- Rename as Riser 1





Riser Connections

- Repeat for the other three risers

Details

Details of Riser 2	
Name	Riser 2
Visibility	Visible
Activity	Not Suppressed
General Attributes	
Type	Linear
Connectivity	Fixed Point to Structure
Start Fixed Point	Riser 2 (Fixed)
End Connection Point	Connection Point 6 (Truss_Spar)
Initial Attachment Point Separation	560 m (Point to Point)
Cable Properties	
Stiffness	15000000 N/m
Unstretched Length	559 m

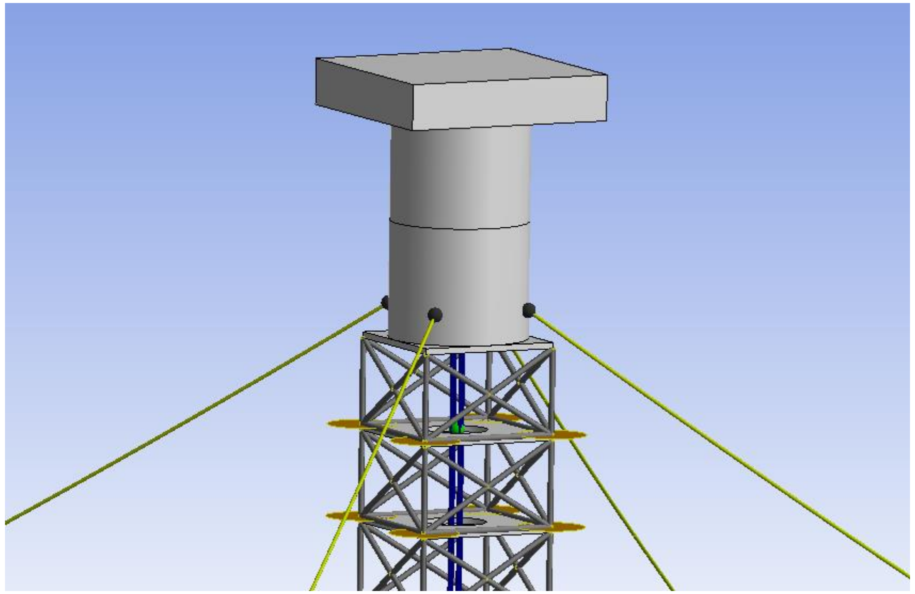
Details

Details of Riser 3	
Name	Riser 3
Visibility	Visible
Activity	Not Suppressed
General Attributes	
Type	Linear
Connectivity	Fixed Point to Structure
Start Fixed Point	Riser 3 (Fixed)
End Connection Point	Connection Point 7 (Truss_Spar)
Initial Attachment Point Separation	560 m (Point to Point)
Cable Properties	
Stiffness	15000000 N/m
Unstretched Length	559 m

Details

Details of Riser 4	
Name	Riser 4
Visibility	Visible
Activity	Not Suppressed
General Attributes	
Type	Linear
Connectivity	Fixed Point to Structure
Start Fixed Point	Riser 4 (Fixed)
End Connection Point	Connection Point 8 (Truss_Spar)
Initial Attachment Point Separation	560 m (Point to Point)
Cable Properties	
Stiffness	15000000 N/m
Unstretched Length	559 m

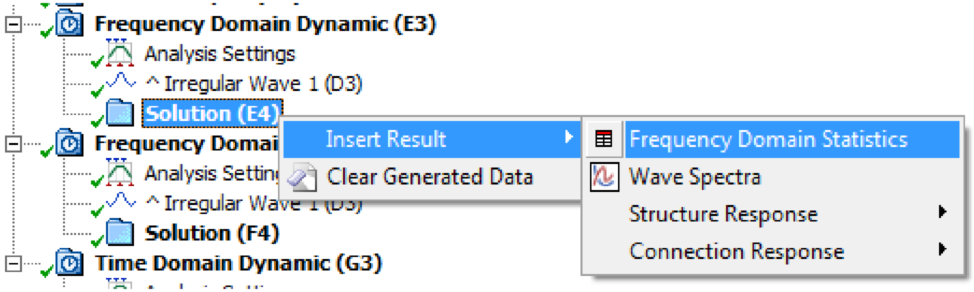
- Connections
  - Connection Data
  - Mooring 1
  - Mooring 2
  - Mooring 3
  - Mooring 4
  - Riser 1
  - Riser 2
  - Riser 3
  - Riser 4



Ansys

Solve

- We can now solve each of the dynamic systems that have been added. Note that if an upstream solution is not already available Workbench will automatically solve for that as well.
- Add some results to compare inclusion of drag linearization in the frequency domain solutions.



Details

Details of Frequency Domain Statistics	
Name	Frequency Domain Statistics
Statistical Measure	Significant Value (Amplitude)
Result A	
Result Type A	Motions
Structure	Truss_Spar
Reference Point	Center of Gravity (Truss_Spar)
Motion Relative To	Origin of Local Structure Axes (LSA)

Without drag linearization

Part Name: Truss_Spar
Motions: *at Center of Gravity, in Local Structure Axes*
Position X: 5.87364 m Y: 0.01900 m Z: 0.96852 m

Part Name: Truss_Spar
Motions: *at Center of Gravity, in Local Structure Axes*
Position X: 4.09014 m Y: 0.01490 m Z: 0.52269 m

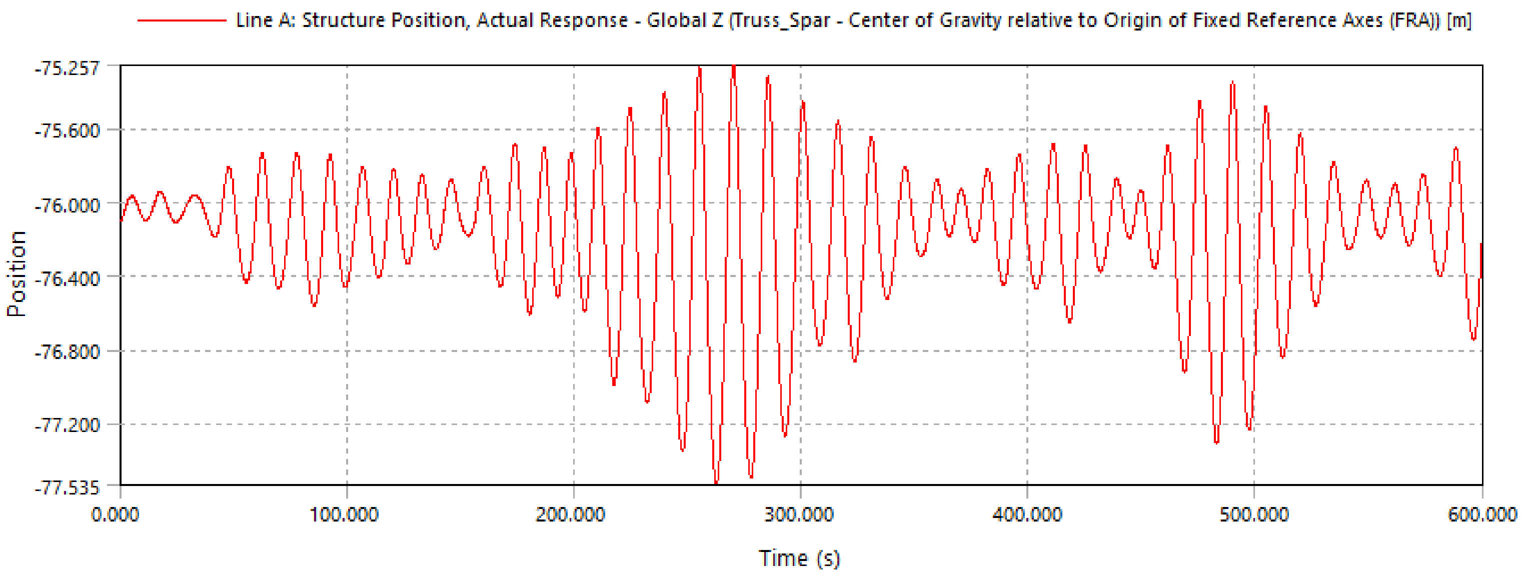
With drag linearization

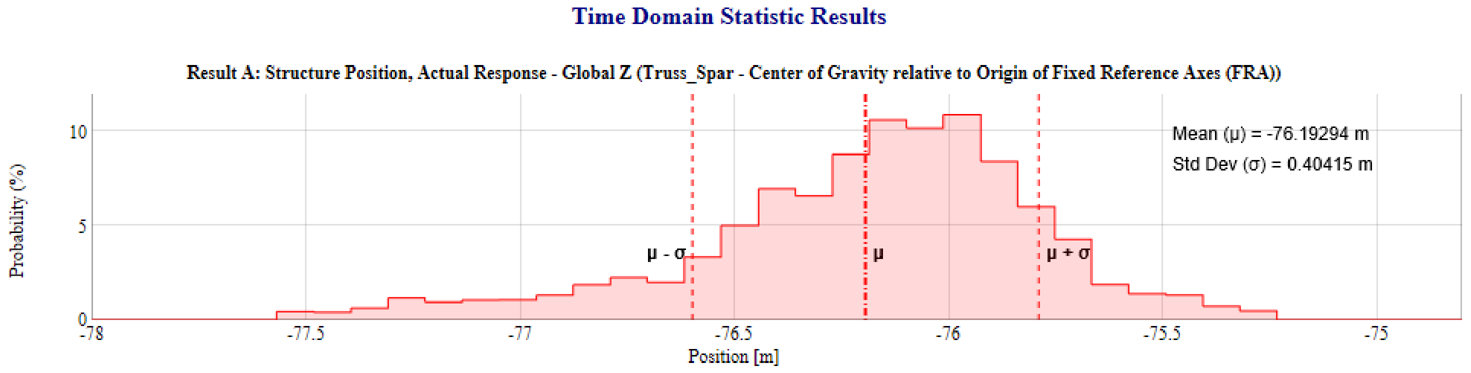
Time Domain Results

- Compare results between Frequency Domain and Time Domain solutions

Details	
Details of Structure Position, Actual Response	
Name	Structure Position, Actual Response
Presentation Method	Line
Axes Selection	Distance/Rotation vs Time
Export CSV File	Select CSV File...
Line A	
Structure	Truss_Spar
Type	Structure Position
SubType	Actual Response
Component	Global Z
Reference Point	Center of Gravity (Truss_Spar)
Motion Relative To	Origin of Fixed Reference Axes (FRA)
Abscissa Position of Minimum	262.5 s
Abscissa Position of Maximum	270.1 s
Minimum Value	-77.535 m
Maximum Value	-75.257 m
Line B	
Structure	Undefined...

Details	
Details of Time Domain Statistics	
Name	Time Domain Statistics
Statistics Calculated Over	All Time Steps
Statistics Shown As	Probability Density Function
Result A	
Result Type A	Structure Position
Structure	Truss_Spar
SubType	Actual Response
Component	Global Z
Reference Point	Center of Gravity (Truss_Spar)
Motion Relative To	Origin of Fixed Reference Axes (FRA)
Statistics Parameters A	
Mean Value	-76.19294 m
Standard Deviation	0.40415 m
Minimum Value	-77.53482 m
Maximum Value	-75.2571 m
Mean of Lowest-Third Peaks	-77.07882 m
Mean of Highest-Third Peaks	-75.46863 m
Result B	
Result Type B	None





Project Completed