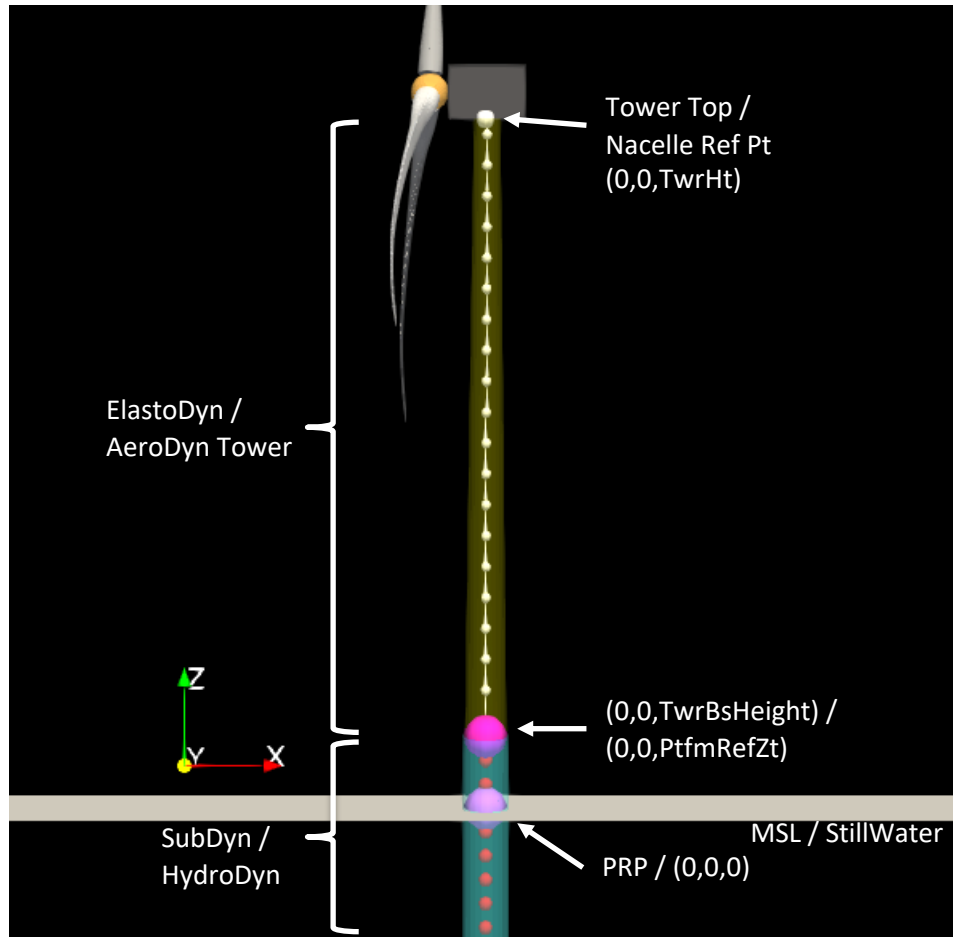


OpenFAST coordinate systems

Andy Platt
HFM workshop
February 1, 2024

ElastoDyn Tower



ElastoDyn:

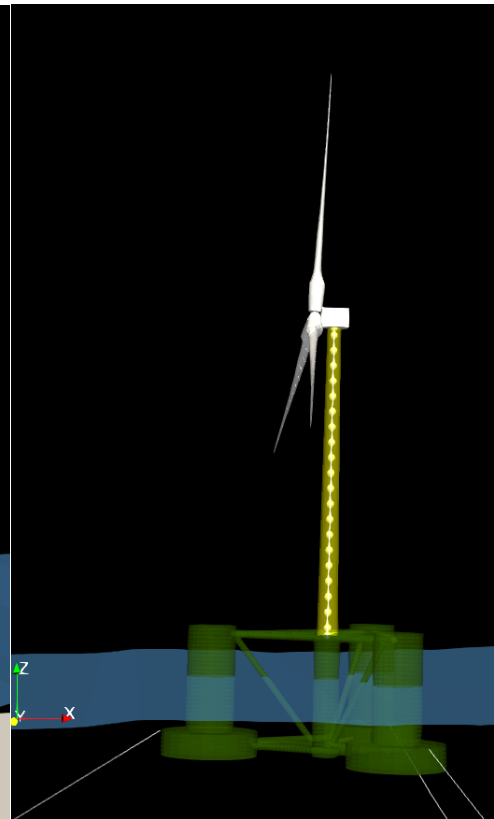
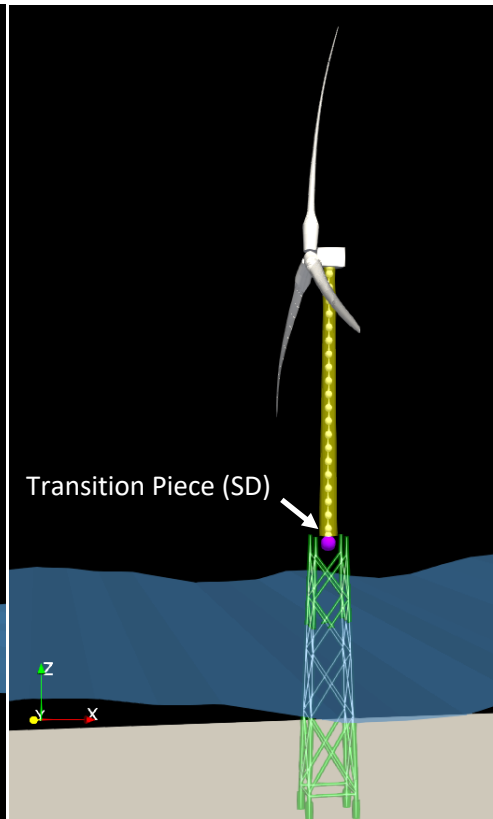
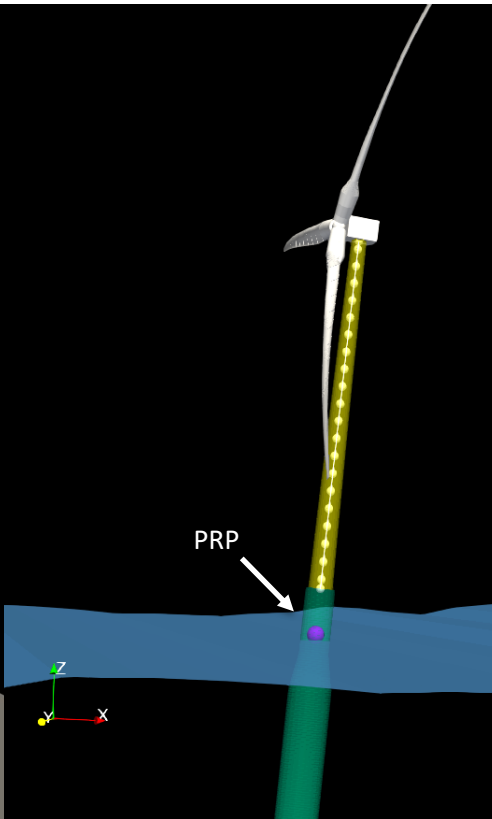
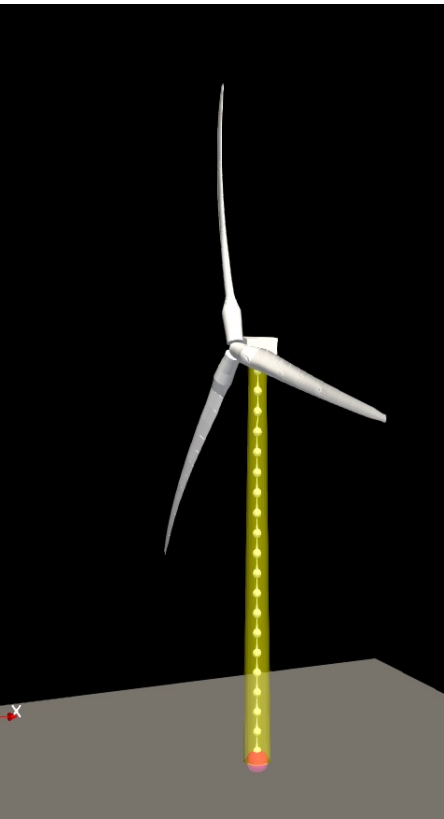
- TwrHt – height above MSL/ground
- TwrBsHeight – height above MSL/ground
- PtfmRefZt - platform connection to tower

HydroDyn / SeaState:

- MSL – mean sea level (0 m)
- MSL2SWL – offset from MSL to still water
- PRP – principle reference point for HydroDyn. Used for single body potential flow (internally used).

IEA 15 (v1.1.8) Monopile

- TwrHt: 144.386 m
- TwrBsHeight: 15.0 m
- MSL2SWL: 0.0 m



5MW_Land

- TwrHt: 87.6 m
- TwrBsHeight: 0.0 m

5MW_OC3Spar

- TwrHt: 87.6 m
- TwrBsHeight: 10.0 m

5MW_OC4Jckt

- TwrHt: 88.15 m
- TwrBsHeight: 20.15 m

5MW_OC4Semi

- TwrHt: 87.6 m
- TwrBsHeight: 10.0 m

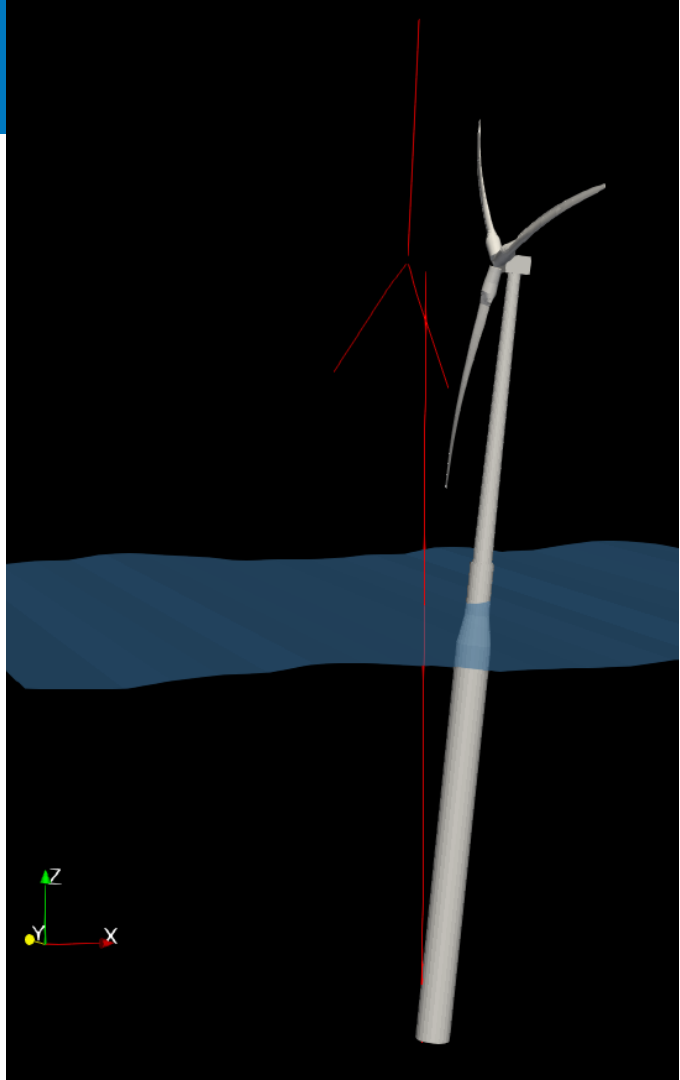
OpenFAST reference frame

Equivalent initial conditions:

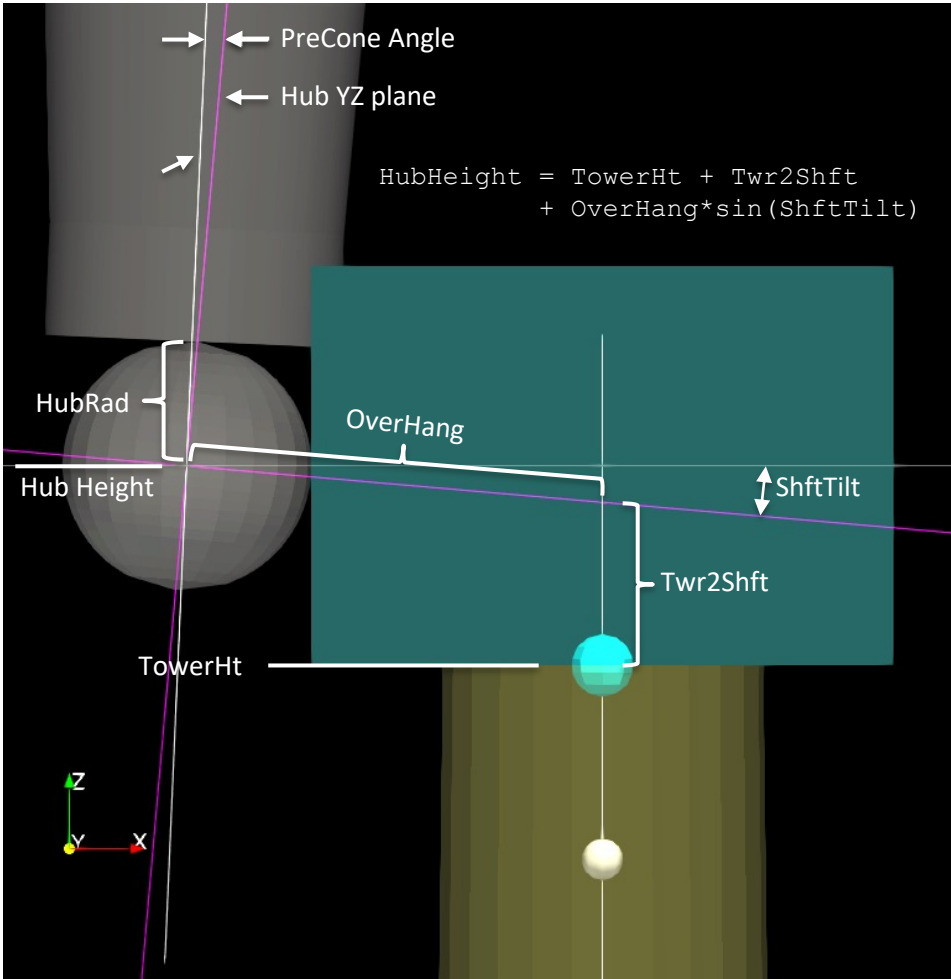
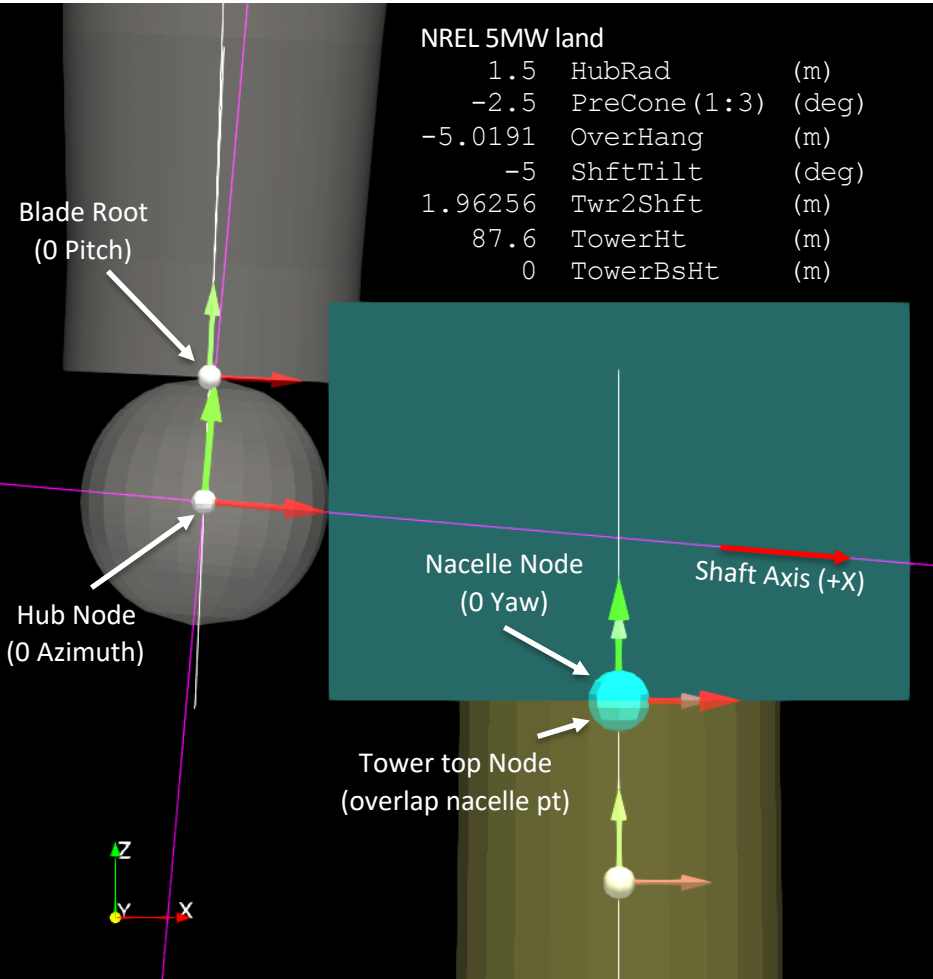
```
----- INITIAL CONDITIONS -----
0  OoPDefl    - Initial out-of-plane blade-tip displacement (m) [not BD]
0  IPDefl     - Initial in-plane blade-tip deflection (m)      [not BD]
0  BlPitch(1) - Blade 1 initial pitch (deg)
0  BlPitch(2) - Blade 2 initial pitch (deg)
0  BlPitch(3) - Blade 3 initial pitch (deg)
0  Azimuth    - Initial azimuth angle for blade 1 (deg)
0  NacYaw     - Initial or fixed nacelle-yaw angle (deg)
0  TTDspFA    - Initial fore-aft tower-top displacement (m)
0  TTDspSS    - Initial side-to-side tower-top displacement (m)
0  PtfmSurge  - horizontal surge translational displacement of platform (m)
0  PtfmSway   - horizontal sway translational displacement of platform (m)
0  PtfmHeave  - vertical heave translational displacement of platform (m)
0  PtfmRoll   - roll tilt rotational displacement of platform (deg)
0  PtfmPitch  - pitch tilt rotational displacement of platform (deg)
0  PtfmYaw    - yaw rotational displacement of platform (deg)
```

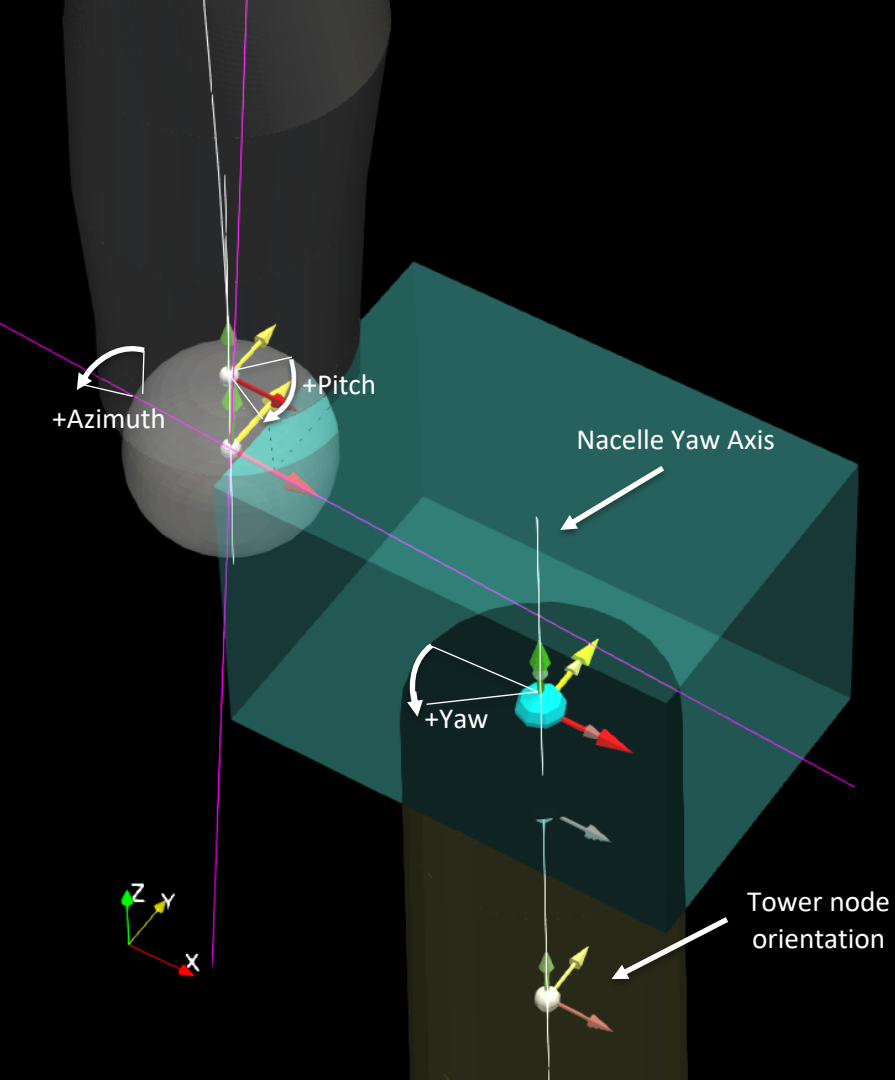
Included in reference frame

```
----- TURBINE CONFIGURATION -----
HubRad      PreCone(1:3) .  AzimBlUp
OverHang    ShftTilt      Twr2Shft
TowerHt     TowerBsHt     PtfmRefzt
```



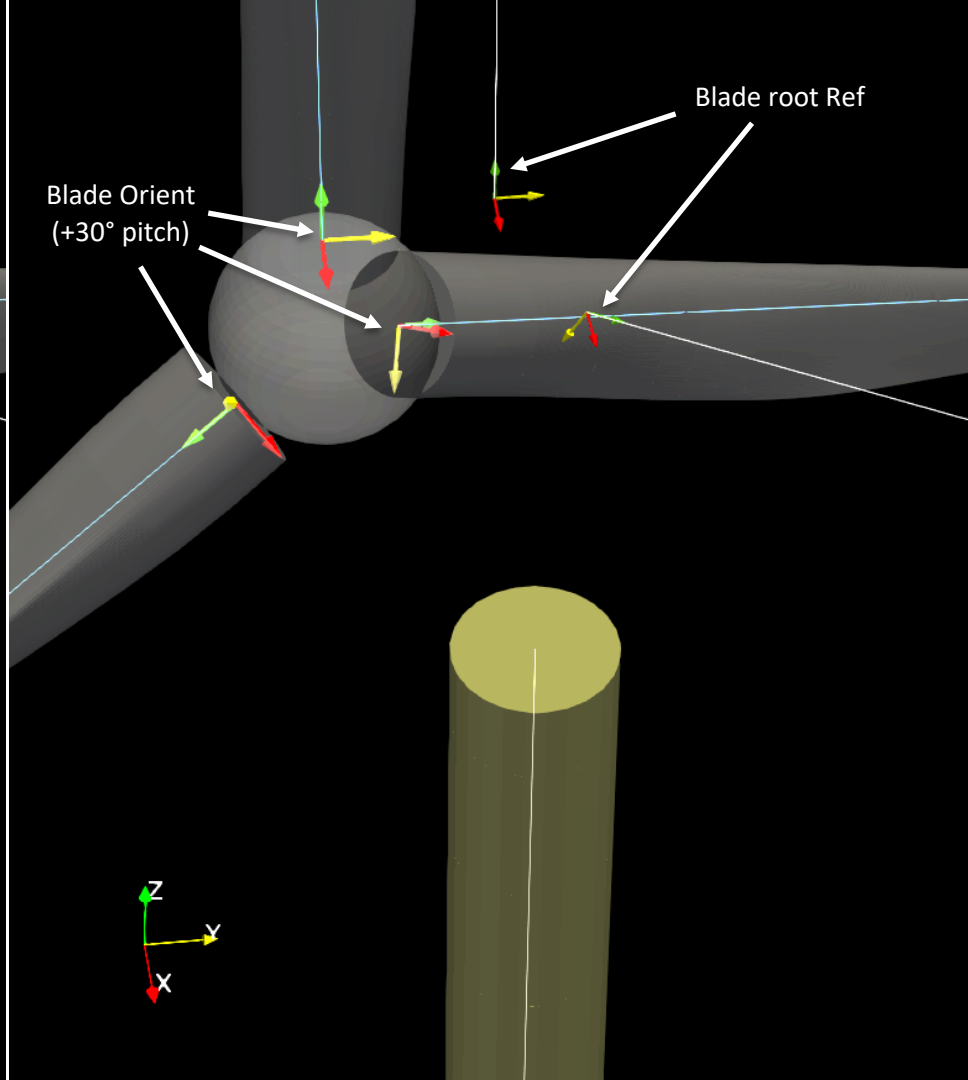
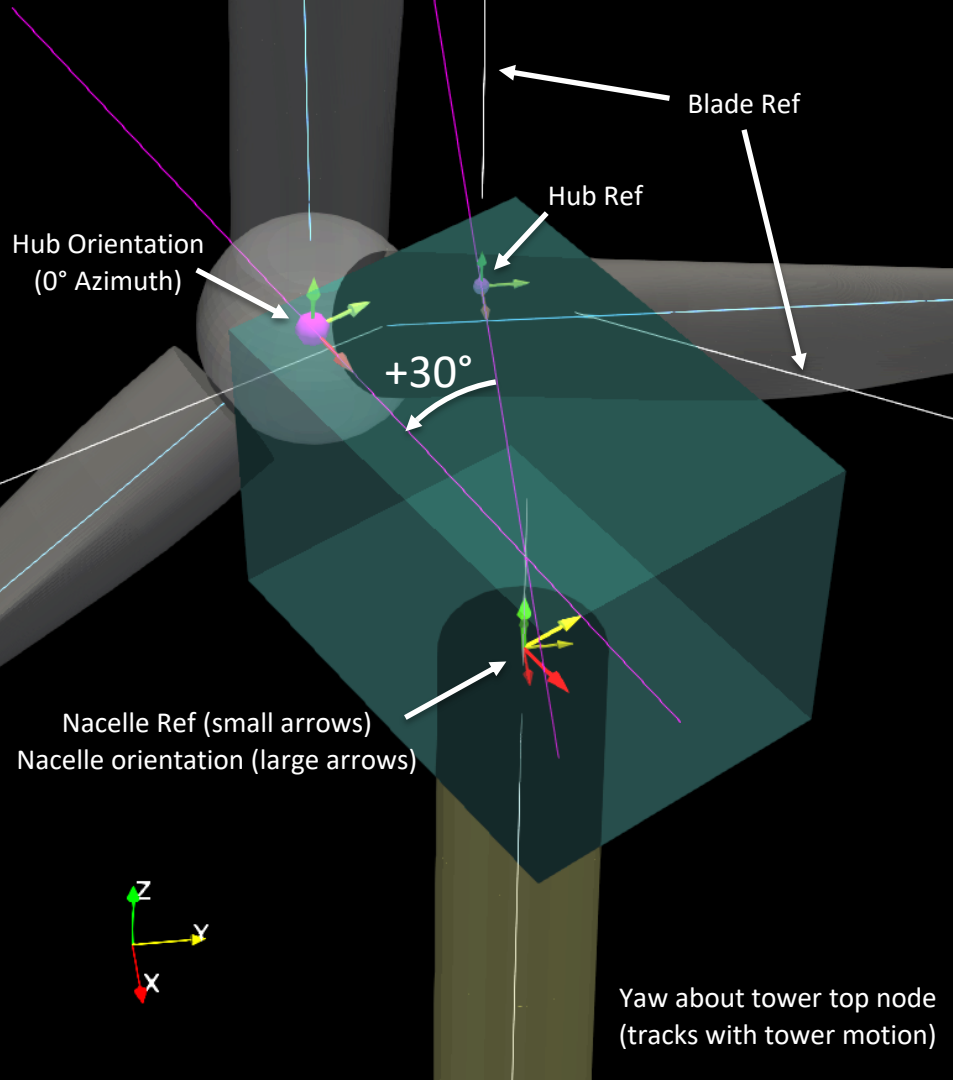
Hub location

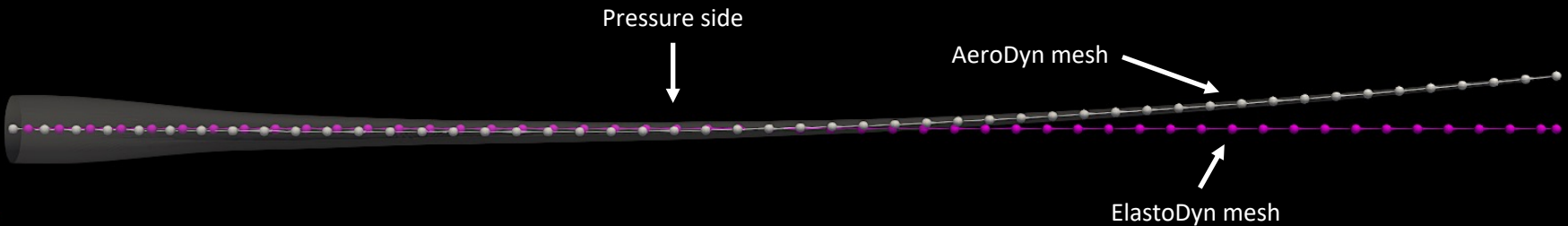
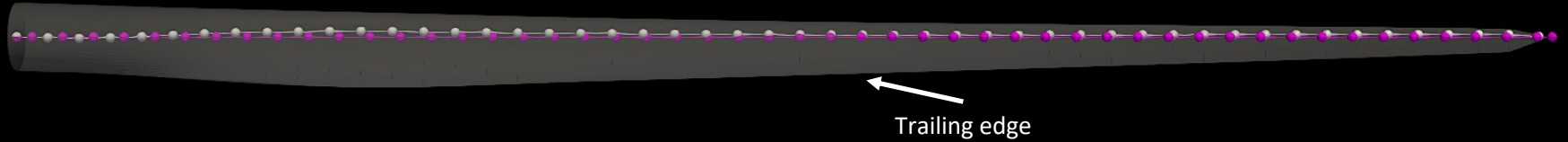




Coordinate frames:

- Tower – reference frame aligned with global frame, attached at `TowerBsHt` to `ground/SubDyn/HydroDyn`
- Nacelle – attached to top node of tower, rotates about tower top local Z axis
- Yaw – about tower top node Z axis (right hand rotation)
- Hub – rotates about shaft X axis, follows rotor azimuth (right hand rotation)
- Blade root mesh – attached to hub with cone angle, offset by hub radius along coned angle. Blade pitches about local Z axis (*left hand rotation*)
- AD/ED/BD blade - attaches to blade root mesh, first node Z axis aligns to root mesh Z axis.





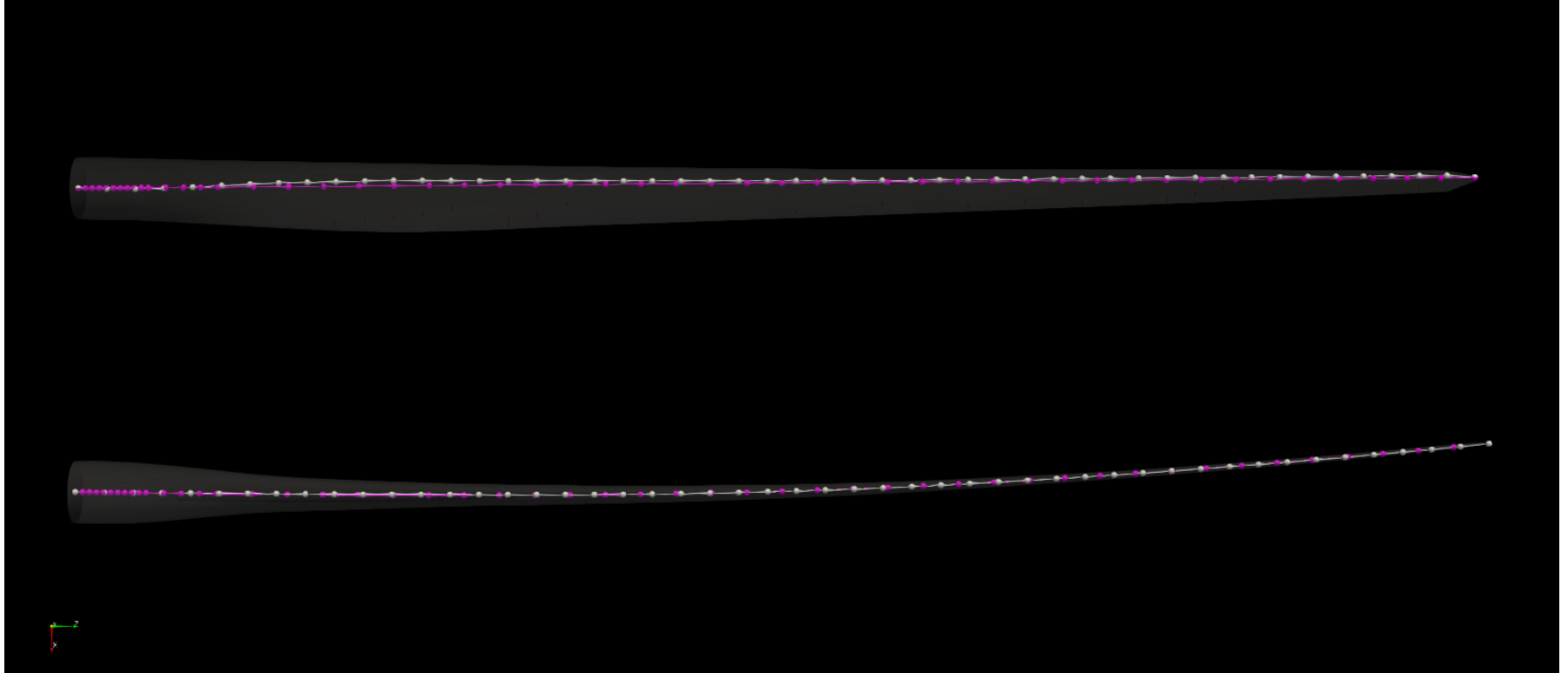
ElastoDyn models structurally straight blades

- 2 Flap modes, 1 Edge mode, no torsion
- Mass and stiffness along straight blade

ElastoDyn is **not** ideally suited for

- Highly flexible blades
- Lots of prebend/precurve

BeamDyn blades



BeamDyn models curved blades

- Geometrically exact beam theory
- Mass and stiffness curvature defined by keypoints

OpenFAST timesteps

- For ElastoDyn:
 - 5e-3 land, maybe smaller floating
- For BeamDyn:
 - Depends on the model
 - IEA15/IEA22 + steady: 4e-5
 - IEA15/IEA22 + turbulent: 1e-5
 - IEA22 still fails on occasion
 - *Wish I had better guidance to give here.*
 - OpenFAST v5.0 will include tight-coupling
 - Timesteps up to 0.005 with BeamDyn

OpenFAST roadmap

- X.Y.Z
 - X – major new features or restructuring. New input files
 - Y – minor new features. New input files
 - Z – bugfix, no input file changes
- 3.x series ends with 3.5.z
 - 3.5 LTS
 - 3.5.3 – in progress (backports of fixes)
- 4.0 (end Feb. 2024?)
 - Includes FSI
 - 4.0 or 4.1 LTS
- 5.0 (end April 2024?)
 - Tight coupling solver
 - 5.Y not planned yet

16 Open	658 Closed	Author	Label	Projects	Milestones						
Y	I	Yaw friction implementation	✗	#2017 opened 14 hours ago by abhineet-gupta · Draft	4 tasks						
Y	I	Linearization with AD15 and IFW	✗	Feature: Linearization	Module: AeroDyn	Module: InflowWind	Module: OpenFAST Lib	#2014 opened 3 days ago by andrew-platt · Draft	v4.0.0		
Y	I	ExtLoads module: Use pointers for wind	✓	C++ API	Module: ExtLoads	Module: InflowWind	#2009 opened last week by andrew-platt	v4.0.0			
Y	I	MHK wave-current superposition, added mass, inertia	✗	#1947 opened on Dec 19, 2023 by hkross · Draft	1 of 7 tasks						
Y	I	Unsteady Aero Driver: adding 3 degrees of freedom for the motion of a generalized airfoil section	✓	Module: AeroDyn	#1910 opened on Nov 30, 2023 by ebraniard	3 of 4 tasks					
Y	I	New AeroDyn input file exposing new BEM options (polar BEM, skew momentum correction, sector averaging)	✗	Module: AeroDyn	#1909 opened on Nov 30, 2023 by ebraniard · Draft	5 tasks	v4.0.0				
Y	I	Adding a simple nacelle drag model in AeroDyn	✗	Module: AeroDyn	#1888 opened on Nov 22, 2023 by mayankchetan · Draft	4 tasks	v4.0.0				
Y	I	Remove IFW data from AD15 inputs	✓	Module: AeroDyn	Module: InflowWind	#1882 opened on Nov 17, 2023 by andrew-platt · Draft	v4.0.0				
Y	I	Add unsteady aerodynamic model for turbine tail fin	✓	#1874 opened on Nov 15, 2023 by abhineet-gupta · Changes requested	1 of 4 tasks						
Y	I	Tight Coupling Solver	✓	#1850 opened on Nov 2, 2023 by deslaughter · Draft							
Y	I	Wake-added turbulence in FAST.Farm	✓	FAST.Farm	Type: Enhancement	#1785 opened on Sep 26, 2023 by ebraniard	1 task	v4.0.0			
Y	I	ifw: add VTK output of slice in XY to driver	✗	Module: InflowWind	#1643 opened on Jun 21, 2023 by andrew-platt	v4.0.0					
Y	I	Add All Output Data to DLL Interface	✗	#1475 opened on Mar 1, 2023 by dzalkind · Draft							
Y	I	AeroDyn14 removal	✗	Module: AeroDyn	Module: OpenFAST Lib	#1429 opened on Feb 1, 2023 by andrew-platt · Changes requested					
Y	I	Reduced order models: AeroDisk and Simplified-ElastoDyn (SED)	✓	FAST.Farm	Module: AeroDisk	Module: OpenFAST Lib	Module: SED	Type: Enhancement	#1295 opened on Oct 21, 2022 by andrew-platt · Draft	5 of 9 tasks	v4.0.0
Y	I	SoilDyn -- soil dynamics module	✓	Module: SoilDyn	#886 opened on Jan 27, 2022 by andrew-platt · Draft	3 tasks	v4.0.0				



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- Figures generated with
 - IEA 15, v1.1.8 (<https://github.com/IEAWindTask37/IEA-15-240-RWT/releases/tag/v1.1.8>)
 - OpenFAST 3.5.2, gcc 10.5.0 , double precision
 - ROSCO 1.8
 - Paraview 5.11.1