

# Propeller

Rob McDonald

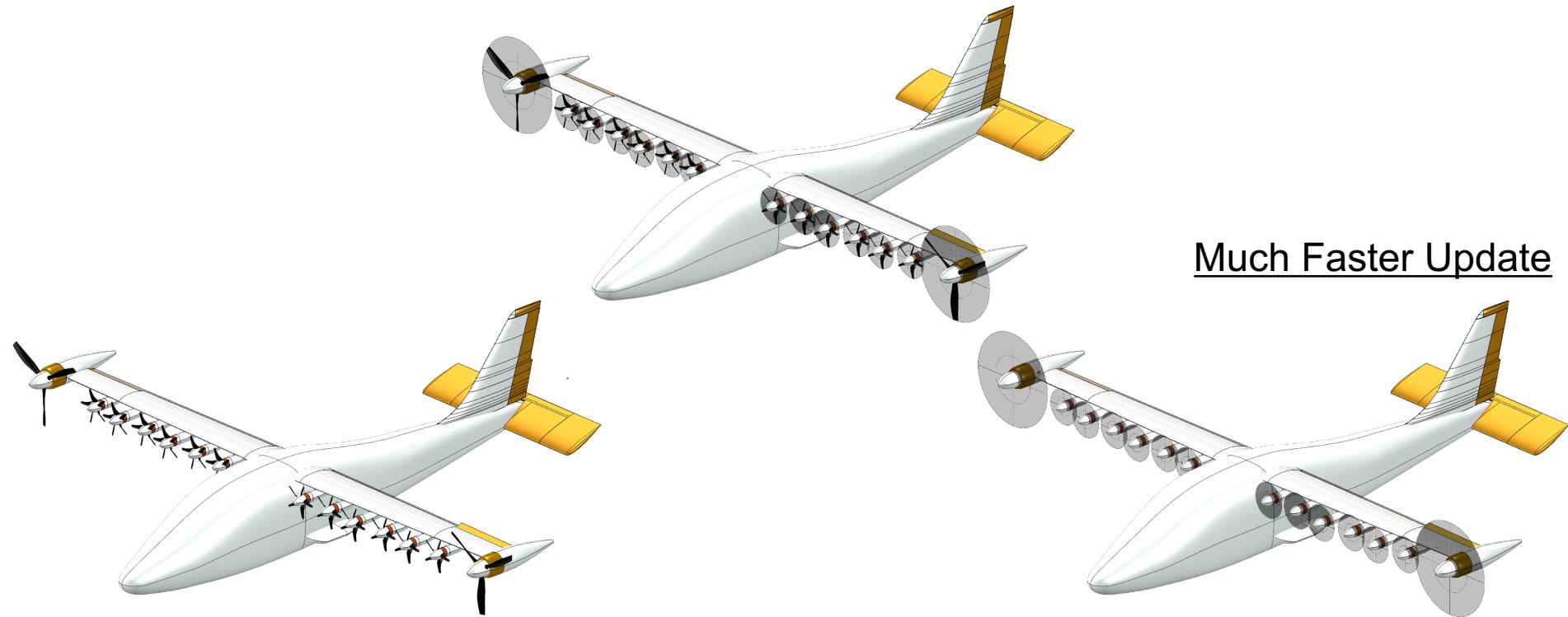
# Design Tab

The screenshot shows the OpenVSP software interface with the following sections:

- Mode:** Prop Mode set to **Blades**.
- General Design:** Contains the following parameters:
  - Diameter: 30.00000
  - Num Blades: 3
  - Rev: 0.00000
  - Rotate: 0.00000
  - Beta 3/4: 20.00000
  - Feather: 0.00000
  - Pre-cone: 0.000
  - Construct X/C: 0.500
  - Feather Axis: 0.500
  - Feather Offset: 0.000
- Prop / Rotor Metrics:** Contains the following data:

Activity Factor	151.54	$r_0$	0.20000
CLi	0.54		
C/R	0.1777	C_T/R	0.1923
$\sigma$	0.1696	$\sigma_T$	0.1837
		$\sigma_P$	0.1855

# Blades, Both, Disk Mode



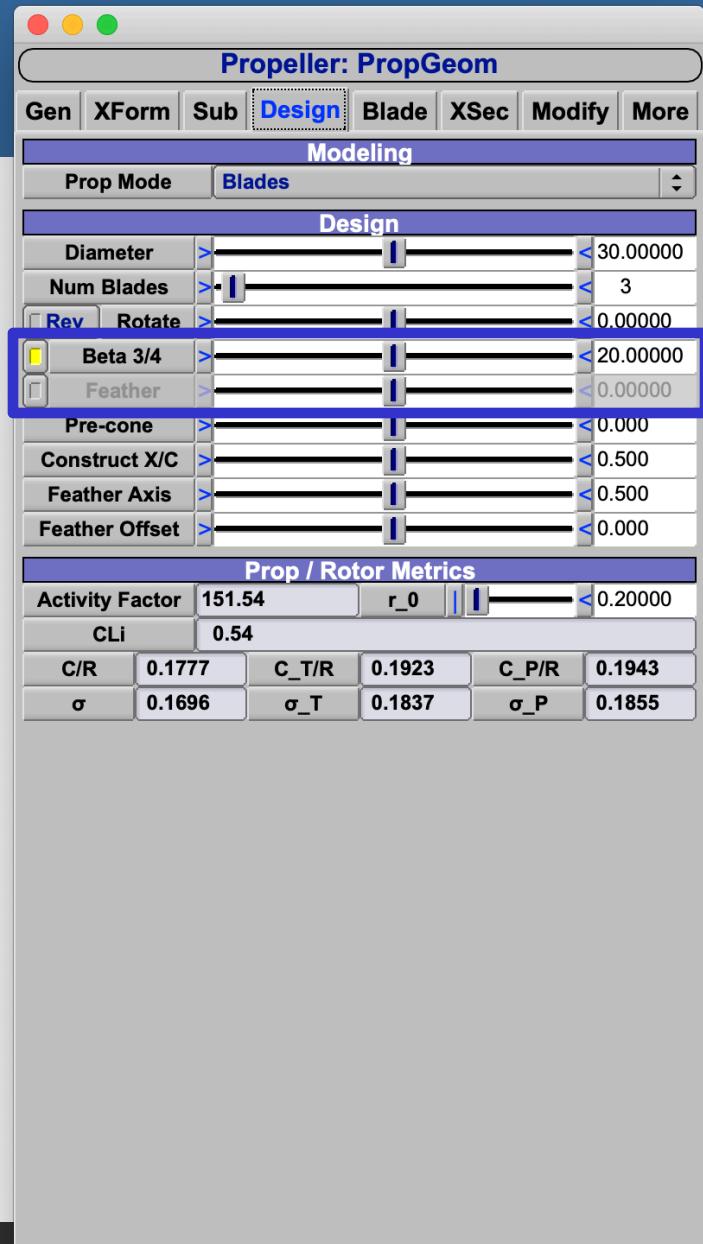
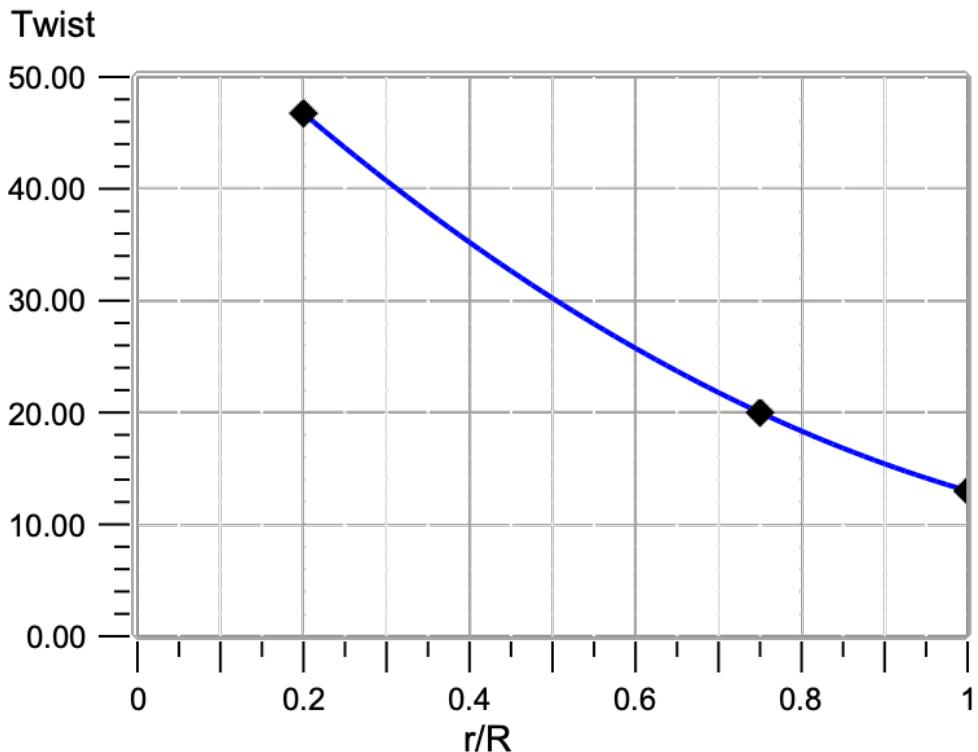
Much Faster Update

Mode also determines representation for export an analysis  
(DegenGeom, VSPAERO, etc.).

# Beta 3/4 & Feather

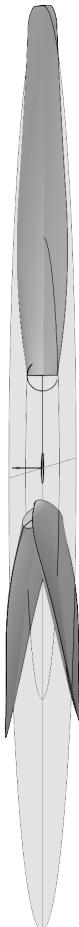
$$\text{Beta}_{3/4} = \text{Twist}_{3/4} + \text{Feather}$$

$X_{3/4}$  : Value at  $r/R = 0.75$

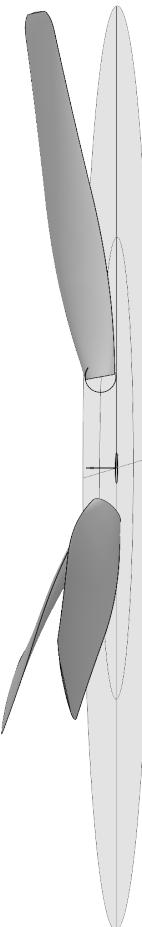


# Pre-cone

Pre-cone = 0.0



10°



Propeller: PropGeom

Gen XForm Sub Design Blade XSec Modify More

Modeling

Prop Mode Blades

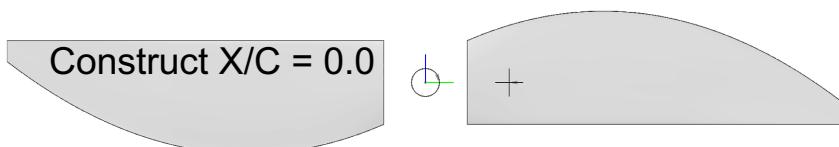
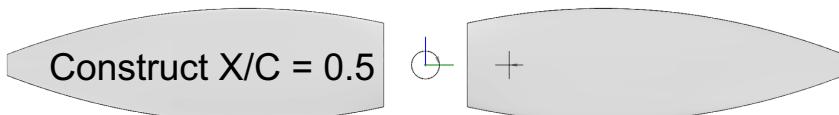
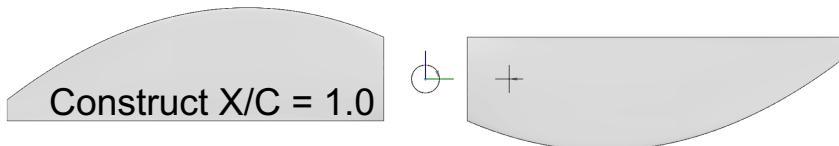
Design

Diameter	> 30.00000
Num Blades	> 3
Rev	Rotate > 0.00000
Beta 3/4	> 20.00000
Feather	< 0.00000
Pre-cone	> 0.000
Construct X/C	> 0.500
Feather Axis	> 0.500
Feather Offset	> 0.000

Prop / Rotor Metrics

Activity Factor	151.54	r_0	0.20000				
CLi	0.54	C/R	0.1777	C_T/R	0.1923	C_P/R	0.1943
σ	0.1696	σ_T	0.1837	σ_P	0.1855		

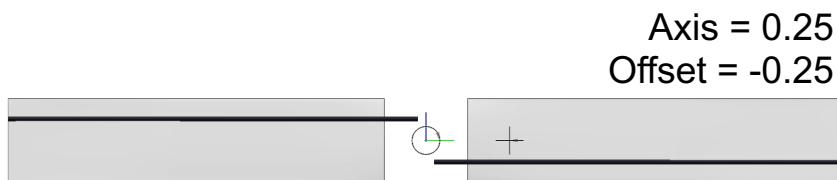
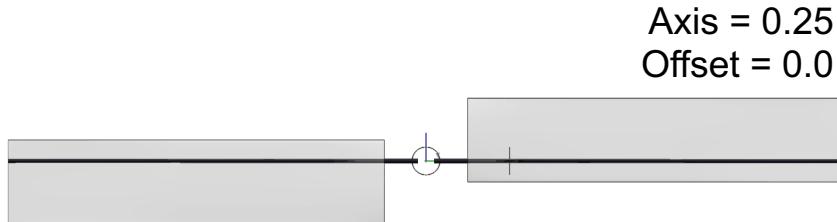
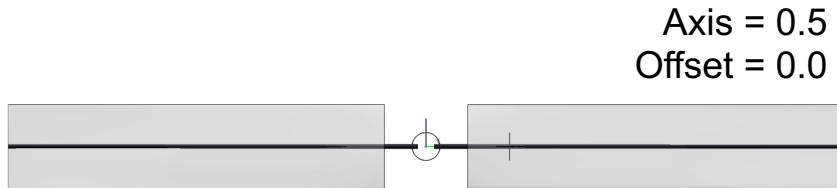
# Construct X/C



Straight line about which planform is developed

The screenshot shows the "Propeller: PropGeom" software interface. The top menu bar includes "Gen", "XForm", "Sub", "Design" (which is highlighted in blue), "Blade", "XSec", "Modify", and "More". Below the menu is a toolbar with buttons for "Modeling", "Prop Mode" (set to "Blades"), and various modeling tools like "Rev", "Rotate", "Beta 3/4", "Feather", "Pre-cone", and "Construct X/C". The "Construct X/C" button is currently selected, indicated by a blue border. The "Design" panel contains sliders for "Diameter" (30.00000), "Num Blades" (3), "Rev" (0.00000), "Rotate" (0.00000), "Beta 3/4" (20.00000), "Feather" (0.00000), "Pre-cone" (0.000), and "Construct X/C" (0.500). The bottom section, "Prop / Rotor Metrics", displays values for "Activity Factor" (151.54), "r\_0" (0.20000), "CLi" (0.54), "C/R" (0.1777), "C\_T/R" (0.1923), "C\_P/R" (0.1943), "σ" (0.1696), "σ\_T" (0.1837), and "σ\_P" (0.1855).

# Feather Axis & Offset



Location of feather axis on the blade (Axis) and relative to rotation axis (Offset).

Propeller: PropGeom

Gen XForm Sub Design Blade XSec Modify More

Modeling

Prop Mode Blades

Design

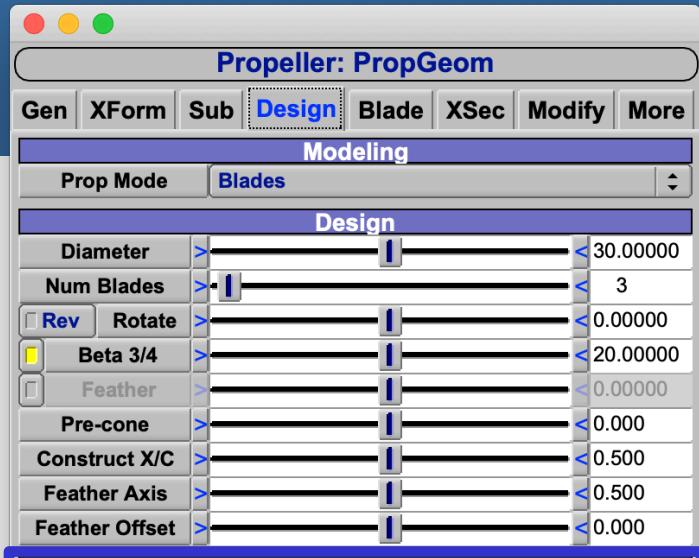
Diameter	30.00000
Num Blades	3
Rev	0.00000
Rotate	0.00000
Beta 3/4	20.00000
Feather	0.00000
Pre-cone	0.000
Construct X/C	0.500
Feather Axis	0.500
Feather Offset	0.000

Prop / Rotor Metrics

Activity Factor	151.54	r_0	0.20000		
CLi	0.54				
C/R	0.1777	C_T/R	0.1923	C_P/R	0.1943
σ	0.1696	σ_T	0.1837	σ_P	0.1855

# Propeller Metrics

- Propeller
  - Activity Factor
  - Integrated Design Lift Coefficient
- Rotor
  - Chord / R
    - Average
    - Thrust Weighted
    - Power Weighted
  - Solidity
    - Average
    - Thrust Weighted
    - Power Weighted



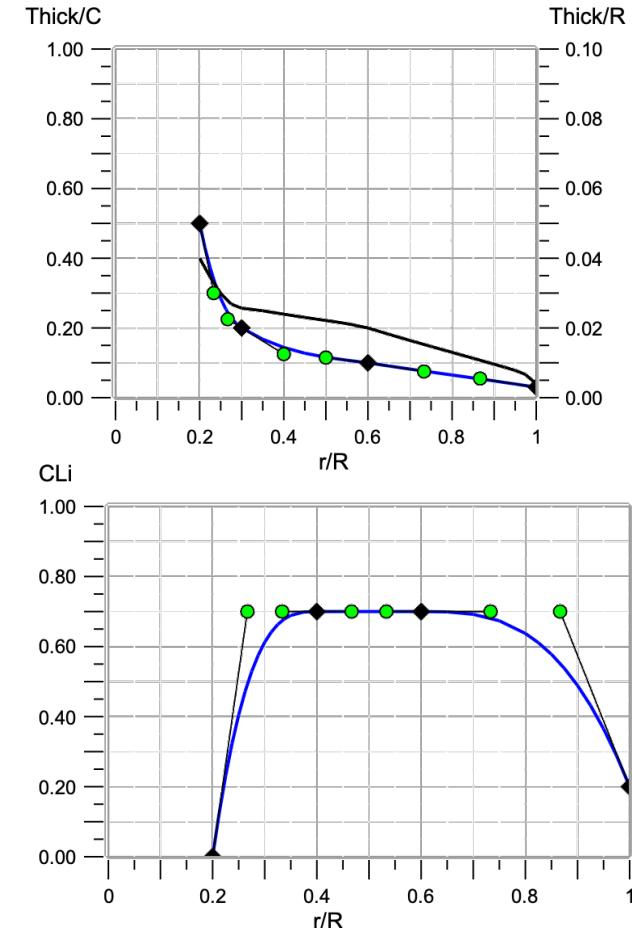
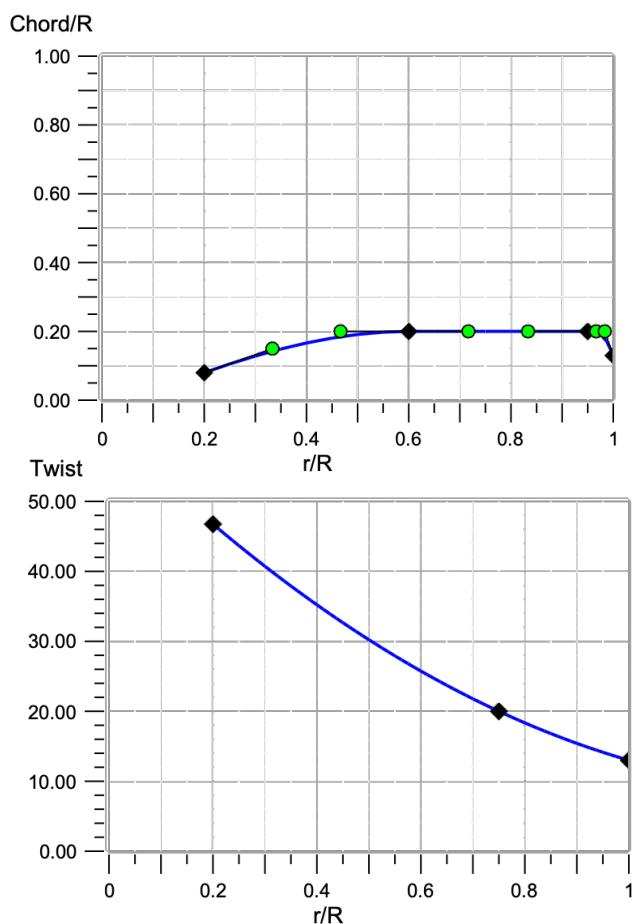
Prop / Rotor Metrics					
Activity Factor	151.54	$r_0$	0.20000		
CLi	0.54				
C/R	0.1777	C_T/R	0.1923	C_P/R	0.1943
$\sigma$	0.1696	$\sigma_T$	0.1837	$\sigma_P$	0.1855

# Curve Control

Planform, twist, and airfoil controlled via smooth continuous curves.

$c_{l,i}$  control only between like airfoil types.

Recommend using as few Xsec types as possible (1 or 2).



# Blade Curve Control

Curve Selector  
Type Control

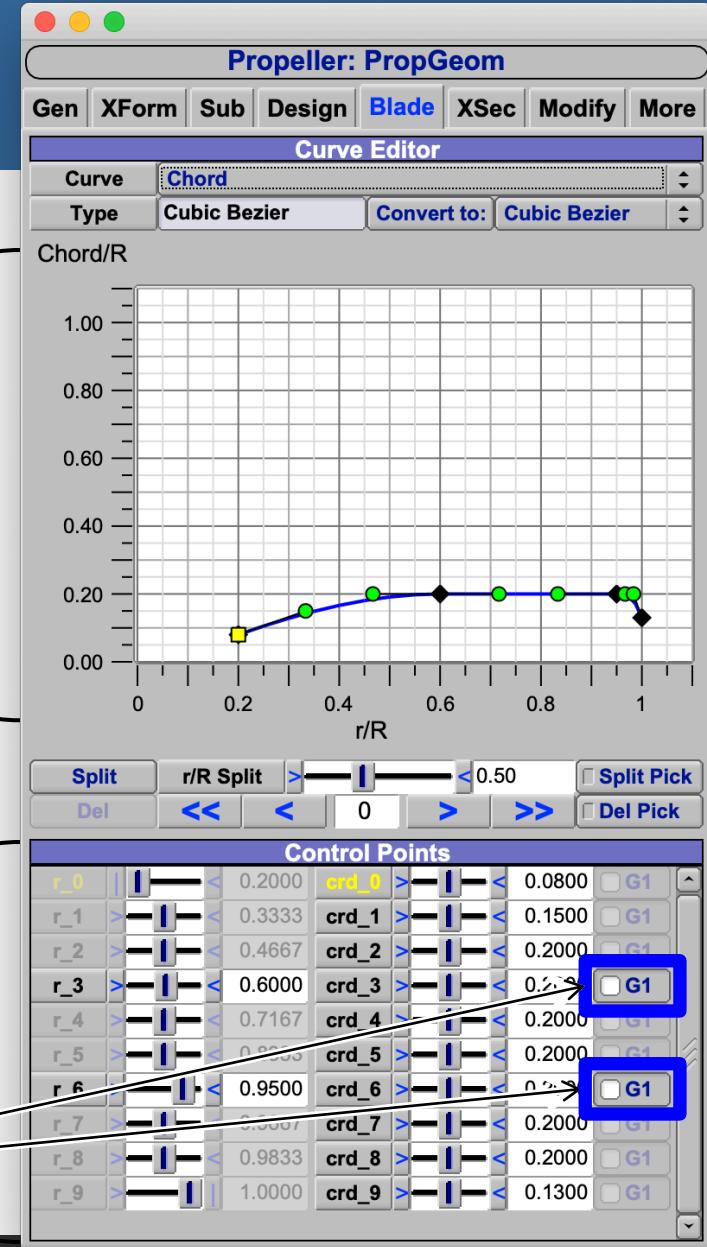
Interactive Curve Editor

Split Curve

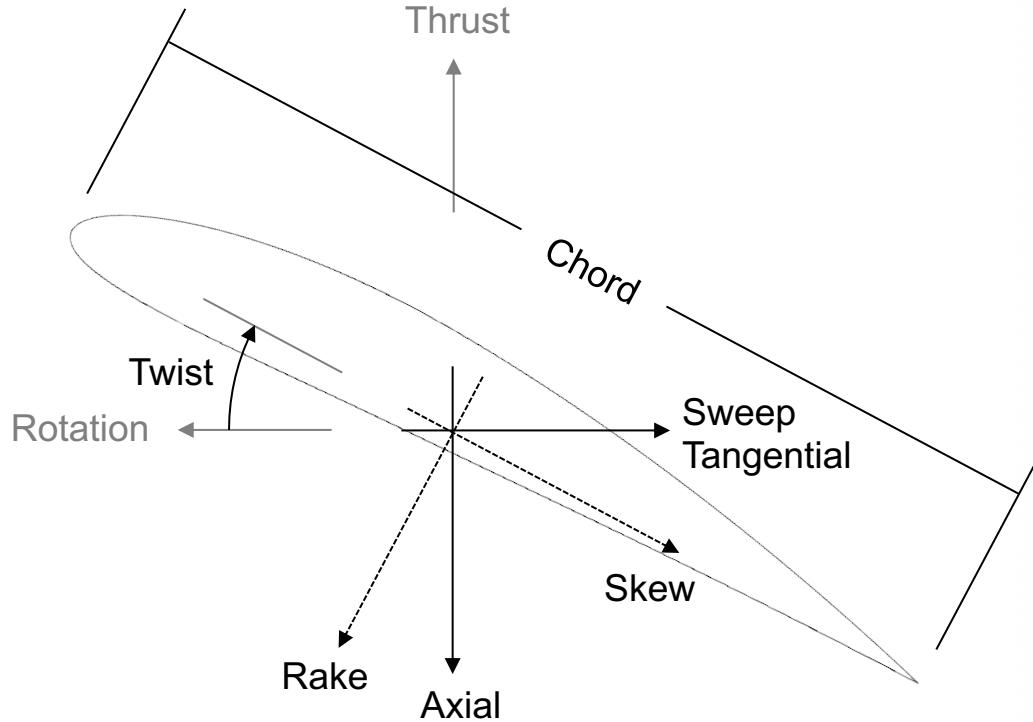
Delete Control Points

Control Point Editor

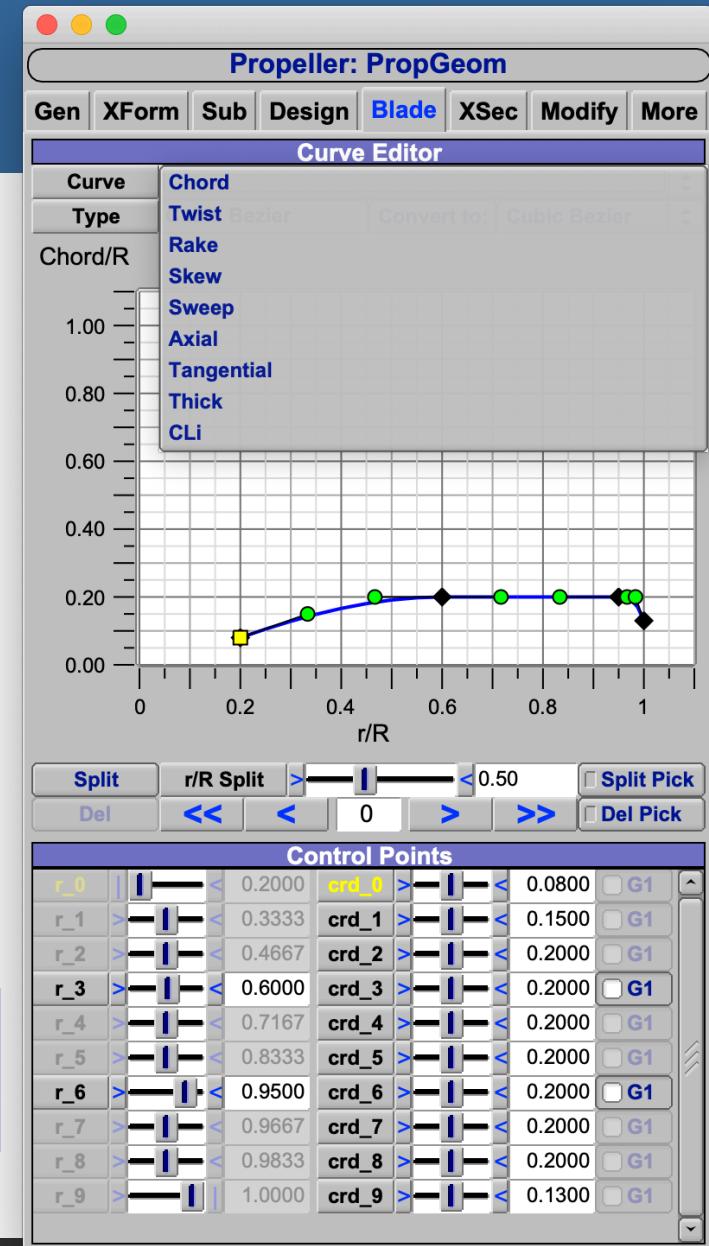
Enforce Continuity



# Planform Curves

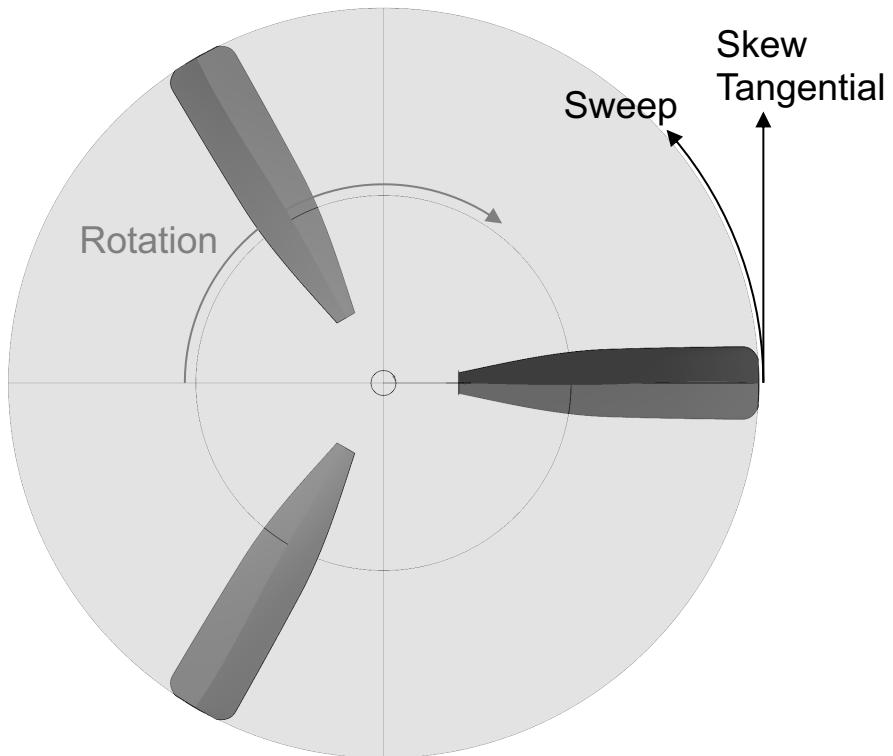


Avoid using redundant controls.  
I.e. use Axial or Rake, not both.

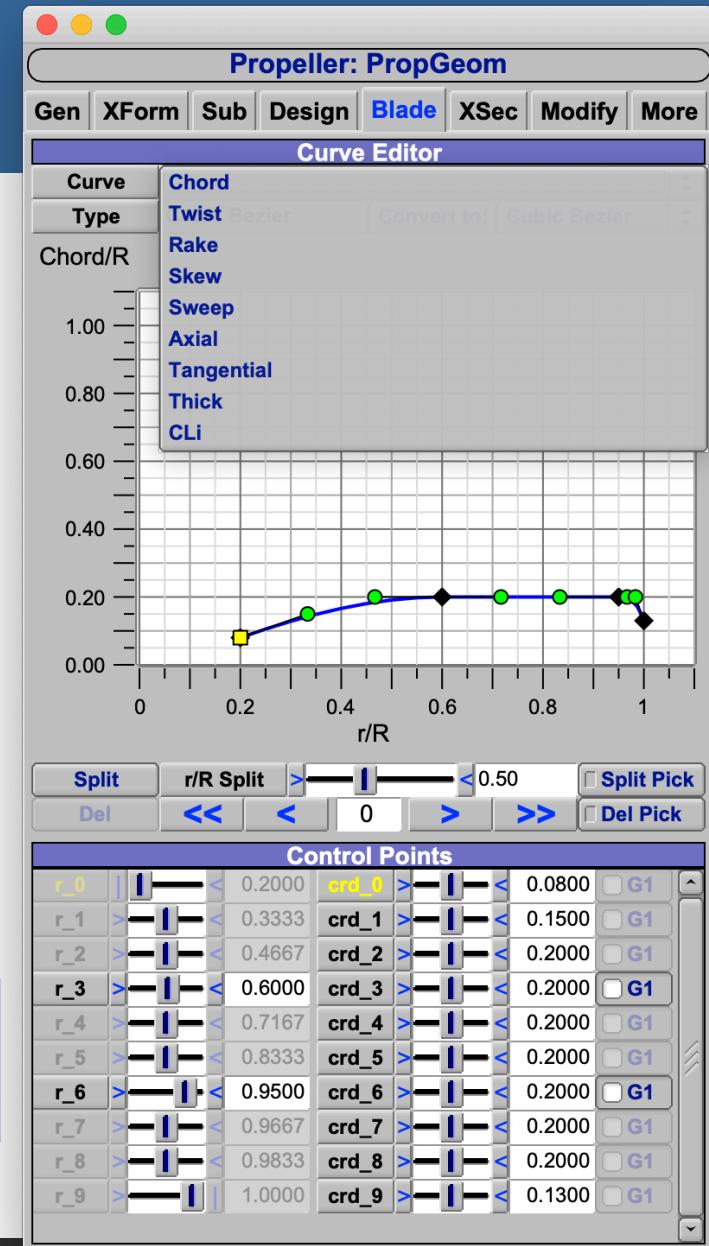


Section view, root to tip

# Planform Curves



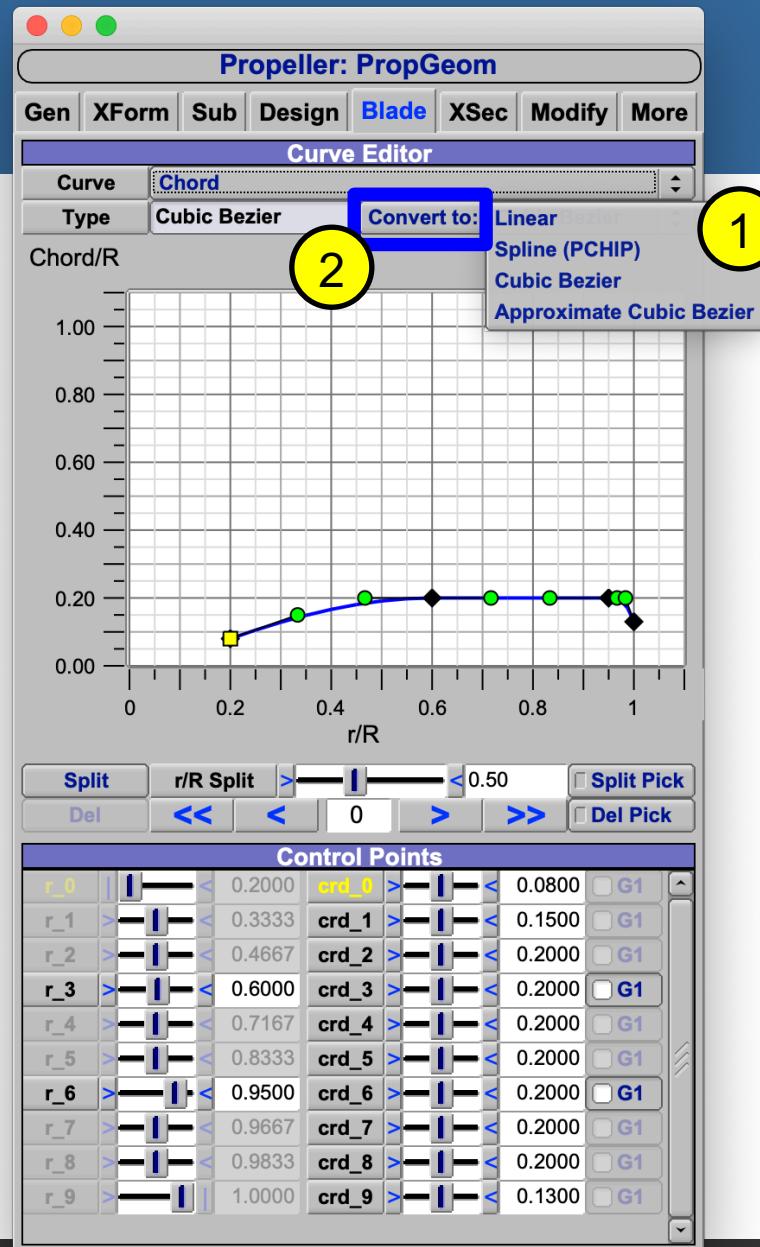
Skew & Tangential change true diameter.  
Rake & Axial change blade length.



Rear view, looking forward

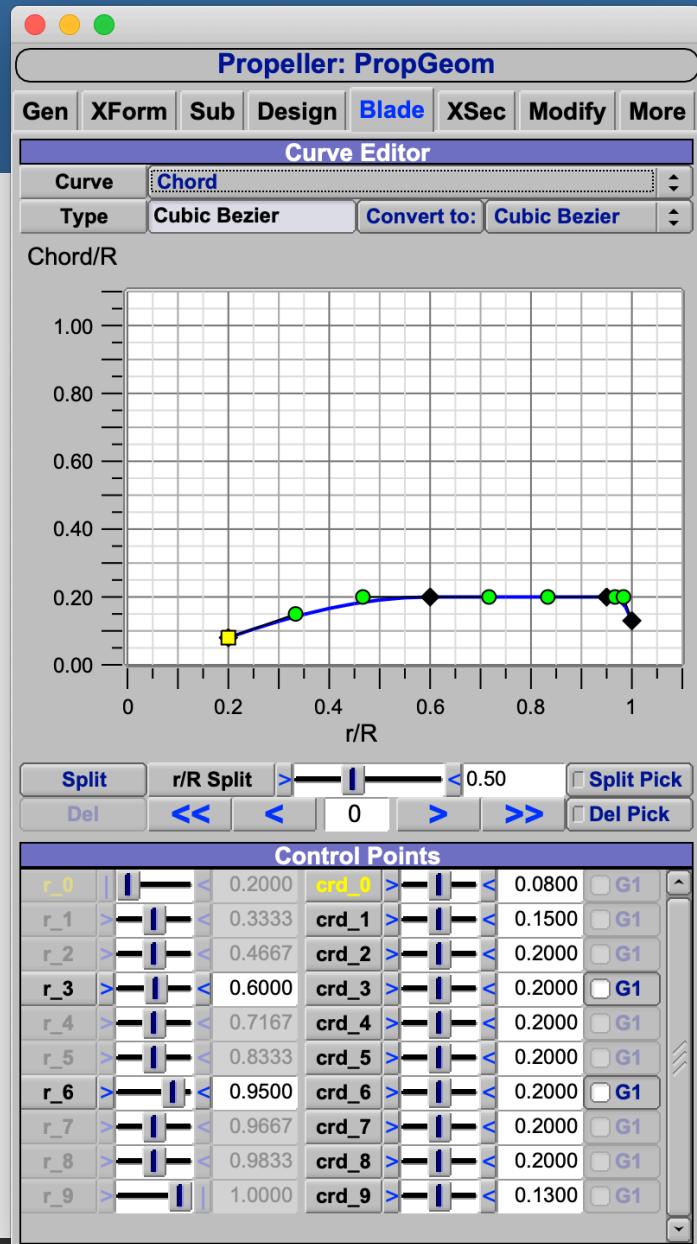
# Type Control

- Linear
  - Extremely simple
  - Great for linear taper / linear twist
- Spline (PCHIP)
  - Piecewise cubic Hermite interpolating polynomial
  - Default type for BEM import
  - Control not super-intuitive
- Cubic Bezier
  - Best for intuitive control of smooth curves
- Approximate Cubic Bezier
  - Converts to Cubic Bezier, but with fewer control points.
  - Great to use after BEM import



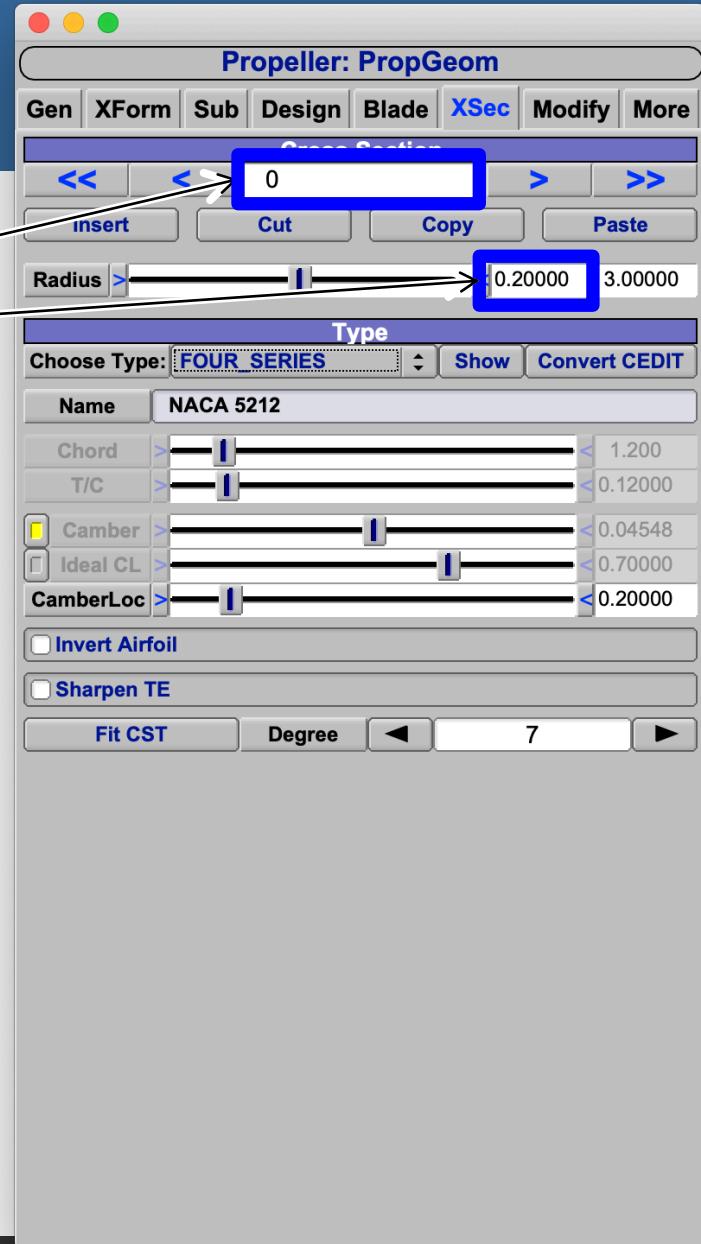
# Curve Editing

- Drag-n-drop curve editing
  - Model does not update until release
  - Cubic Bezier tangents move with control points
- Split curve
  - Specified r/R
  - Click to pick
- Delete control points
  - By index selector (yellow highlight)
  - Click to pick
- Control point editor
  - Adjustable range slider inputs for control points
  - Enforce G1 continuity
  - Unavailable Params greyed out



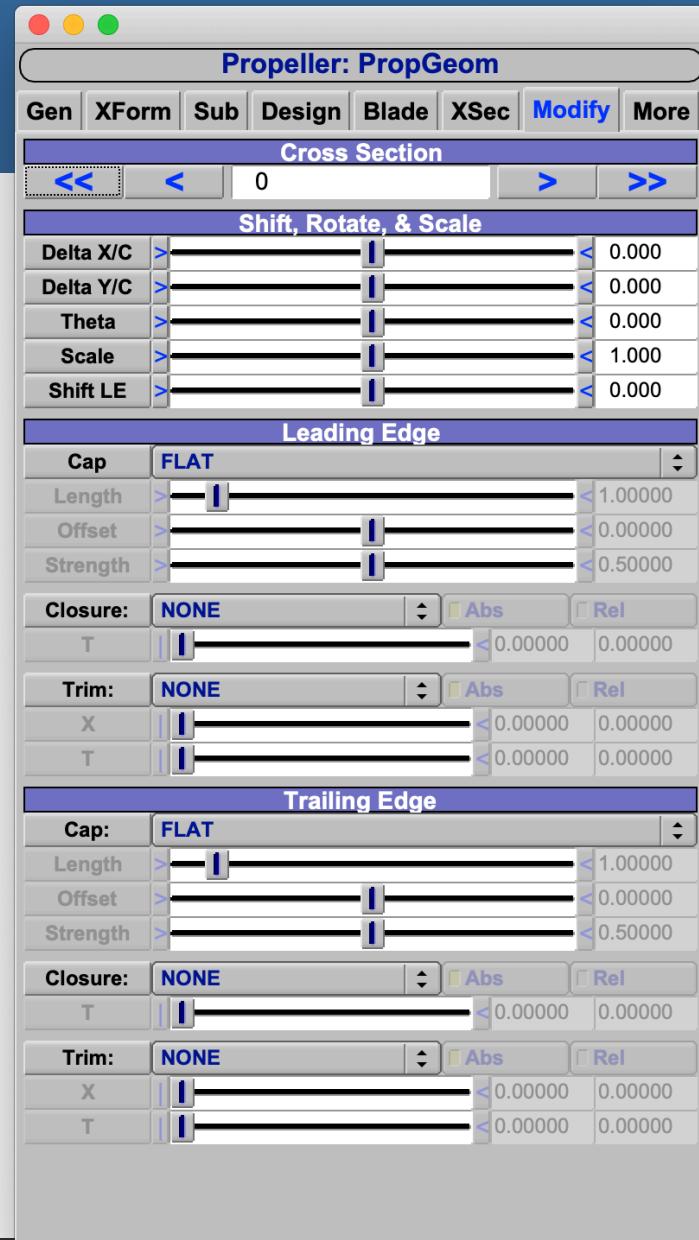
# XSec

- Almost identical to Wing Airfoil control
- Radius ( $r/R$ )
  - 0<sup>th</sup> XSec control's hub  $r/R$
  - Controls location where XSec type specified
- Use as few XSec's as possible
  - Two to four sufficient almost all circumstances
  - Two – blades with single section type
  - Three – blades with circular / elliptical cuff
  - Four – blades with two foil types and transition
- Exceptions
  - File airfoils
  - CST airfoils
  - Both are clunky and awkward with propeller
  - Strongly recommend analytical types



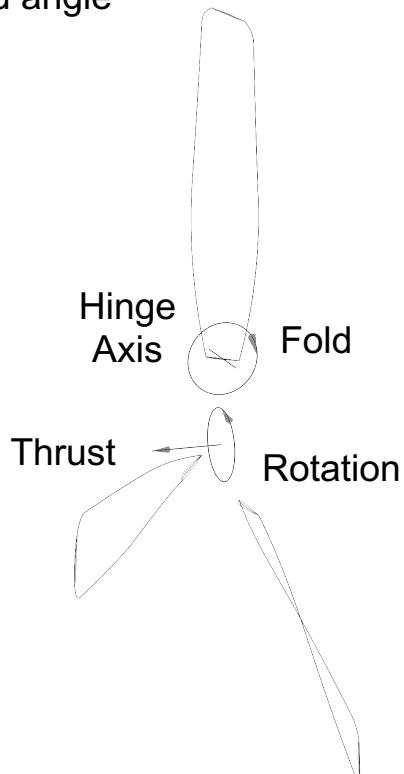
# Modify

- Identical to Wing Modify control
- Should be smart (DWIM)
  - Blunted airfoils with Abs thickness should maintain dimensional thickness even as chord varies.



# More

- **Folding**
  - Control of folding axis (position & direction)
  - Control of fold angle



Propeller: PropGeom

Gen XForm Sub Design Blade XSec Modify More

**Folding**

Angle	>	0.000
Radial/R	>	0.200
Axial/R	>	0.000
Offset/R	>	0.000
Azimuth	>	0.000
Elevation	>	0.000

**Tip Treatment**

Cap Tess	3
Root Cap Type	Flat
Length	1.00000
Offset	0.00000
Strength	0.50000

**Sweep Stretch**

Tip Cap Type	Round
Length	1.00000
Offset	0.00000
Strength	1.00000

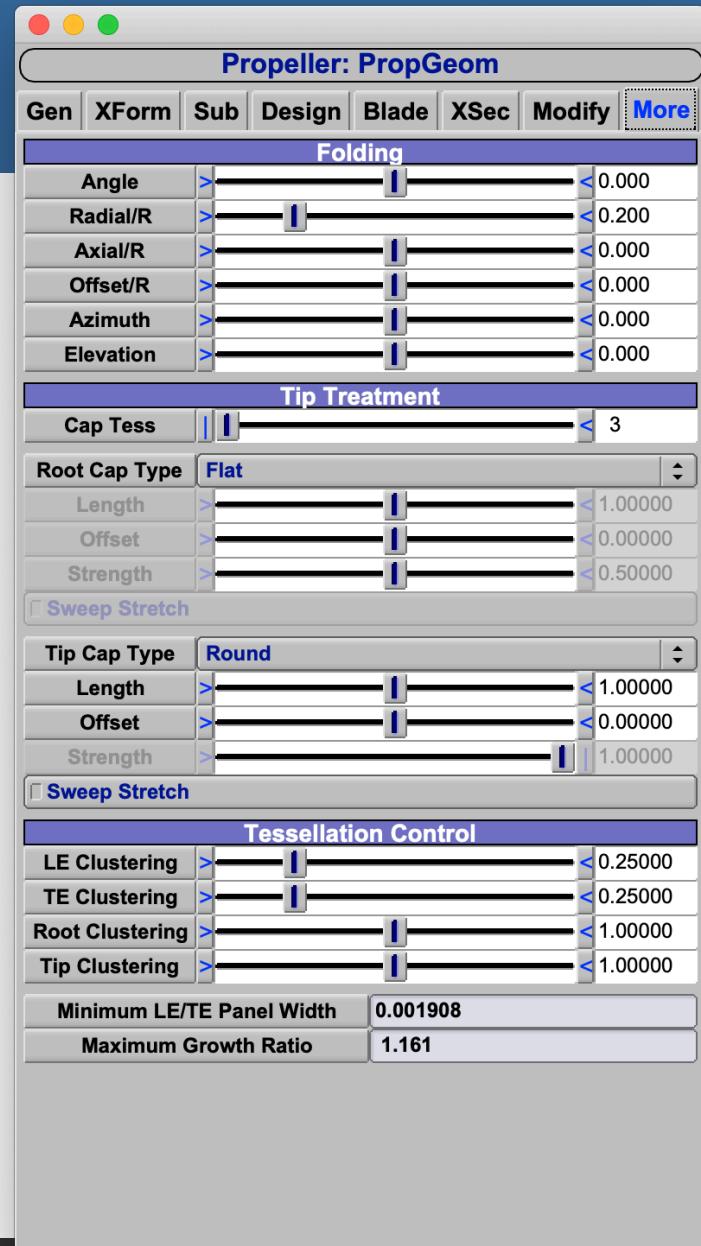
**Tessellation Control**

LE Clustering	0.25000
TE Clustering	0.25000
Root Clustering	1.00000
Tip Clustering	1.00000

Minimum LE/TE Panel Width	0.001908
Maximum Growth Ratio	1.161

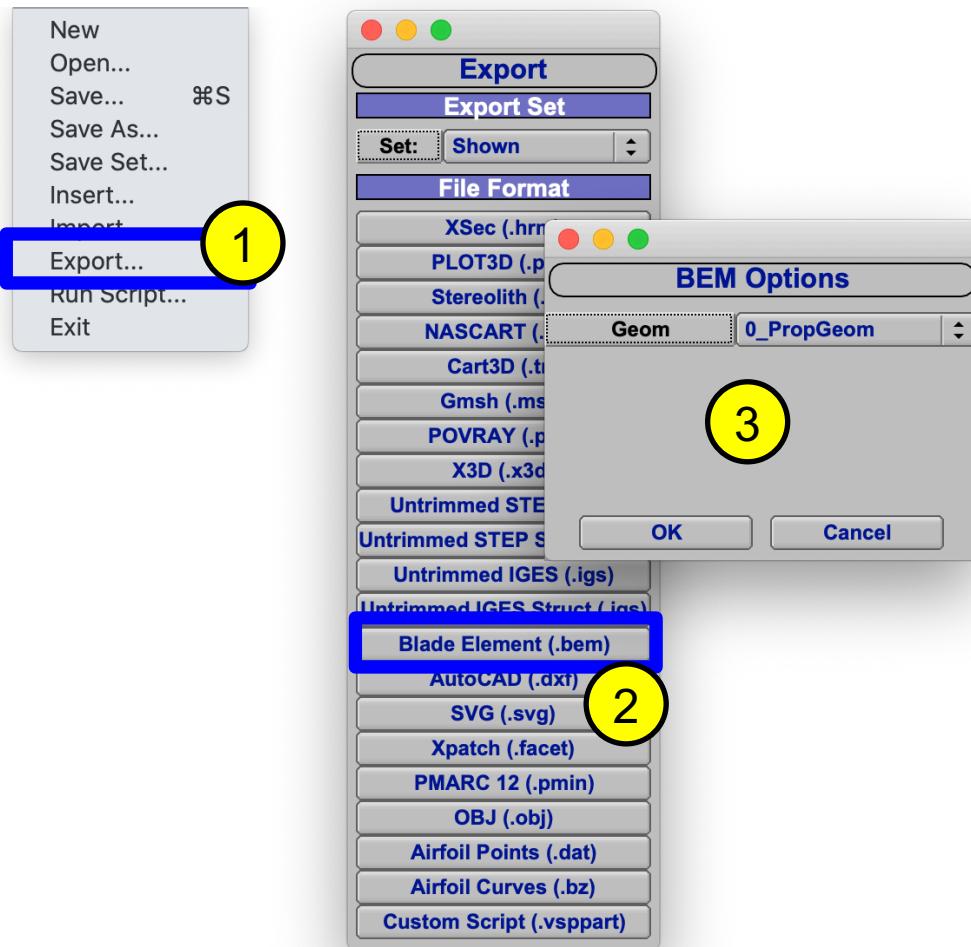
# More

- Tip Treatment
  - Identical to similar Wing controls
- Tessellation Control
  - Num\_U & Num\_W on Gen tab
  - Clustering and tessellation controlled for entire prop



# BEM Export

- Access through File...



# BEM File

```
...BEM Propeller...
Num_Sections: 66 ← Num_Sections determined by Num_U
Num_Blade: 3
Diameter: 30.0000000
Beta 3/4 (deg): 20.0000000
Feather (deg): 0.0000000
Pre_Cone (deg): 0.0000000
Center: 0.0000000, 0.0000000, 0.0000000
Normal: -1.0000000, 0.0000000, 0.0000000

Radius/R, Chord/R, Twist (deg), Rake/R, Skew/R, Sweep, t/c, CLi, Axial, Tangential
0.2000000, 0.0800000, 46.7500000, 0.0000000, 0.0000000, 0.0000000, 0.1200000, 0.7000000, 0.0000000, 0.0000000
0.21230769, 0.08640386, 45.98069069, 0.0000000, 0.0000000, 0.0000000, 0.1200000, 0.7000000, 0.0000000, 0.0000000
...
0.98769231, 0.17001209, 13.26915223, 0.0000000, 0.0000000, 0.0000000, 0.03229378, 0.24474829, 0.0000000, 0.0000000
1.0000000, 0.1300000, 13.0000000, 0.0000000, 0.0000000, 0.0000000, 0.0300000, 0.2000000, 0.0000000, 0.0000000

Section 0 X, Y
1.0000000, 0.0000000
0.99322572, -0.00017159
...
0.00408190, -0.00534301
0.00000000, 0.00000000
-0.00130232, 0.00689865
...
0.99313741, 0.00175775
1.0000000, 0.0000000

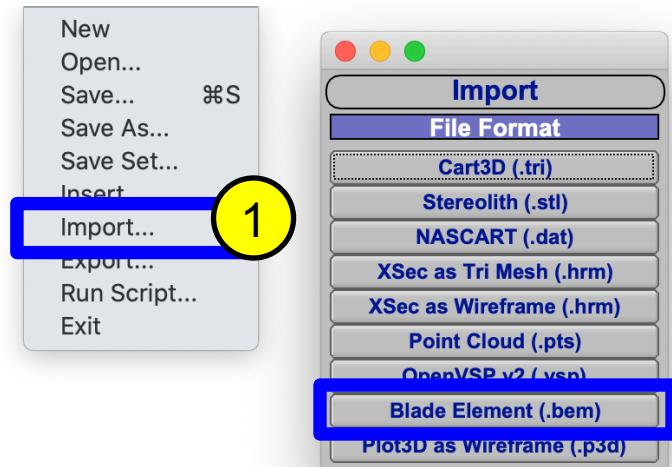
Section 1 X, Y
1.0000000, 0.0000000
```

← Blade planform and airfoil curves

← Airfoil ordinates

# BEM Import

- Imports BEM file & creates propeller
  - Ignores airfoil ordinates
  - Curves set to PCHIP w/ point at each station
  - Recommend 'Approximate Cubic Bezier'
  - Likely very over-defined
  - Will be slow until cleanup
  - May still be slow after cleanup



# Questions?

# Practice