Engineering Sketch Pad (ESP)

Training Session 2.4
Sketcher Fundamentals

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Overview

- Purpose of Sketches
- Sketching Segments
- Sketching methods
    - programmatically
    - interactively
- Hands-on exercises
    - U-shaped bracket (version 1)
    - U-shaped bracket (version 2)
    - oval
    - bi-convex airfoil (with arcs)
    - swivel base
    - V-slide plate
    - bi-convex airfoil (with splines)
    - fuselage cross-section (with Beziers)

Purpose of Sketches

- Method for generating a SheetBody, WireBody, or NodeBody
- Sketches are used a basis of grown Bodys
  - `EXTRUDE`, `REVOLVE`, `RULE`, and `BLEND`

Sketching Segments

- `LINSEG` — straight line segment
- `CIRARC` — circular arc
- `BEZIER` — Bezier curve
- `SPLINE` — cubic spline

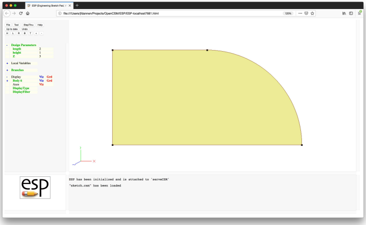
Sketching Methods

- Programmatically
  - can generate Sketch in 3D
  - user does all required math
  - is very robust
- Interactively
  - can generate Sketch only in 2D
  - required math is done by solving constraints
  - is somewhat fragile

Sketching Programmatically

- Begin with a SKBEG statement, which provides an initial point
- Add LINSEG, CIRARC, BEZIER, or SPLINE Segments
  - for the BEZIER and SPLINE statements, one curve is created from the point before these statement, using all the BEZIER or SPLINE statements
  - to have two adjacent curves, put a zero-length LINSEG between them
- Ends with a SKEND statement
  - if there are no Segments, a NodeBody is created
  - if the last Segment does not end at the point specified in the SKBEG statement, a WireBody is created
  - if the Sketch is closed, a SheetBody is created (unless the `wireonly` flag on the SKEND statement is non-zero)

Programmatic Sketch Example



Design Parameters

length	2
height	1
Z	3

```
ESP has been initialized and is attached to 'serveCSM'
"sketch.csm" has been loaded
```

```
# sketch

DESPMTR    L          2.0
DESPMTR    H          1.0
DESPMTR    Z          3.0

SET        s2         1/sqrt(2)

SKBEG      1.0                2.0         Z
   LINSEG  1.0+L              2.0         Z
   CIRARC  1.0+L-(1-s2)*H     2.0+s2*H    Z \
           1.0+L-H            2.0+H       Z
   LINSEG  1.0                2.0+H       Z
   LINSEG  1.0                2.0         Z
SKEND

END
```

Steps to Creating a Sketch Interactively

1. Define the Design Parameters
2. Create an empty Sketch
3. Draw the Segments
4. Constrain the Sketch
5. Solve the Sketch

Creating a Sketch

Step 1: Define the Design Parameters

- Press **Design Parameters** in the Tree window to create each of the Design Parameters
- Most Design Parameters are a scalar, so that they have only 1 row and 1 column
- Enter nominal value(s) in the box(es) that appears
- Press **OK** to proceed
- Repeat as needed

Creating a Sketch

Step 2: Create an Empty Sketch

- Press **Branches** in the Tree window to create a `SKBEG` Branch
  - coordinates should be specified at one point on the boundary of the Sketch
  - coordinates can be defined in terms of a Design Parameter
- A `SKEND` is automatically created for you
- The Sketcher is entered automatically

Creating a Sketch

Step 3: Draw the Segments (1)

- Start drawing the Sketch at the point defined in the SKBEG Branch
  - **X** and **Y** Constraints are automatically generated at the initial point
  - these constraints cannot be deleted
- Draw the Segments by proceeding counter-clockwise around the Sketch (which is consistent with the right-hand rule pointing out of the screen)
- Line between previous point and cursor shows proposed position of next Segment
  - blue is default color
  - if drawn in orange, a vertical (V) or horizontal constraint (H) will be added automatically

Creating a Sketch

Step 3: Draw the Segments (2)

- Supported Segment types include:
  - (straight) line Segment
    - **l** or **L** or mouse click
  - (circular) arc Segment
    - **c** or **C**
    - Segment turns red until you press the mouse button to set its approximate radius
  - cubic spline
    - **s** or **S**
    - cubic splines are shown only as straight line Segments in the Sketcher
  - Bezier curve control points
    - **b** or **B**
  - . . .

Creating a Sketch

Step 3: Draw the Segments (3)

- Supported Segment types include:
    - zero-length Segment
        - **z** or **Z**
        - constraints automatically set
    - leave Sketch open (and switch mode to “Constraining...”)
        - **o** or **O**
- When Sketch is closed, its interior is filled with gray (and the mode is switched to “Constraining...”)
- Pressing the **Undo** button will remove the last Segment

Creating a Sketch

Step 4: Constrain the Sketch (1)

- As many constraints (**ncon**) must be defined as there are degrees of freedom (**ndof**) in the Sketch
  - these values are listed in the Key window
  - the fill turns to light green when they match (**ncon=ndof**)
  - having them match is necessary, but not sufficient, for a Sketch to be properly constrained

Creating a Sketch

Step 4: Constrain the Sketch (2)

- Constraints that can be applied to Segments:
  - set the Segment's length
    - **l** or **L**
  - make the Segment horizontal ($y_{\text{beg}} = y_{\text{end}}$)
    - **h** or **H**
    - might be automatically created if Segment was orange when created
  - make the Segment vertical ($x_{\text{beg}} = x_{\text{end}}$)
    - **v** or **V**
    - might be automatically created if Segment was orange when created
  - set the inclination in degrees (measured counter-clockwise from the right horizontal)
    - **i** or **I**

Creating a Sketch

Step 4: Constrain the Sketch (3)

- Constraints that can be applied to circular arcs:
  - acute radius (positive if convex when drawing counter-clockwise)
    - **r** or **R**
  - X-coordinate at arc center
    - **x** or **X**
  - Y-coordinate at arc center
    - **y** or **Y**
  - sweep angle in degrees (positive if convex when drawing counter-clockwise)
    - **s** or **S**

Creating a Sketch

Step 4: Constrain the Sketch (4)

- Constraints that can be applied to points:
  - specify X-coordinate
    - **x** or **X**
  - specify Y-coordinate
    - **y** or **Y**
  - adjacent Segments are perpendicular
    - **p** or **P**
  - adjacent Segment are tangent (parallel)
    - **t** or **T**
  - turning angle between adjacent Segments in degrees (positive if turning to the left)
    - **a** or **A**

Creating a Sketch

Step 4: Constrain the Sketch (5)

- Constraints that can be applied to a pair of points:
  - specify width ($x_{\text{end}} - x_{\text{beg}}$)between two points
    - **w** or **W**
    - if first point is toward the left, a positive value should be specified
    - if first point is toward the right, a negative value should be specified
  - specify depth ($y_{\text{end}} - y_{\text{beg}}$) between two points
    - **d** of **D**
    - if first point is toward the bottom, a positive value should be specified
    - if first point is toward the top, a negative value should be specified

Creating a Sketch

Step 4: Constrain the Sketch (6)

- Other options:
    - remove Constraints
        - <
        - if more than one constraint is present, you are asked which constraint to remove
    - inquire about constraints at current point or Segment
        - **?**
- Pressing the **Undo** button will remove/restore the last constraint

Creating a Sketch

Step 4: Constrain the Sketch (7)

- Special shortcuts
  - `::L[i]` is the length of the Segment `i`
  - `::I[i]` is the inclination of Segment `i` (in degrees)
  - `::R[i]` is the radius of CIRARC Segment `i`
  - `::S[i]` is the sweep of CIRARC Segment `i` (in degrees)
- Segment numbers can be determined by pressing **?** near the center of a Segment

Creating a Sketch

Step 4: Constrain the Sketch (8)

- If you need help during the constraint process
  - Press the yellow **Constraining...** button
- Redundant constraints are shown in red
  - Use the < key to remove a redundant constraint
- Suggested new constraints are shown in green
  - Add the constraint using a key that matches the hint

Creating a Sketch

Step 5: Solve the Sketch

- Press **Press to Solve**
  - if successful, Sketch will change on screen
  - if unsuccessful, read about error in Messages window to help you diagnose the problem
- Press **Sketch→Save** to return to normal (non-Sketching) mode
- Press **Press to Re-build** to see the completed Sketch

Editing an Existing Sketch

- Select one of the Branches between the `SKBEG` and `SKEND` Branches (inclusive) and press **Enter Sketcher**
- Follow directions given above

Deleting an Existing Sketch

- Select each of the Branches between the `SKBEG` and `SKEND` and press **Delete Branch** for each. Then delete the `SKEND` and `SKBEG` Branches.
- Select the `SKBEG` Branch and press **Delete Branch** (to delete whole sketch at once)

Image Manipulation in the Sketcher

- Recenter Sketch
  - **Ctrl-h** key or **H** button
- Move the Sketch to the left
  - **Ctrl-l** key or **L** button or ← key
- Move the Sketch to the right
  - **Ctrl-r** key or **R** button or → key
- Move the Sketch to the bottom
  - **Ctrl-b** key or **B** button or ↓ key
- Move the Sketch to the top
  - **Ctrl-t** key or **T** button or ↑ key
- Zoom in
  - **Ctrl-i** key or **PgUp** key or **+** button
- Zoom out
  - **Ctrl-o** key or **PgDn** key or **-** button

Sketching Best Practices

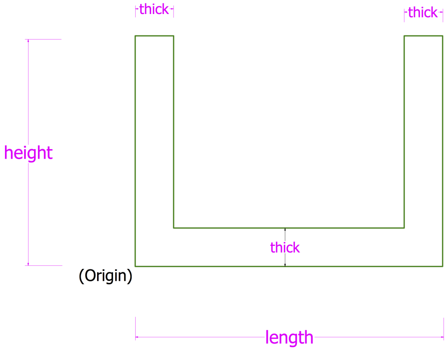
- Try to start the Sketch at a point with known coordinates
- Proceed around the sketch in a counter-clockwise direction
- Constrain the X-coordinate at one or more points (or arc centers)
- Constrain the Y-coordinate at one of more points (or arc centers)
- Specify the orientation of one or more Segments
    - this is sometimes done by specifying the coordinates of both ends
- Avoid redundancies, such as:
    - points at which angles are constrained and which are adjacent to Segments in which the inclination is constrained
    - dimensions specified for both a series of Segments as well as their combination

Hands-on Exercises

- U-shaped bracket (version 1)
- U-shaped bracket (version 2)
- oval
- bi-convex airfoil (with arcs)
- swivel base
- V-slide plate
- bi-convex airfoil (with splines)
- fuselage cross-section (with Beziers)

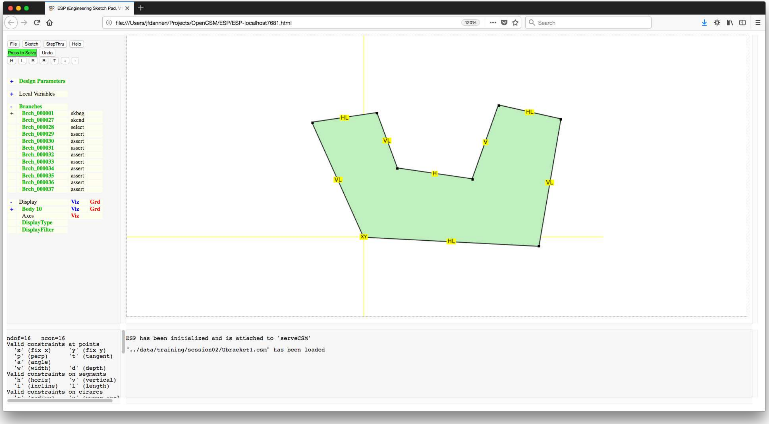
Example: U-bracket (version 1)

Hint: move mouse until blue line turns orange to automatically generate horizontal and vertical constraints



Measurements
length = 4.00
height = 3.00
thick = 0.5

Solution: U-bracket (version 1)


ESP (Engineering Sketch Pad, V
file:///Users/jfdannen/Projects/OpenCSM/ESP/ESP-localhost7681.html
120%
Search
File
Sketch
StepThru
Help
Press to Solve
Undo
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+ Design Parameters

+ Local Variables

-	Branches		
+	Brch_000001	skbeg	
	Brch_000027	skend	
	Brch_000028	select	
	Brch_000029	assert	
	Brch_000030	assert	
	Brch_000031	assert	
	Brch_000032	assert	
	Brch_000033	assert	
	Brch_000034	assert	
	Brch_000035	assert	
	Brch_000036	assert	
	Brch_000037	assert	
-	Display	Viz	Grd
+	Body 10	Viz	Grd
	Axes	Viz	
	DisplayType		
	DisplayFilter		

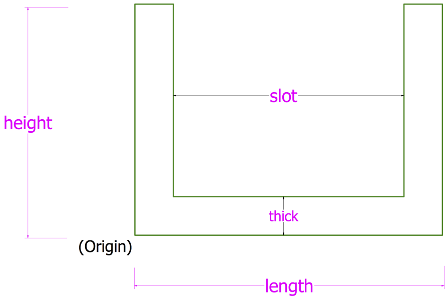
```
ndof=16   ncon=16
Valid constraints at points
  'x' (fix x)      'y' (fix y)
  'p' (perp)       't' (tangent)
  'a' (angle)
  'w' (width)      'd' (depth)
Valid constraints on segments
  'h' (horiz)      'v' (vertical)
  'i' (incline)    'l' (length)
Valid constraints on cirarcs
```

```
ESP has been initialized and is attached to 'serveCSM'

"../data/training/session02/Ubracket1.csm" has been loaded
```

Example: U-bracket (version 2)

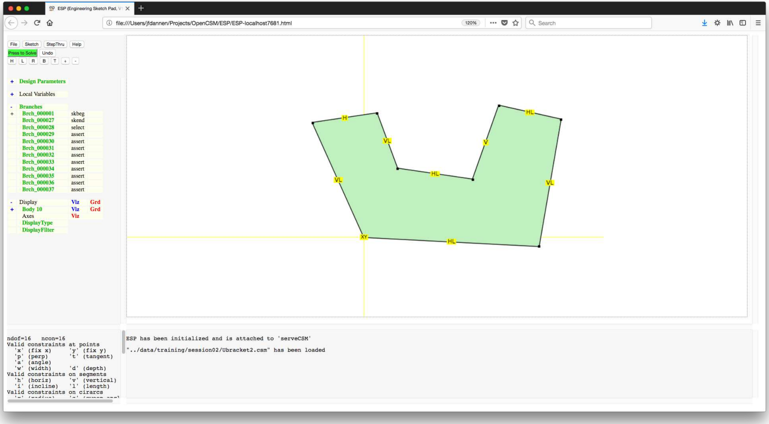
Hint: You can specify the length of a Segment to be equal to Segment 5's length with `::L[5]` (where the Segment number can be obtained with the "?" command).



Measurements
length = 4.00
height = 3.00
thick = 0.5
slot = 2.00

Note: slot
is centered

Solution: U-bracket (version 2)


ESP (Engineering Sketch Pad, V
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StepThru
Help
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XY
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+	Design Parameters		
+	Local Variables		
-	Branches		
+	Brch_000001	skbeg	
	Brch_000027	skend	
	Brch_000028	select	
	Brch_000029	assert	
	Brch_000030	assert	
	Brch_000031	assert	
	Brch_000032	assert	
	Brch_000033	assert	
	Brch_000034	assert	
	Brch_000035	assert	
	Brch_000036	assert	
	Brch_000037	assert	
-	Display	Viz	Grd
+	Body 10	Viz	Grd
	Axes	Viz	
	DisplayType		
	DisplayFilter		

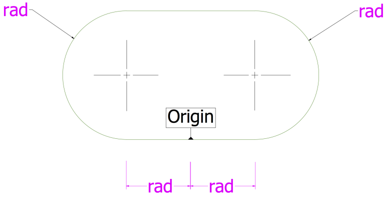
```
ndof=16   ncon=16
Valid constraints at points
  'x' (fix x)     'y' (fix y)
  'p' (perp)      't' (tangent)
  'a' (angle)
  'w' (width)     'd' (depth)
Valid constraints on segments
  'h' (horiz)     'v' (vertical)
  'i' (incline)   'l' (length)
Valid constraints on cirarcs
  'r' (radius)    's' (sweep angl
```

```
ESP has been initialized and is attached to 'serveCSM'

"../data/training/session02/Ubracket2.csm" has been loaded
```

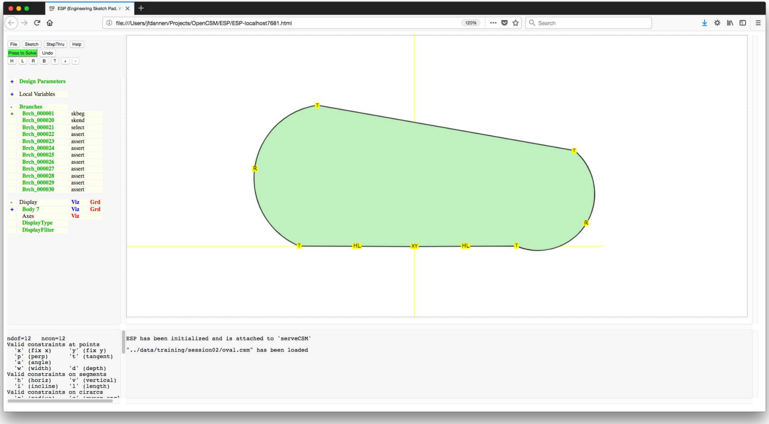
Example: Oval

Hint: tangency constraints may be useful for this case



Measurements:
rad = 0.50

Solution: Oval


ESP (Engineering Sketch Pad, V
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StepThru
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T

+	Design Parameters		
+	Local Variables		
-	Branches		
+	Brch_000001	skbeg	
	Brch_000020	skend	
	Brch_000021	select	
	Brch_000022	assert	
	Brch_000023	assert	
	Brch_000024	assert	
	Brch_000025	assert	
	Brch_000026	assert	
	Brch_000027	assert	
	Brch_000028	assert	
	Brch_000029	assert	
	Brch_000030	assert	
-	Display	Viz	Grd
+	Body 7	Viz	Grd
	Axes	Viz	
	DisplayType		
	DisplayFilter		

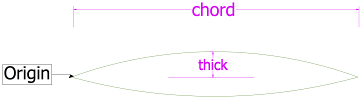
```
ndof=12   ncon=12
Valid constraints at points
  'x' (fix x)     'y' (fix y)
  'p' (perp)      't' (tangent)
  'a' (angle)
  'w' (width)     'd' (depth)
Valid constraints on segments
  'h' (horiz)     'v' (vertical)
  'i' (incline)   'l' (length)
Valid constraints on cirarcs
```

```
ESP has been initialized and is attached to 'serveCSM'

"../data/training/session02/oval.csm" has been loaded
```

Example: Biconvex airfoil (with arcs)

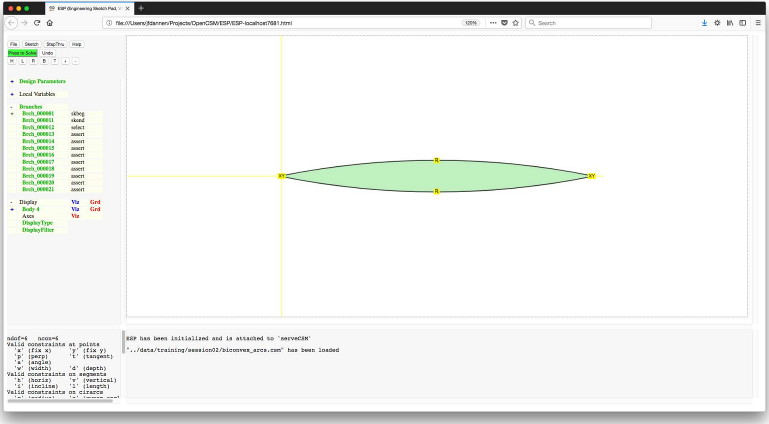
Hint: the `radius()` function can be used if one knows the bounding coordinates and the “dip” (see “Help” for details)



Measurements:
chord = 2.00
thick = 0.10

Note:
Circular Arcs

Solution: Biconvex airfoil (with arcs)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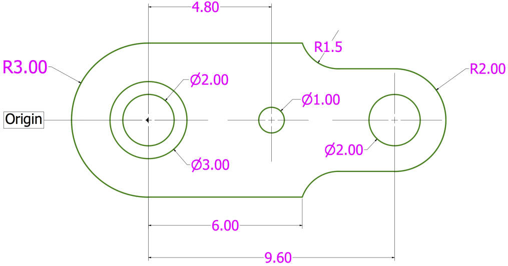
+	Design Parameters		
+	Local Variables		
-	Branches		
+	Brch_000001	skbeg	
	Brch_000011	skend	
	Brch_000012	select	
	Brch_000013	assert	
	Brch_000014	assert	
	Brch_000015	assert	
	Brch_000016	assert	
	Brch_000017	assert	
	Brch_000018	assert	
	Brch_000019	assert	
	Brch_000020	assert	
	Brch_000021	assert	
-	Display	Viz	Grd
+	Body 4	Viz	Grd
	Axes	Viz	
	DisplayType		
	DisplayFilter		

```
ndof=6   ncon=6
Valid constraints at points
  'x' (fix x)     'y' (fix y)
  'p' (perp)      't' (tangent)
  'a' (angle)
  'w' (width)     'd' (depth)
Valid constraints on segments
  'h' (horiz)     'v' (vertical)
  'i' (incline)   'l' (length)
Valid constraints on cirarcs
```

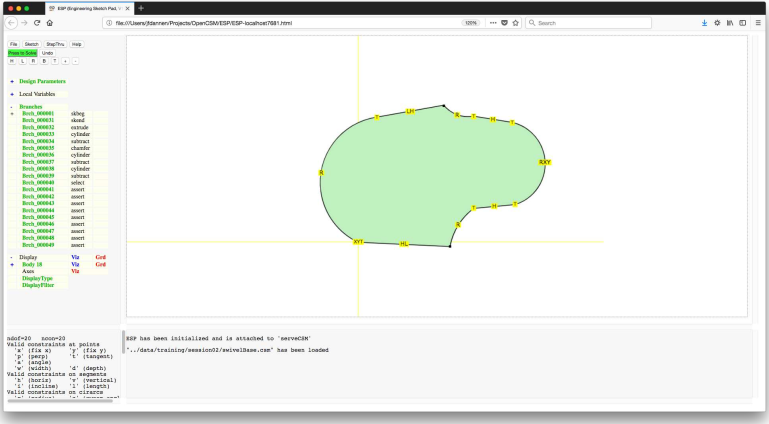
```
ESP has been initialized and is attached to 'serveCSM'

"../data/training/session02/biconvex_arcs.csm" has been loaded
```

Example: Swivel Base

Hint: nested Sketches can be generated with a series of Sketches



Solution: Swivel Base


ESP (Engineering Sketch Pad, V
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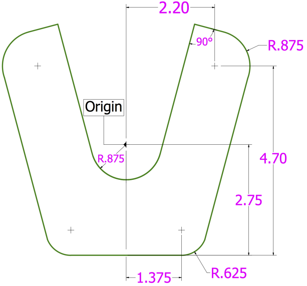
+	Design Parameters		
+	Local Variables		
-	Branches		
+	Brch_000001	skbeg	
	Brch_000031	skend	
	Brch_000032	extrude	
	Brch_000033	cylinder	
	Brch_000034	subtract	
	Brch_000035	chamfer	
	Brch_000036	cylinder	
	Brch_000037	subtract	
	Brch_000038	cylinder	
	Brch_000039	subtract	
	Brch_000040	select	
	Brch_000041	assert	
	Brch_000042	assert	
	Brch_000043	assert	
	Brch_000044	assert	
	Brch_000045	assert	
	Brch_000046	assert	
	Brch_000047	assert	
	Brch_000048	assert	
	Brch_000049	assert	
-	Display	Viz	Grd
+	Body 18	Viz	Grd
	Axes	Viz	
	DisplayType		
	DisplayFilter		

```
ndof=20   ncon=20
Valid constraints at points
  'x' (fix x)      'y' (fix y)
  'p' (perp)       't' (tangent)
  'a' (angle)
  'w' (width)      'd' (depth)
Valid constraints on segments
  'h' (horiz)      'v' (vertical)
  'i' (incline)    'l' (length)
Valid constraints on cirarcs
```

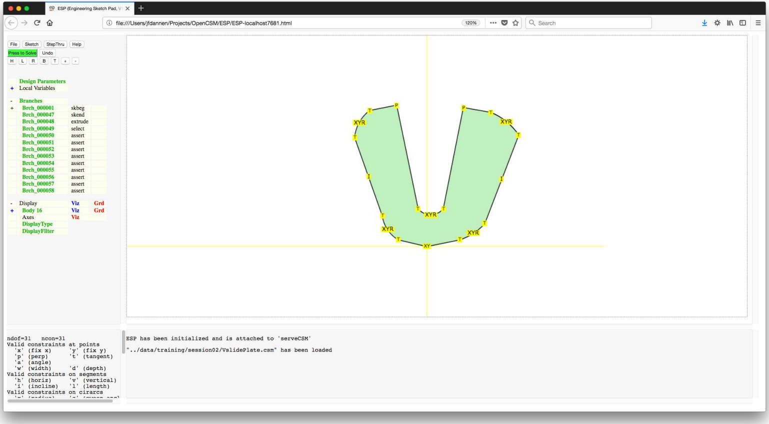
```
ESP has been initialized and is attached to 'serveCSM'

"../data/training/session02/swivelBase.csm" has been loaded
```

Example: V-slide Plate

Hint: to make Segments parallel, set an inclination Constraint (and see “Expression rules” in Help)



Solution: V-slide Plate



ESP (Engineering Sketch Pad, V
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Search
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I
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XY
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XYR
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XYR
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P
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XYR
T

Design Parameters
+ Local Variables

-	Branches	
+	Brch_000001	skbeg
	Brch_000047	skend
	Brch_000048	extrude
	Brch_000049	select
	Brch_000050	assert
	Brch_000051	assert
	Brch_000052	assert
	Brch_000053	assert
	Brch_000054	assert
	Brch_000055	assert
	Brch_000056	assert
	Brch_000057	assert
	Brch_000058	assert

-	Display	Viz	Grd
+	Body 16	Viz	Grd
	Axes	Viz	
	DisplayType		
	DisplayFilter		

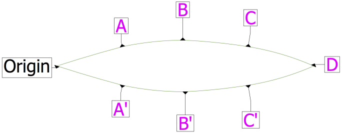
```
ndof=31   ncon=31
Valid constraints at points
  'x' (fix x)     'y' (fix y)
  'p' (perp)      't' (tangent)
  'a' (angle)
  'w' (width)     'd' (depth)
Valid constraints on segments
  'h' (horiz)     'v' (vertical)
  'i' (incline)   'l' (length)
Valid constraints on cirarcs
  'r' (radius)    's' (sweep angl
```

```
ESP has been initialized and is attached to 'serveCSM'

"../data/training/session02/VslidePlate.csm" has been loaded
```

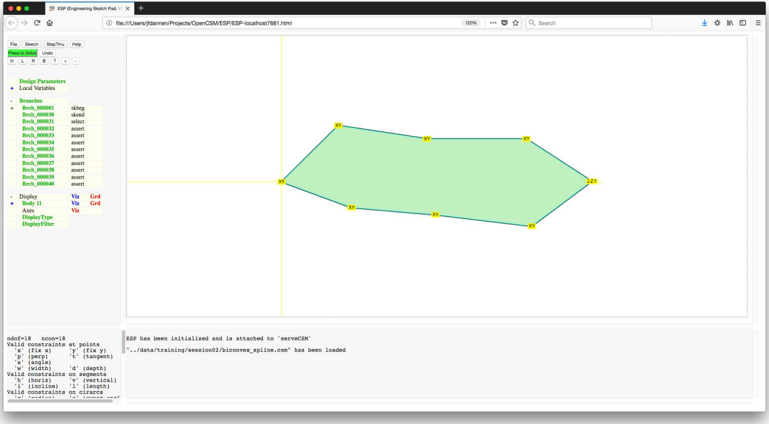
Example: Biconvex Airfoil (with splines)

Hint: adjacent splines (with slope discontinuities) can be obtained by putting a zero-length line Segments between them



	x	y
A:	.255	.075
B:	.500	.100
C:	.745	.075
D:	1.00	0.00

Solution: Biconvex Airfoil (with splines)


ESP (Engineering Sketch Pad, V
file:///Users/jfdannen/Projects/OpenCSM/ESP/ESP-localhost7681.html
120%
Search
File
Sketch
StepThru
Help
Press to Solve
Undo
H
L
R
B
T
+
-
XY
XY
XY
XY
ZZY
XY
XY
XY

	Design Parameters		
+	Local Variables		
-	Branches		
+	Brch_000001	skbeg	
	Brch_000030	skend	
	Brch_000031	select	
	Brch_000032	assert	
	Brch_000033	assert	
	Brch_000034	assert	
	Brch_000035	assert	
	Brch_000036	assert	
	Brch_000037	assert	
	Brch_000038	assert	
	Brch_000039	assert	
	Brch_000040	assert	
-	Display	Viz	Grd
+	Body 11	Viz	Grd
	Axes	Viz	
	DisplayType		
	DisplayFilter		

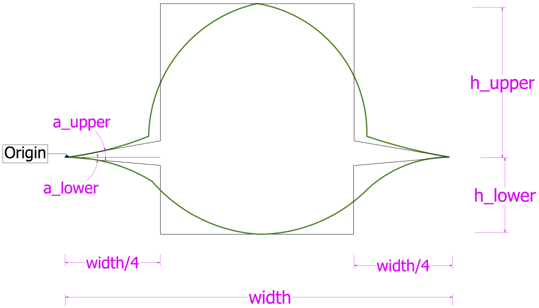
```
ndof=18   ncon=18
Valid constraints at points
  'x' (fix x)     'y' (fix y)
  'p' (perp)      't' (tangent)
  'a' (angle)
  'w' (width)     'd' (depth)
Valid constraints on segments
  'h' (horiz)     'v' (vertical)
  'i' (incline)   'l' (length)
Valid constraints on cirarcs
  'r' (radius)    's' (sweep angl
```

```
ESP has been initialized and is attached to 'serveCSM'

"../data/training/session02/biconvex_spline.csm" has been loaded
```

Example: Fuselage X-section (with Beziers)

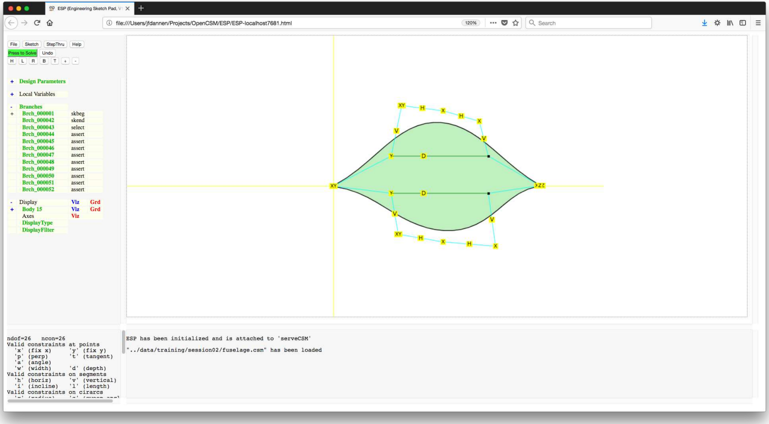
Hint: the Bezier control points are constrained in the same way as any other point



Measurements:
width = 5.00
h_upper = 2.00
h_lower = 1.00
a_upper = 10°
a_lower = 5°

Note:
4 Bezier Cubics

Solution: Fuselage X-section (with Beziers)


ESP (Engineering Sketch Pad, V
file:///Users/jfdannen/Projects/OpenCSM/ESP/ESP-localhost7681.html
120%
Search
File
Sketch
StepThru
Help
Press to Solve
Undo
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V
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Y
D
XY
XZZ
Y
D
V
V
XY
H
X
H
X

+	Design Parameters		
+	Local Variables		
-	Branches		
+	Brch_000001	skbeg	
	Brch_000042	skend	
	Brch_000043	select	
	Brch_000044	assert	
	Brch_000045	assert	
	Brch_000046	assert	
	Brch_000047	assert	
	Brch_000048	assert	
	Brch_000049	assert	
	Brch_000050	assert	
	Brch_000051	assert	
	Brch_000052	assert	
-	Display	Viz	Grd
+	Body 15	Viz	Grd
	Axes	Viz	
	DisplayType		
	DisplayFilter		

```
ndof=26   ncon=26
Valid constraints at points
  'x' (fix x)      'y' (fix y)
  'p' (perp)       't' (tangent)
  'a' (angle)
  'w' (width)      'd' (depth)
Valid constraints on segments
  'h' (horiz)      'v' (vertical)
  'i' (incline)    'l' (length)
Valid constraints on cirarcs
  'r' (radius)     's' (sweep angl
```

```
ESP has been initialized and is attached to 'serveCSM'

"../data/training/session02/fuselage.csm" has been loaded
```