

# Engineering Sketch Pad (ESP) Training

## Session 2: Sketching Fundamentals

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## Overview

- Introduction
- Creating a Sketch
- Editing an existing Sketch
- Image manipulation in the Sketcher
- Sketching Best Practices
- 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)



## Introduction

- A Sketch is a two-dimensional figure that can be used:
  - in grown primitives, such as extrude, rule, blend, and revolve
  - to create a non-manifold Sheet Body
  - to create a non-manifold Wire Body (if open)
- Sketches are defined in terms of:
  - Segments
  - Sketch variables (and their initial values)
  - Constraints



## Steps to Creating a Sketch

- 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
    - **I** 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 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 ( $x_{\text{beg}} = x_{\text{rmend}}$ )
    - **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 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 counter-clockwise)
    - **s** or **S**



## Creating a Sketch

### Step 4: Constrain the Sketch (4)

- Constraints 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 to the left)
    - $a$  or  $A$



## Creating a Sketch

### Step 4: Constrain the Sketch (5)

- Constraints applied to pairs of points:
  - specify width ( $x_{\text{end}} - x_{\text{beg}}$ ) between two points
    - $w$  or  $W$
    - the specified sign is important
  - specify depth ( $y_{\text{end}} - y_{\text{rmbeg}}$ ) between two points
    - $d$  or  $D$
    - the specified sign is important



## 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 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 **Save Sketch** 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



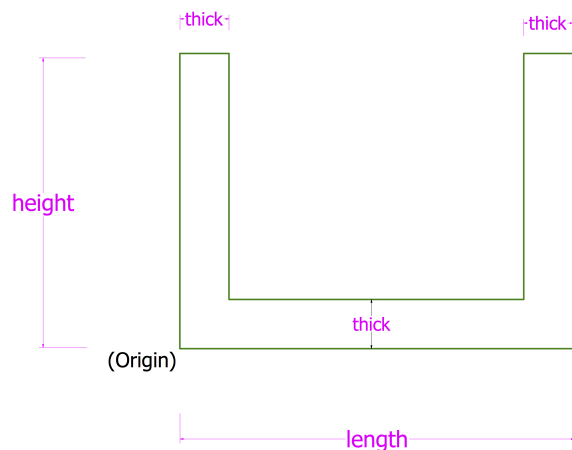
## Hands-on Exercises

- 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

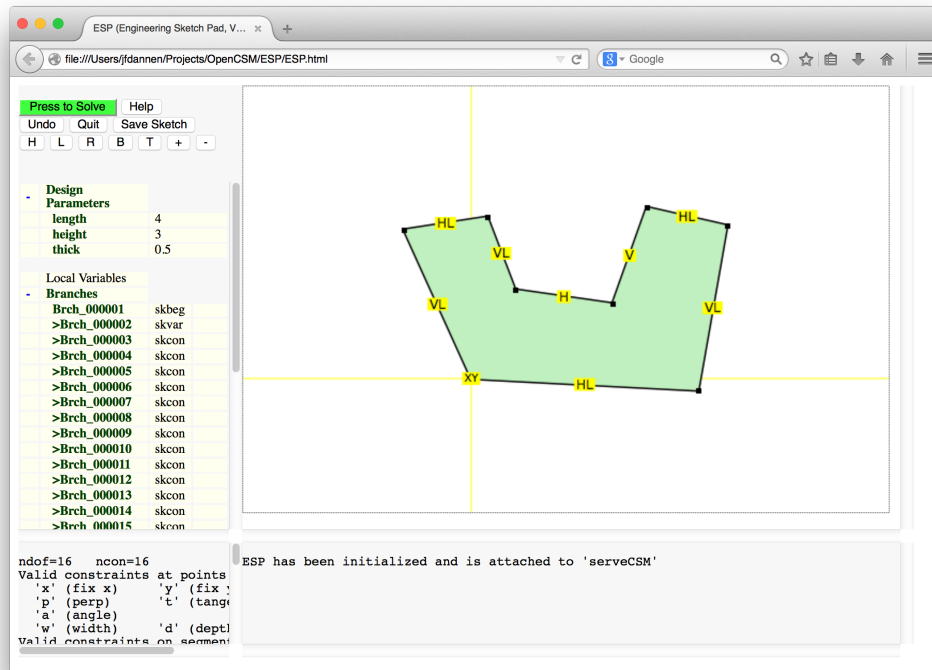


**Measurements**

length = 4.00  
height = 3.00  
thick = 0.5

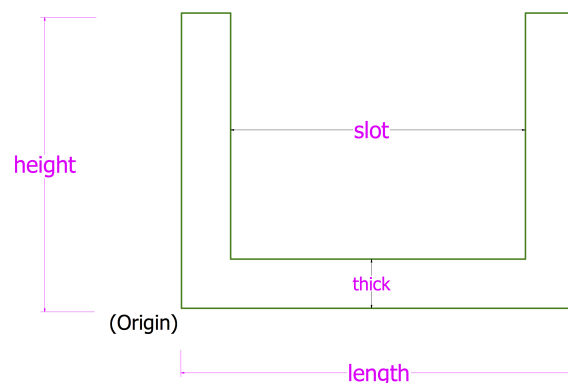


## Solution: U-bracket (version 1)



## 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).



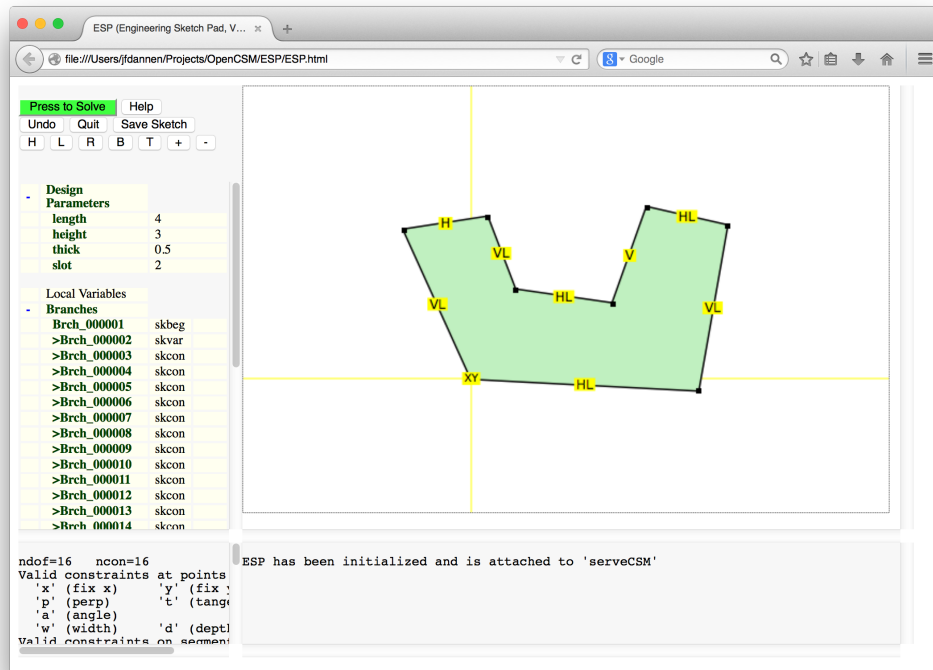
### Measurements

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

Note: slot  
is centered

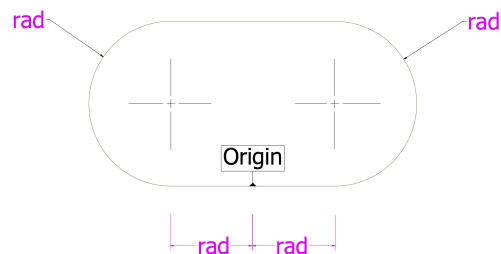


## Solution: U-bracket (version 2)



## Example: Oval

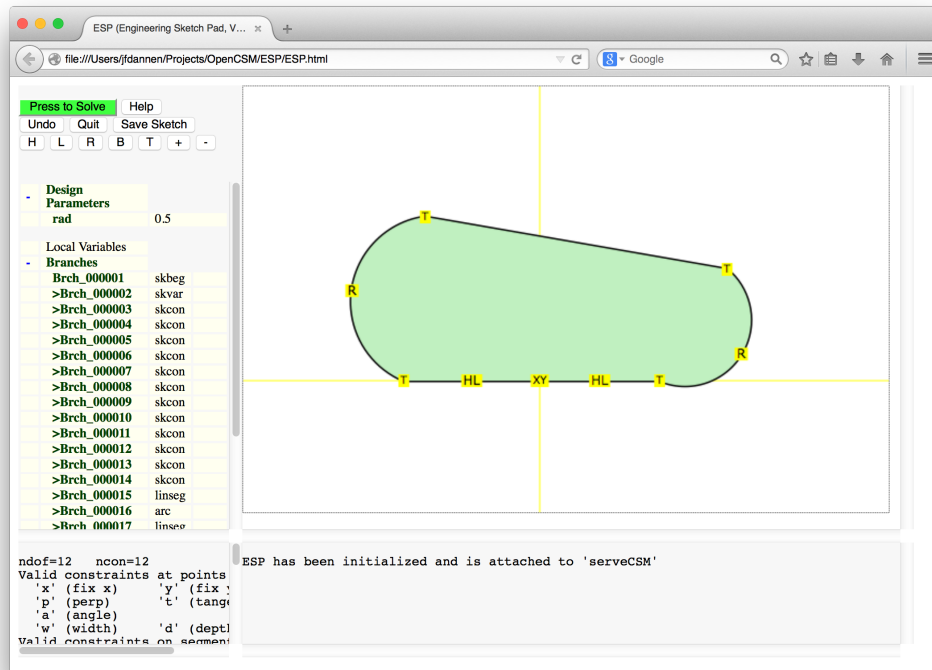
Hint: tangency constraints may be useful for this case



**Measurements:**  
rad = 0.50

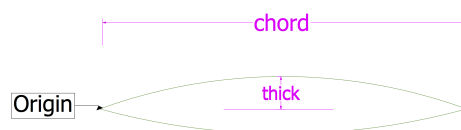


## Solution: Oval (version 2)



## 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:

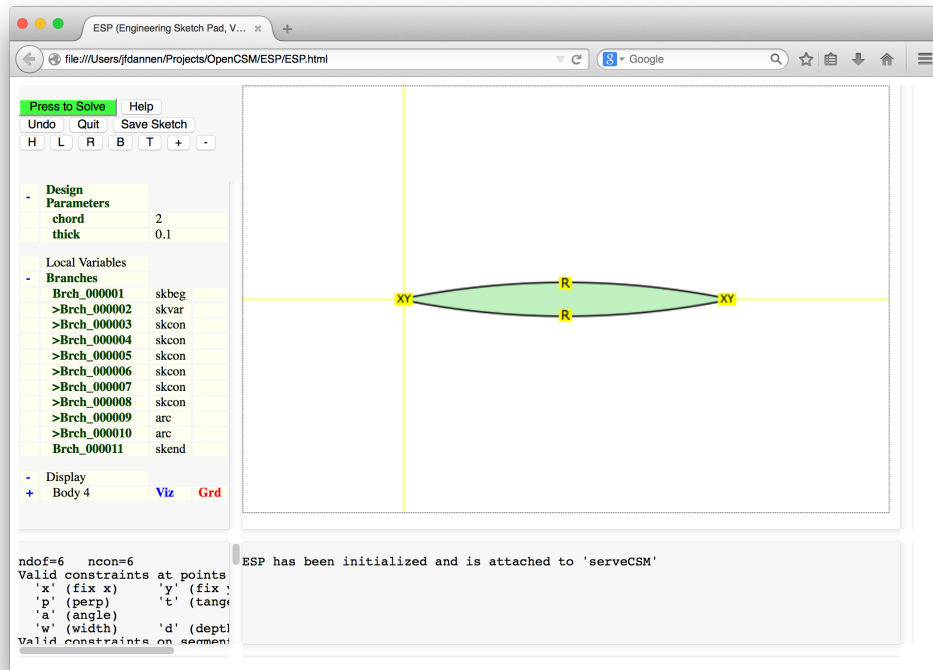
chord = 2.00  
thick = 0.10

### Note:

Circular Arcs

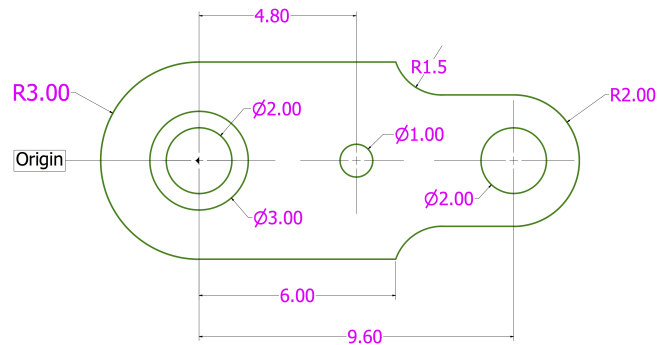


## Solution: Biconvex airfoil (with arcs)



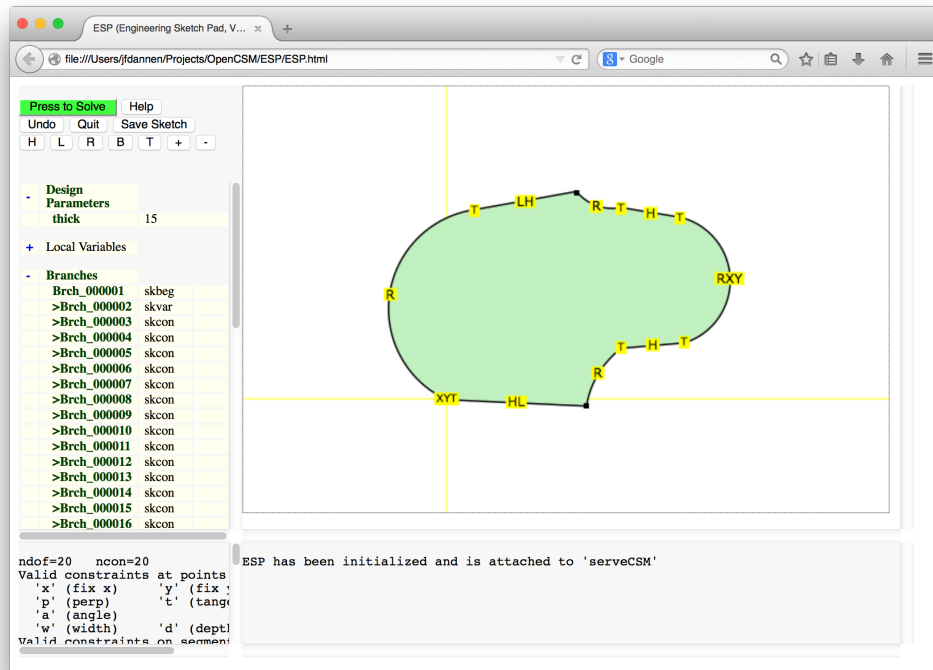
## Example: Swivel Base

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



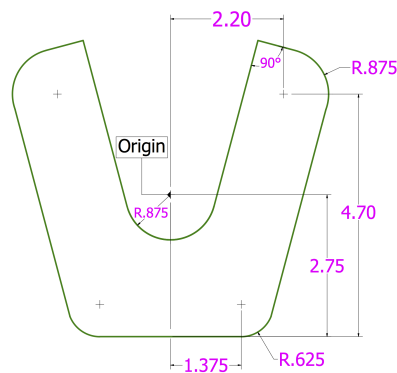


## Solution: Swivel Base



## Example: V-slide Plate

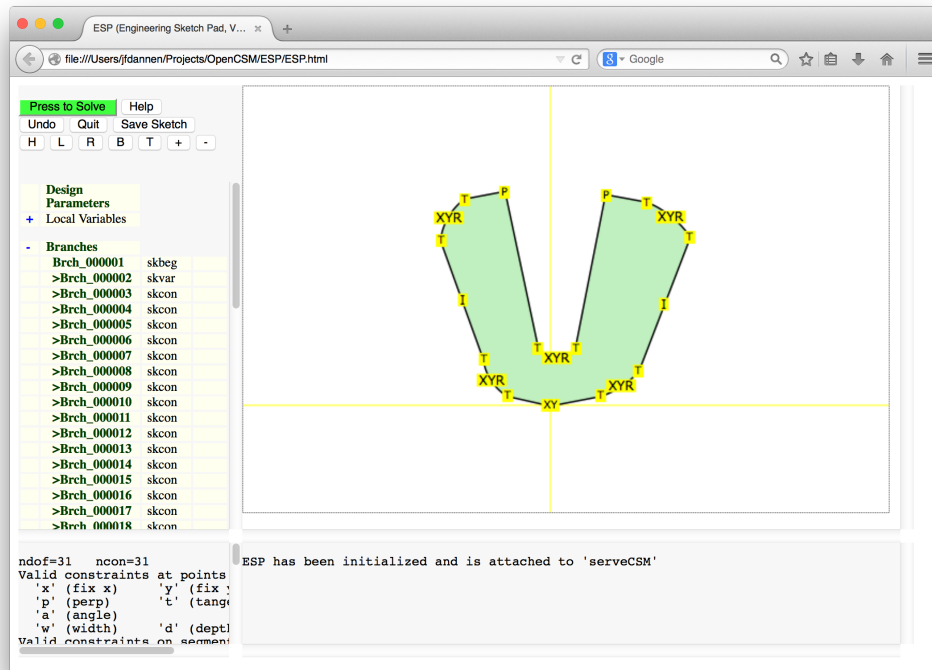
Hint: to make Segments parallel, set an inclination Constraint (and see "Expression rules" in Help)





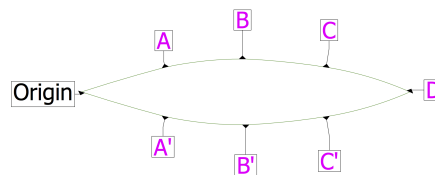


## Solution: V-slide Plate



## Example: Biconvex Airfoil (with splines)

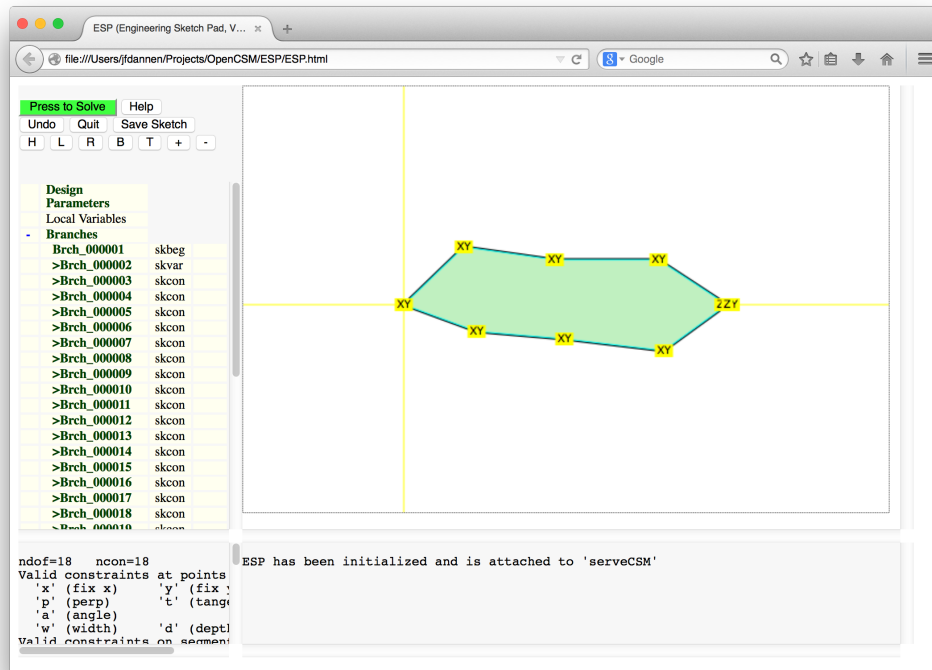
Hint: adjacent splines (with slope discontinuities) can be obtained by putting a zero-length line segments between them



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

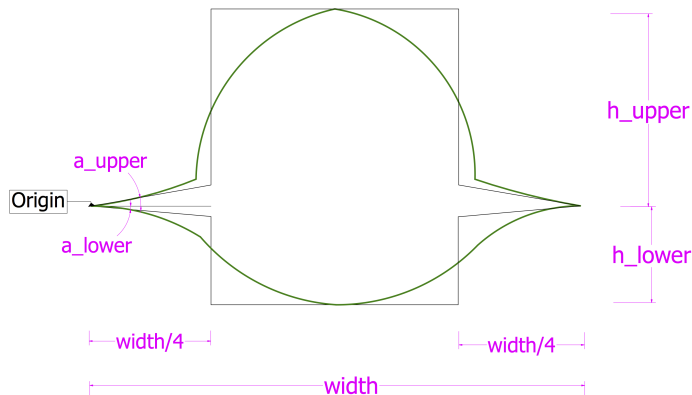


## Solution: Biconvex Airfoil (with splines)



## Example: Fuselage X-section (with Beziers)

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



### Measurements:

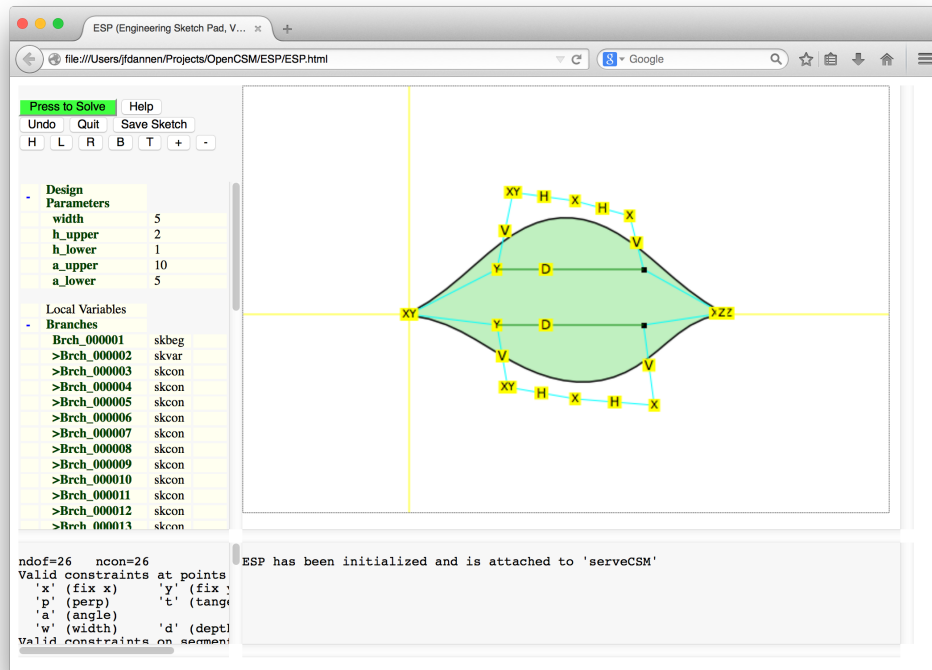
width = 5.00  
h\_upper = 2.00  
h\_lower = 1.00  
a\_upper = 10°  
a\_lower = 5°

### Note:

4 Bezier Cubics



## Solution: Fuselage X-section (with Beziers)



## Muddy Cards

- What operations were most confusing to you?
- How easy was it for you to diagnose problems when they occurred?
- Is one level of “undo” sufficient?
- What operations would you like to see added to the Sketcher?
- ...