

# Engineering Sketch Pad (ESP) Training

## Session 2: Sketching Fundamentals

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Revised for v1.08





# 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
- (new in v1.08) a skend is automatically created for you
- (new in v1.08) 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 (new in v1.08)
    - **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 ( $y_{\text{end}} - y_{\text{rm beg}}$ ) between two points
    - **d** or **D**
    - the specified sign is important



# Creating a Sketch

## Step 4: Constrain the Sketch (6)

- Other options:
  - remove Constraints
    - <
    - (new in v1.08) 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.
- (new in v1.08) 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



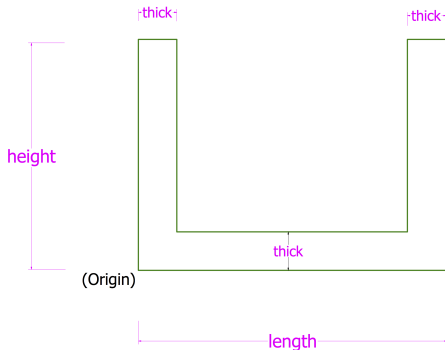
# Hands-on Exercises

- 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... x)

file:///Users/jfdannen/Projects/OpenCSM/ESP/ESP.html

Press to Solve Help  
Undo Quit Save Sketch  
H L R B T + -

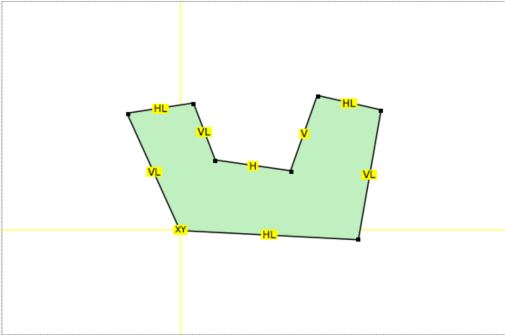
Design Parameters

length	4
height	3
thick	0.5

Local Variables

Branches

Brch_000001	skbeg
>Brch_000002	skvar
>Brch_000003	skcon
>Brch_000004	skcon
>Brch_000005	skcon
>Brch_000006	skcon
>Brch_000007	skcon
>Brch_000008	skcon
>Brch_000009	skcon
>Brch_000010	skcon
>Brch_000011	skcon
>Brch_000012	skcon
>Brch_000013	skcon
>Brch_000014	skcon
>Brch_000015	skcon



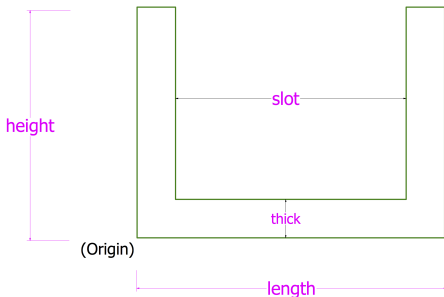
ndof=16 ncon=16  
Valid constraints at points  
'x' (fix x) 'y' (fix y)  
'p' (perp) 't' (tangent)  
'a' (angle)  
'w' (width) 'd' (depth)  
Valid constraints on segments

ESP has been initialized and is attached to 'serveCSM'



## 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... x)

file:///Users/jfdannen/Projects/OpenCSM/ESP/ESP.html

Press to Solve Help  
Undo Quit Save Sketch  
H L R B T + -

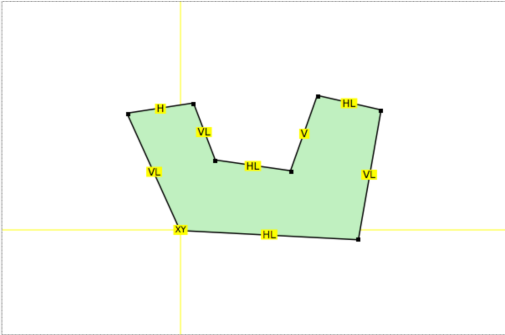
Design Parameters

length	4
height	3
thick	0.5
slot	2

Local Variables

Branches

Brch_000001	skbeg
>Brch_000002	skvar
>Brch_000003	skcon
>Brch_000004	skcon
>Brch_000005	skcon
>Brch_000006	skcon
>Brch_000007	skcon
>Brch_000008	skcon
>Brch_000009	skcon
>Brch_000010	skcon
>Brch_000011	skcon
>Brch_000012	skcon
>Brch_000013	skcon
>Brch_000014	skcon



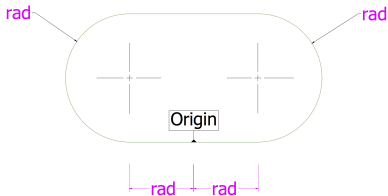
ndof=16 ncon=16  
Valid constraints at points  
'x' (fix x) 'y' (fix y)  
'p' (perp) 't' (tangent)  
'a' (angle)  
'w' (width) 'd' (depth)  
Valid constraints on segments

ESP has been initialized and is attached to 'serveCSM'



## Example: Oval

Hint: tangency constraints may be useful for this case



**Measurements:**

rad = 0.50



# Solution: Oval (version 2)

ESP (Engineering Sketch Pad, V... x)

file:///Users/jfdannen/Projects/OpenCSM/ESP/ESP.html

Press to Solve Help  
Undo Quit Save Sketch  
H L R B T + -

Design Parameters  
rad 0.5

Local Variables  
Branches  
Brch\_000001 skbeg  
>Brch\_000002 skvar  
>Brch\_000003 skcon  
>Brch\_000004 skcon  
>Brch\_000005 skcon  
>Brch\_000006 skcon  
>Brch\_000007 skcon  
>Brch\_000008 skcon  
>Brch\_000009 skcon  
>Brch\_000010 skcon  
>Brch\_000011 skcon  
>Brch\_000012 skcon  
>Brch\_000013 skcon  
>Brch\_000014 skcon  
>Brch\_000015 linseg  
>Brch\_000016 arc  
>Brch\_000017 linseg

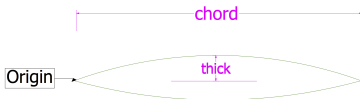
ndof=12 ncon=12  
Valid constraints at points  
'x' (fix x) 'y' (fix y)  
'p' (perp) 't' (tangent)  
'a' (angle)  
'w' (width) 'd' (depth)  
Valid constraints on segments

ESP has been initialized and is attached to 'serveCSM'



## 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

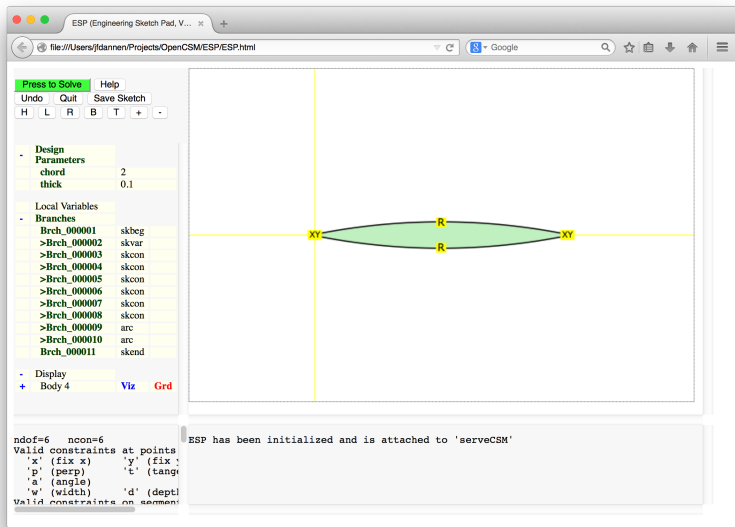
thick = 0.10

### **Note:**

Circular Arcs



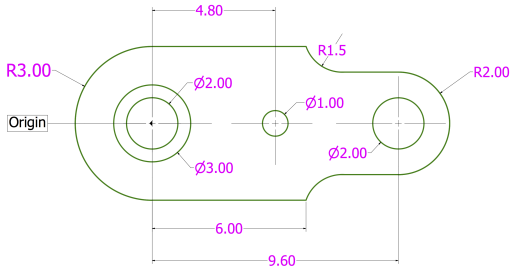
# Solution: Biconvex airfoil (with arcs)





## Example: Swivel Base

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





# Solution: Swivel Base

ESP (Engineering Sketch Pad, V... x

file:///Users/jfdannen/Projects/OpenCSM/ESP/ESP.html

Press to Solve Help  
Undo Quit Save Sketch  
H L R B T + -

Design Parameters  
thick 15

Local Variables

Branches

Brch_000001	skbeg
>Brch_000002	skvar
>Brch_000003	skcon
>Brch_000004	skcon
>Brch_000005	skcon
>Brch_000006	skcon
>Brch_000007	skcon
>Brch_000008	skcon
>Brch_000009	skcon
>Brch_000010	skcon
>Brch_000011	skcon
>Brch_000012	skcon
>Brch_000013	skcon
>Brch_000014	skcon
>Brch_000015	skcon
>Brch_000016	skcon

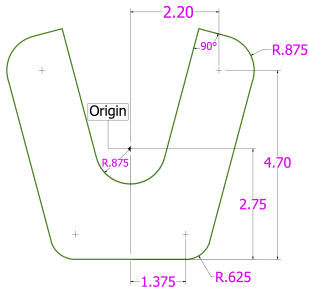
ndof=20 ncon=20  
Valid constraints at points  
'x' (fix x) 'y' (fix y)  
'p' (perp) 't' (tangent)  
'a' (angle)  
'w' (width) 'd' (depth)  
Valid constraints on segments

ESP has been initialized and is attached to 'serveCSM'



## Example: V-slide Plate

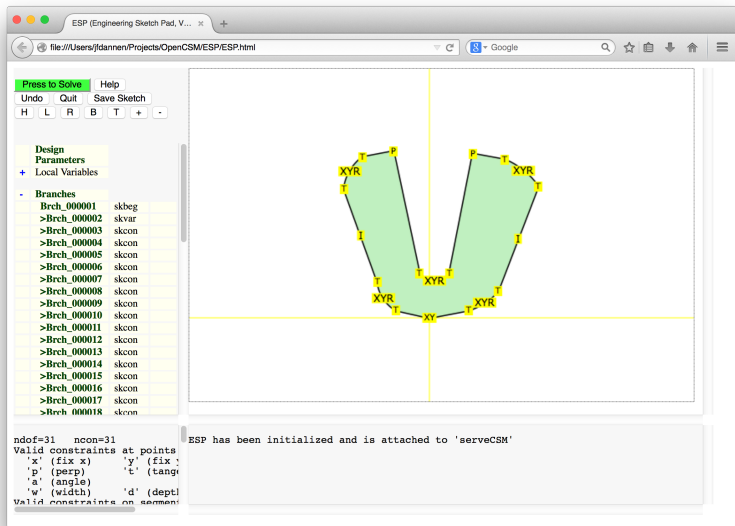
Hint: to make Segments parallel, set an inclination Constraint (and see “Expression rules” in Help)







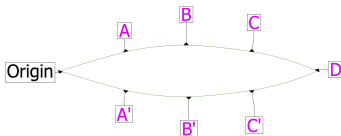
# Solution: V-slide Plate





## Example: Biconvex Airfoil (with splines)

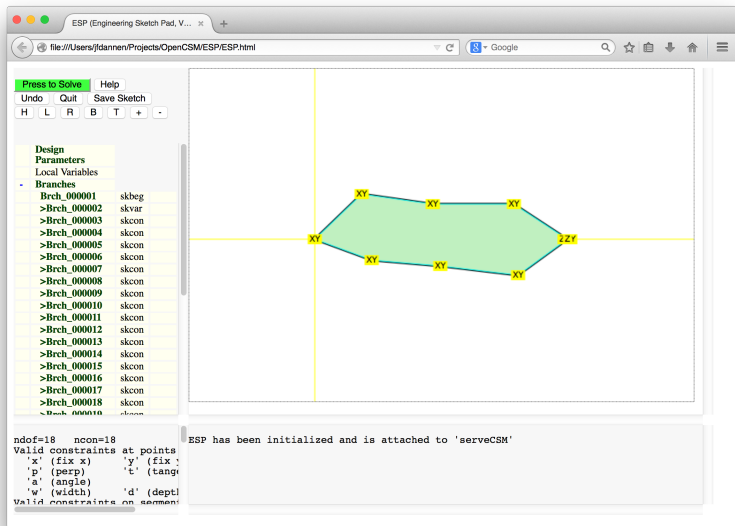
Hint: adjacent splines (with slope discontinuities) can be obtained by putting a zero-length line segments between them



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



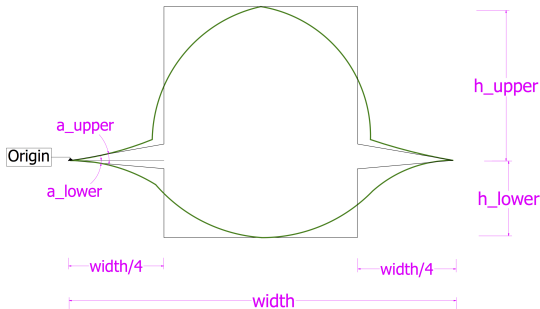
# Solution: Biconvex Airfoil (with splines)





# 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)

ESP (Engineering Sketch Pad, V... x)

file:///Users/jfdannen/Projects/OpenCSM/ESP/ESP.html

Press to Solve Help  
Undo Quit Save Sketch  
H L R B T + -

Design Parameters

width	5
h_upper	2
h_lower	1
a_upper	10
a_lower	5

Local Variables

Branches

Brch_000001	skbeg
>Brch_000002	skvar
>Brch_000003	skcon
>Brch_000004	skcon
>Brch_000005	skcon
>Brch_000006	skcon
>Brch_000007	skcon
>Brch_000008	skcon
>Brch_000009	skcon
>Brch_000010	skcon
>Brch_000011	skcon
>Brch_000012	skcon
>Brch_000013	skcon

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

ESP has been initialized and is attached to 'serveCSM'



# 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?
- ...