# Engineering Sketch Pad (ESP)

# Training Session 6
# UDPs, UDFs, and UDCs

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# Overview

- User-defined Primitives (UDPs) and Functions (UDFs)
  - Difference Between UDPs and UDFs
  - Using UDPARG and UDPRIM Statements
- Creating Simple Cross-sections
- Creating a simple NodeBody, WireBody, SheetBody, and SolidBody
- User-defined Components (UDCs)
  - Include-style
  - Function-style
- Homework Exercise

# Differences Between UDPs and UDFs

- Users can add their own user-defined primitives (UDPs)
  - creates a single Body
  - do not consume any Bodys from the Stack
  - are written in C, C++, or FORTRAN and are compiled
  - can be written either top-down or bottom-up or both
  - have access to the entire suite of methods provided by `EGADS`
  - are coupled into `ESP` dynamically at run time
- Users can add their own user-defined functions (UDFs)
  - are the same as UDPs, except they consume one or more Bodys from the Stack

# Calling a UDP (1)

- UDPs are called with a `UDPRIM` statement

```
UDPRIM    $primtype $argName1 argValue1 \
                    $argName2 argValue2 \
                    $argName3 argValue3 \
                    $argName4 argValue4
```

- `$primtype` must start with a letter
- At most 4 name-value pairs can be specified on the `UDPRIM` statement
- More name-value pairs can be specified in any number of `UDPARG` statements that precede the `UDPRIM` statement

```
UDPARG    $primtype $argName1 argValue1 \
                    $argName2 argValue2 \
                    $argName3 argValue3 \
                    $argName4 argValue4
```

- name-value pairs are processed in order (with possible over-writing)

# Calling a UDP (2)

- For UDPs that read an external file, one can use `<<` to tell `ESP` to create a file from the following lines, up to a line that starts with `>>`
- For example:

```
UDPRIM     editAttr  filename <<  verbose 1
        NODE ADJ2FACE tagType=spar tagIndex=1
        AND  ADJ2FACE tagType=lower
        AND  ADJ2EDGE tagType=root
        SET           capsConstraint=pointConstraint1
>>
SET        A  10
```

has two Branches (`UDPRIM` and `SET`)

# UDPARG and UDPRIM Examples

- The following generate identical Boxes

```
UDPRIM box dx 1 dy 2 dz 3
```

- and

```
UDPARG box dx 1
UDPRIM box dy 2 dz 3
```

- and

```
UDPARG box dx 11 dy 22 dz 33
UDPRIM box dx 1  dy 2  dz 3
```

- and

```
UDPARG box dx 1
UDPARG box dy 2
UDPARG box dz 3
UDPRIM box
```

# Return Values from UDPs

- Some UDPs return values to the calling script
- The returned values have names that are prepended by two at-signs (for example: `volume` in the UDP is available as `@@volume` after the `UDPRIM` executes)
- These values stay in effect until overwritten by another UDP (or a UDF or a UDC)

# UDPs Shipped with ESP (1)

- `bezier $filename debug=0 @@imax @@jmax cp[]`
  - generate a Bezier WireBody, SheetBody, or SolidBody from an input file
- `biconvex thick=0 camber=0`
  - generate a biconvex airfoil SheetBody
- `box dx=0 dy=0 dz=0 rad=0 @@area @@volume`
  - generate a (rectangular) WireBody, SheetBody, or SolidBody centered at the origin (with possibly-rounded corners)
- `csm $filename $pmtrname pmtrvalue=0 @@volume`
  - call `OpenCSM` recursively to read a `.csm` file and create a Body
- `ellipse rx=0 ry=0 rz=0 nedge=2 thbeg=0`
  - generate an ellipse SheetBody centered at the origin (try to use the `supell` UDP instead)
- `fitcurve $filename ncp ordered periodic xform[] @@npnt @@rms`
  - fit a Bspline curve WireBody to a set of points

# UDPs Shipped with **ESP** (2)

- `freeform $filename imax=1 jmax=1 kmax=1 xyz[]`
  - generate a freeform WireBody, SheetBody, or SolidBody from an input file
- `hex corners[] uknots[] vknots[] wknots[] @@area @@volume`
  - create a general hexahedron SolidBody from its corners segments
- `import $filename bodynumber=1 @@numbodies`
  - read a Body (or Bodys) out of a `.step` file
- `kulfan class[] ztail[] aupper[] alower[]`
  - generate a Kulfan SheetBody airfoil
- `naca series=0012 thickness=0 camber=0 maxloc=0.4 offset=0 sharpte=0`
  - generate a NACA 4-series SheetBody airfoil or WireBody camberline

# UDPs Shipped with ESP (3)

- `naca456 thkcode toc xmaxt leindex camcode cmax xmaxc cl a`
  - generate a NACA 4-, 5-, or 6-series SheetBody airfoil
- `nurbbody $filename`
  - generate a Body from a series of NURBS
- `parsec yte poly[] param[] meanline ztail[]`
  - generate a Parsec SheetBody airfoil by either specifying Sobieski's parameters or spline parameters
- `pod length=0 fineness=0 @@volume`
  - generates a VSP-like SolidBody pod
- `poly points[]`
  - generate a general SolidBody polyhedron, SheetBody polygon, WireBody line, or NodeBody point

# UDPs Shipped with ESP (4)

- `prop nblade cpower lambda reyr rtip rhub clift cdrag alfa shdiam=0 shxmin shxmax spdiam=0 spxmin @@cthrust @@eff`
  - generates a propeller and optional shaft and spinner
- `radwaf ysize=0 zsize=0 nspoke=0 xframe[]`
  - generate a radial SheetBody waffle, which is useful for creating fuselage structures
- `sample dx dy dz center[] @@area @@volume`
  - used as an example for users who want to create their own UDP
- `sew $filename toler=0 bodynum=1`
  - sew Faces in a `step` file into a SolidBody

# UDPs Shipped with **ESP** (5)

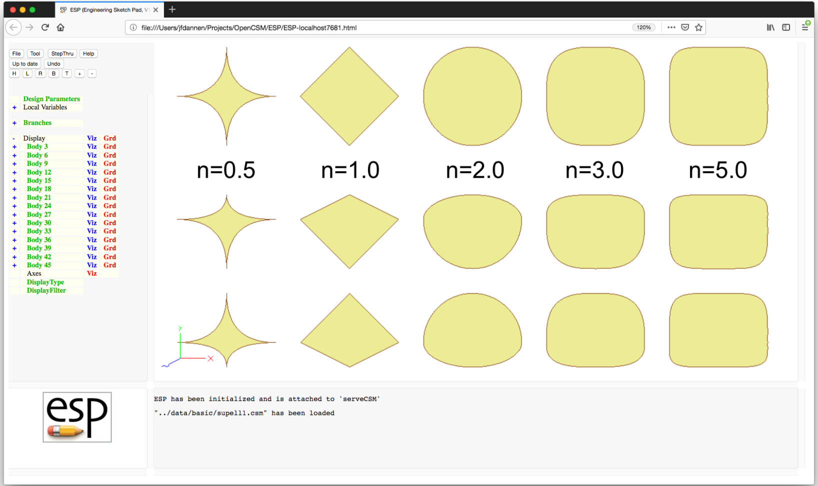
- `stag rad1=0.1 beta1=30 gama1=10 rad2=0.05 beta2=-40 gama2=5 alfa=-30 xfrnt=0.333 xrear=0.667`
  - simple turbomachinery airfoil generator to generate a SheetBody
- `supell rx rx_w rx_e ry ry_s ry_n n n_w n_e n_s n_n n_sw n_se n_nw n_ne offset nquad`
  - generate a 4-quadrant SheetBody super-ellipse
- `waffle depth=1 segments[] $filename progress=0`
  - generate a SheetBody waffle by extruding a 2D group of segments

# Creating NACA Airfoils

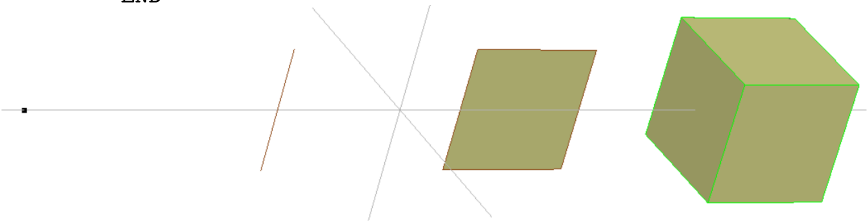
```
# naca

UDPRIM naca thickness 0.00 camber 0.04
TRANSLATE -2 0 0

UDPRIM naca thickness 0.12 camber 0.00

UDPRIM naca thickness 0.12 camber 0.04
TRANSLATE +2 0 0

END
```

# Creating Super-ellipses

Generated with `$ESP_ROOT/data/basic/supell1.csm`



```
# simple

POINT     -3 0 0
UDPRIM box  dy 1.0
TRANSLATE -1 0 0
UDPRIM box  dx 1.0  dy 1.0
TRANSLATE +1 0 0
UDPRIM box  dx 1.0  dy 1.0  dz 1.0
TRANSLATE +3 0 0

END
```



# UDFs Shipped with ESP (1)

- `createBEM $filename space=0 imin=3 imax=5 nocrod=0`
  - create a NASTRAN-type built-up-element (BEM) file from Body on Stack
- `createPoly $filename hole[]`
  - create a TETGEN `.poly` file between the two Bodys on the top of the Stack
- `droop xle=-100 thetale=0 xte=100 thetate=0`
  - applies leading- or trailing-edge droop to the Body on the top of the Stack
- `editAttr $attrname $input $output overwrite=0 $filename verbose=0 @@nchange`
  - edit the Attributes for the Body on the top of the Stack
- `flend slopea=1 slopeb=1 toler=1e-6 equis=0 npnt=33 plot=0`
  - create a flend (similar to fillet) that connects the one or two Bodys on the top of the Stack

# UDFs Shipped with ESP (2)

- `ganged $op toler=0`
  - perform ganged SUBTRACTs or UNIONs to Bodys on the Stack back to the Mark
- `guide nxsect=5 origin=0 axis=0`
  - sweep a SheetBody or WireBody along a WireBody guide curve
- `matchBodys toler @@nnodes @@nedges @@nfaces`
- `nuscale xscale=1 yscale=1 zscale=1 xcent=0 ycent=0 zcent=0`
  - converts Body on top of stack to BSplines and applies separate scaling in each coordinate direction
- `printBbox`
  - print the bounding boxes associated with the Bodys on the Stack

# UDFs Shipped with ESP (3)

- `printBrep`
  - print Brep information associated with the Bodys on the Stack
- `printEgo`
  - print EGO information associated with the Bodys on the Stack
- `slices nslice dirn=0`
  - creates uniform slices of Body on top of stack
- `stiffener beg[] end[] depth=0 angle=0`
  - create a stiffener that is orthogonal to the SheetBody on the top of the Stack

- UDFs are called in exactly same way as UDPs are called

# Writing Your Own UDP or UDF

- see `EngSketchPad/doc/UDP_UDF/udp_udf.pdf`

# User-defined Components (UDCs)

- A UDC is a series of statements that are contained in a `.udc` file
- The statements in the UDC can be treated in two ways:
  - Include-style
    - statements within the UDC are simply processed as if they were included in the enclosing `.csm` or `.udc` file
    - the `.udc` file must start with an `INTERFACE . ALL` statement
    - Variables and Parameters in the `.udc` file have the same scope as its caller (that is, the UDC shares variables with its caller)
  - Function-style
    - Variables and Parameters in the `.udc` file have local scope (that is, the UDC's variable are private)
    - Variables in the UDC get values via `INTERFACE . IN` statements
    - The UDC can output some of its variables via `INTERFACE . OUT` statements

# Example Include-style UDC

- In `test1.csm`

```
SET    A   1
SET    B   10
SET    C   0
UDPRIM $/test2
SET    D   C^2
```

- In `test2.udc`

```
INTERFACE   .  ALL
SET         C  A+B
```

- After running, `C`=11 and `D`=121

# Example Function-style UDC

- In `test3.csm`

```
SET    A    1
SET    B    10
SET    C    0
UDPRIM $/test4  first A  second B
SET    D    C^2
```

- In `test4.udc`

```
INTERFACE  first  IN  0
INTERFACE  second IN  0
INTERFACE  sum    OUT 0
SET        C      999
SET        sum    first+second
```

- After running, `C`=0, `D`=0, and `@@sum`=11

# UDCs Shipped with ESP (1)

- `applyTparams factor=1`
  - apply `.tParams` to the Edges and Faces of the Body on the top of the Stack
- `biconvex thick=0`
  - generate a biconvex airfoil
- `boxudc dx=0 dy=0 dz=0 @@vol`
  - similar to the box UDP
- `contains @@contains`
  - determine if either of the two Bodys on the top of the Stack contains the other
- `diamond thick=0`
  - generate a double-diamond airfoil
- `duct diameter=1 length=2 thickness=0.10 camber=0.04`
  - generate a duct

# UDCs Shipped with ESP (2)

- `expressions xx yy zz @@aa @@bb`
  - a test UDC that has no other practical use
- `flapz xflap yflap theta=15 gap=0.01 openEnd=0`
  - cut a (deflected) flap in a Body
- `fuselage xloc zloc width height noselist taillist`
  - generate a fuselage
- `gen_rot xbeg=0 ybeg=0 zbeg=0 xend=1 yend=1 zend=1 rotang=0 @@azimuth @@elevation`
  - general rotation with two fixed points
- `overlaps @@overlaps`
  - determine if the two Bodys on the top of the Stack overlap each other
- `popupz xbx ybax height=1`
  - pop up a part of the configuration

# UDCs Shipped with ESP (3)

- `spoilerz xbox ybox depth=1 thick=0.1 theta=30 overlap=0.002 extend=0.20`
  - pop up a spoiler
- `strut length=2.0 thickness=0.2 height=1.0 sweep=0`
  - generate a strut (between a duct and wing)
- `swap`
  - swaps the two Bodys or Marks on the top of the stack
- `wake mirror=0area=100 aspect=8 taper=0.8 twist=-5 sweep=0 dihedral=0 camber=0.04 wakeLen=3.0 wakeAng=0`
  - generate a wake
- `wing mirror=0 area=100 aspect=8 taper=0.8 twist=-5 sweep=0 dihedral=0 thickness=0.12 sharpte=0 camber=0.04 inboard=0 outboard=1 pctchord=0 angleft=0 angrite=0 spar1=0 spar2=0 nrib=0 @@span`
  - generate a wing

# Calling a UDC

- UDCs are called with a `UDPRIM` statement
- `$primtype` must start with a slash (`/`), dollar-slash (`$/`), or dollar-dollar-slash (`$$/`)
  - if `/`, then the UDC file is in the current working directory
  - if `$/`, then the UDC file is in the same directory as the `.csm` file
  - if `$$/`, then the UDC file is in `ESP_ROOT/udc`
- The `UDPRIM` statement can be preceded by one or more `UDPARG` statements
- name-value pairs are processed in order (with possible over-writing)

# Writing a UDC

- Define the interface
  - input variables (with default values)
  - output variables (with default values)
  - dimensioned variables (which all default to 0)
- Add assertions to ensure valid inputs
- Make sure all “output” variables are assigned values

# Example UDC — swap.udc

```
# make sure that there are at least entities on the Stack
IFTHEN @stack.size LT 2
   THROW  999  # not enough entries on Stack
# if Mark,Mark on top of Stack
ELSEIF @stack[@stack.size-1] EQ 0  AND  @stack[@stack.size] EQ 0
# if Body,Mark on top of Stack
ELSEIF @stack[@stack.size] EQ 0
   STORE   .
   STORE   tempSwap 99
   MARK
   RESTORE tempSwap 99
# if Mark,Body on top of Stack
ELSEIF @stack[@stack.size-1] EQ 0
   STORE   tempSwap 99
   STORE   .
   RESTORE tempSwap 99
   MARK
# if Body,Body on top of Stack
ELSE
   STORE   tempSwap 98
   STORE   tempSwap 99
   RESTORE tempSwap 98
   RESTORE tempSwap 99
ENDIF
```

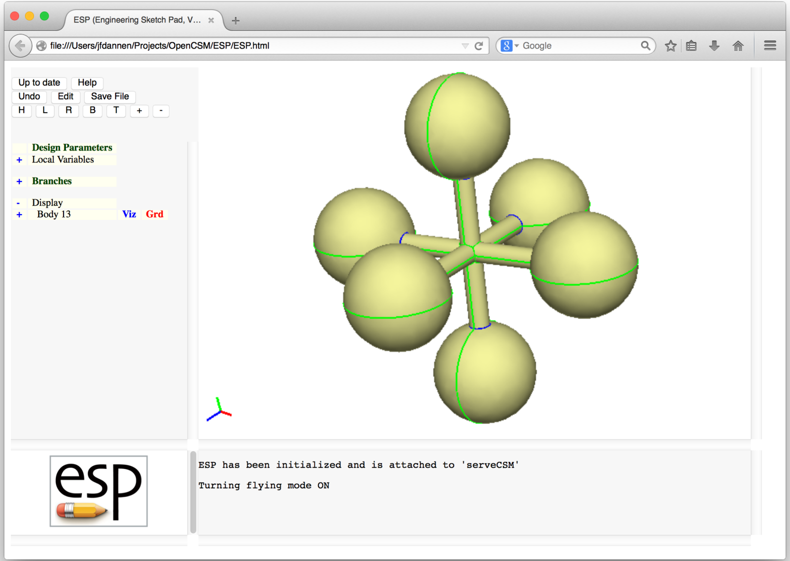
# Example UDC — `dumbbell.udc`

```
# dumbbell

INTERFACE Lbar     in  0    # length of bar
INTERFACE Dbar     in  0    # diameter of bar
INTERFACE Dball    in  0    # diameter of balls
INTERFACE vol      out 0    # volume

ASSERT    ifpos(Lbar,1,0)   1
ASSERT    ifpos(Dbar,1,0)   1
ASSERT    ifpos(Dball,1,0)  1
SET       Lhalf    "Lbar / 2"

CYLINDER  -Lhalf  0  0  +Lhalf  0  0  Dbar
SPHERE    -Lhalf  0  0   Dball
UNION
SPHERE    +Lhalf  0  0   Dball
UNION

SET       vol    @volume

END
```

# Example UDC — `jack.csm`

```
# jack

UDPARG  $/dumbbell  Lbar   5.0
UDPARG  $/dumbbell  Dball  1.0
UDPRIM  $/dumbbell  Dbar   0.2
SET     foo @@vol
STORE   dumbbell 0 1

RESTORE dumbbell
ROTATEY 90  0  0
UNION

RESTORE dumbbell
ROTATEZ 90  0  0
UNION

# show that vol was a local variable in .udc
ASSERT  ifnan(vol,1,0)  1
END
```

# Example UDC — Jack



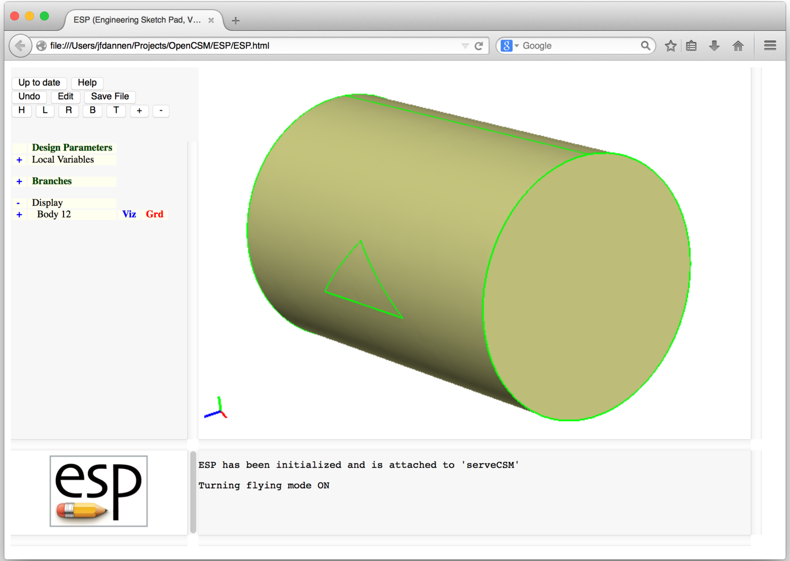
# Example UDC — cutter.udc

```
# cutter

INTERFACE xx    in  0
INTERFACE yy    in  0
INTERFACE zbeg  in  0
INTERFACE zend  in  0

ASSERT    ifpos(xx.size-2,1,0)  1
ASSERT    ifzero(xx.size-yy.size,1,0)  1

SKBEG        xx[1]    yy[1]    zbeg
   PATBEG i xx.size-1
      LINSEG  xx[i+1]  yy[i+1]  zbeg
   PATEND
   LINSEG     xx[1]    yy[1]    zbeg
SKEND  1

EXTRUDE   0  0  zend-zbeg

END
```

# Example UDC — scribeCyl.csm

```
# scribeCyl

DIMENSION xpoints   1  3
DIMENSION ypoints   1  3

SET       xpoints  "-1.;  1.;  .0;"
SET       ypoints  "-.5; -.5; +.5;"

CYLINDER  -3  0  0  +3  0  0  2
ROTATEX   90  0  0

UDPARG    $/cutter  xx    xpoints
UDPARG    $/cutter  yy    ypoints
UDPARG    $/cutter  zbeg  0
UDPRIM    $/cutter  zend  3
SUBTRACT

END
```

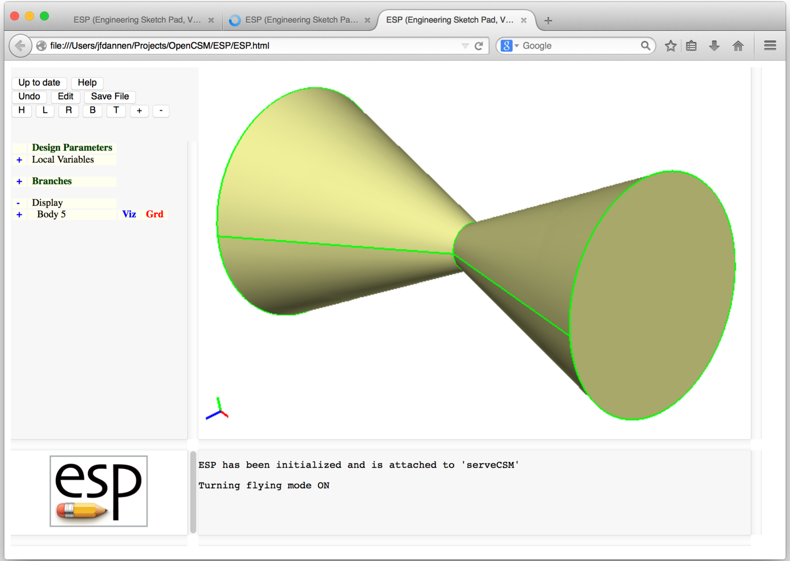
# Example UDC — Scribed Cylinder



# Homework Exercises

- Reflected cone
- Files in `$ESP_ROOT/training/ESP/data/session06` will get you started

# Reflected Cone (1)



# Reflected Cone (2)

- Write `mirrorDup.udc` to
  - store a copy of the Body on the top of the Stack
  - mirror the Body across a plane whose normal vector and distance from the origin are given
  - union the original and mirrored Bodys
- Apply `mirrorDup.udc` to a cone
  - cone base at $(5, 0, 0)$
  - cone vertex at $(0, 0, 0)$
  - cone diameter is 4
  - reflection across a plane at $x = 1$