Engineering Sketch Pad

Writing a UDP or UDF at Revision 1.21

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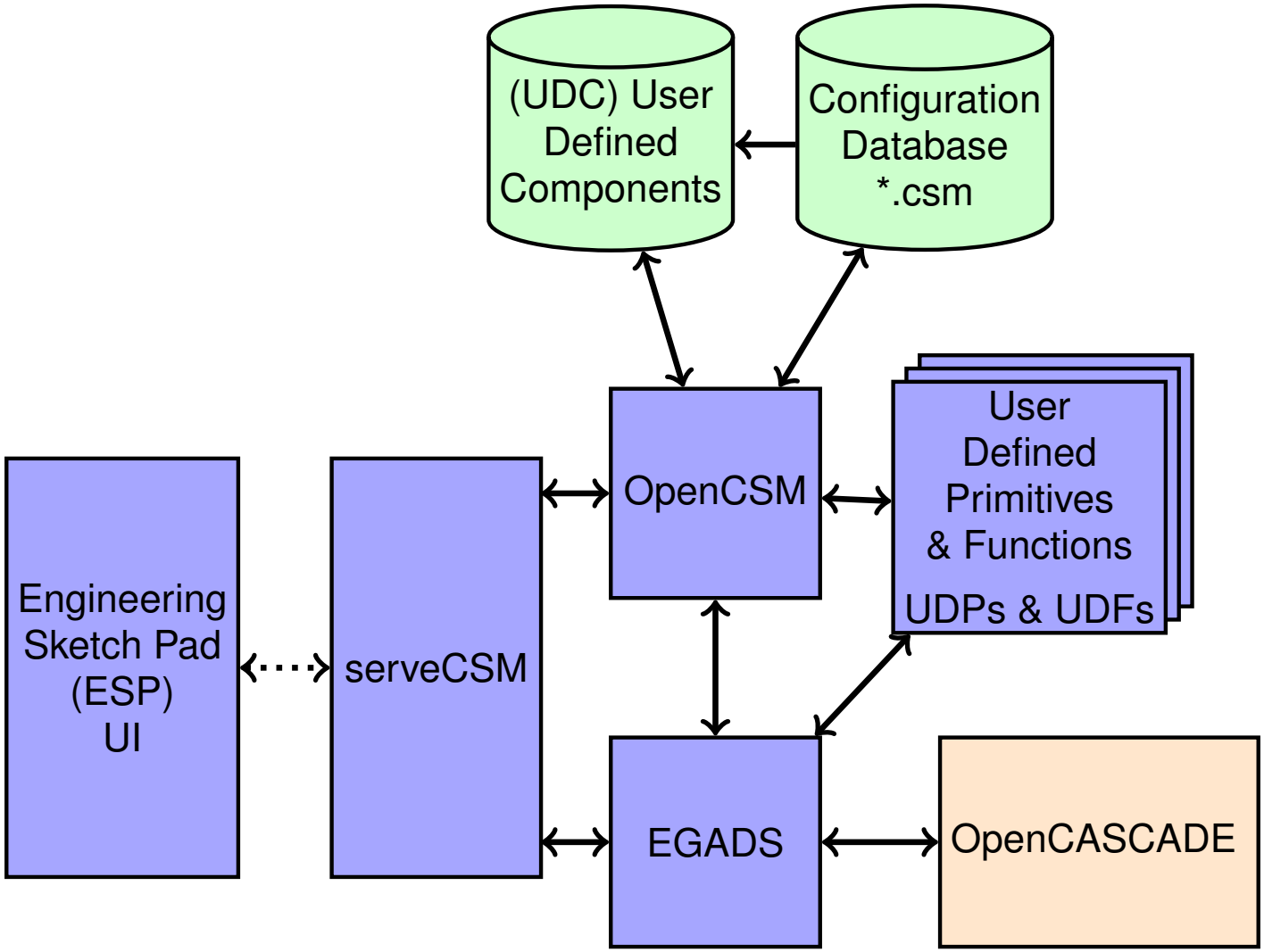
Overview

- Objects
- The API
- Steps to writing a UDP/UDF
- Tire UDP
  - structure of code
  - code walk-through
  - stand-alone execution
  - execution as a UDP

ESP's Geometry Subsystem Architecture



EGADS Overview

The Engineering Geometry Aircraft Design System (EGADS) is an open-source geometry interface to OpenCASCADE

- reduces OpenCASCADE's 17,000 methods to about 70 calls
  - Supports C, C++ & FORTRAN
- provides *bottom-up* and/or *top-down* construction
- geometric primitives
  - curve: line, circle, ellipse, parabola, hyperbola, offset, bezier, BSpline (including NURBS)
  - surface: plane, spherical, conical, cylindrical, toroidal, revolution, extrusion, offset, bezier, BSpline (including NURBS)
- solid creation and Boolean operations (*top-down*)
- provides persistent user-defined attributes on topological entities
- adjustable tessellator (*vs* a surface mesher) with support for finite-differencing in the calculation of parametric sensitivities

EGADS Overview

- System Support
  - 64-bit pointers (only)
  - Mac OSX with **clang**, **ifort** and/or **gfortran**
  - LINUX with **gcc**, **ifort** and/or **gfortran**
  - Windows with Microsoft Visual Studio C++ and **ifort**
  - No globals (but not thread-safe due to OpenCASCADE)
  - Various levels of output (0-none, through 3-debug)
  - Written in C and C++
- EGADS Objects (**ego**s)
  - Pointer to a C structure – allows for an *Object-based* API
  - Treated as "blind" pointers (i.e., not meant to be dereferenced)
  - **ego**s are INTEGER*8 variables in FORTRAN

EGADS Objects – egos

- Context – Holds the *globals*
- Transform
- Tessellation
- Nil (allocated but not assigned) – internal
- Empty – internal
- Reference – internal
- Geometry
  - pcurve, curve, surface
- Topology
  - Node, Edge, Loop, Face, Shell, Body, Model
- *Effective Topology*
  - EEdge, ELoop, EFace, EShell, EBody

See `$ESP_ROOT/include/egadsTypes.h` for a list of `defines`

EGADS Objects – Attribution

- Attributes – metadata consisting of name/value pairs
  - Unique name – no spaces
  - A single type: Integer, Real, String, CSys
  - A length (not for strings)
- Objects
  - Any (non-internal) Object can have multiple Attributes
  - Only Attributes on Topological Objects are copied and are persistent (saved)
- SBO & Intersection Functions
  - Unmodified Topological Objects maintain their Attributes
  - Face Attributes are carried through to the resultant fragments
  - All other Attributes are lost
- CSys Attributes are modified through Transformations

EGADS Geometry Objects

- surface
  - 3D surfaces of 2 parameters $[u, v]$
  - Types: Plane, Spherical, Cylindrical, Revolution, Toroidal, Trimmed, Bezier, BSpline, Offset, Conical, Extrusion
  - All types abstracted to $[x, y, z] = f(u, v)$
- pcurve – Parameter Space Curves
  - 2D curves in the Parametric space $[u, v]$ of a surface
  - Types: Line, Circle, Ellipse, Parabola, Hyperbola, Trimmed, Bezier, BSpline, Offset
  - All types abstracted to $[u, v] = g(t)$
- curve
  - 3D curve – single running parameter (t)
  - Same types as pcurve but abstracted to $[x, y, z] = g(t)$

Boundary Representation – BRep

Top Down ↓ ↑ *Bottom Up*

Topological Entity	Geometric Entity	Function
Model		
Body	Solid, Sheet, Wire	
Shell		
Face	**surface**	$(x, y, z) = \mathbf{f}(u, v)$
Loop		
Edge	**curve**	$(x, y, z) = \mathbf{g}(t)$
Node	**point**	

- Nodes that bound Edges may not be on underlying curves
- Edges in the Loops that trim the Face may not sit on the surface hence the use of pcurves

EGADS Topology Objects

- Node
  - Contains $[x, y, z]$
  - Types: none
- Edge
  - Has a 3D curve (if not Degenerate)
  - Has a t range (t_{min} to t_{max}, where $t_{min} < t_{max}$)
    Note: The positive orientation is going from t_{min} to t_{max}
  - Has a Node for t_{min} and for t_{max} – can be the same Node
  - Types:
    - OneNode – periodic
    - TwoNode – normal
    - Degenerate – single Node, t range used for the associated pcurve

EGADS Topology Objects

- Loop – without a reference surface
  1. Free standing connected Edges that can be used in a non-manifold setting (for example in WireBodies)
  2. A list of connected Edges associated with a Plane (which does not require pcurves)
     - An ordered collection of Edge objects with associated senses that define the connected *Wire/Contour/Loop*
     - Segregates space by maintaining material to the left of the running Loop (or traversed right-handed pointing out of the intended volume)
     - No Edges should be Degenerate
     - Types: Open or Closed (comes back on itself)

EGADS Topology Objects

- Loop – with a reference surface
  1. Collections of Edges (like without a surface) followed by a corresponding collection of pcurves that define the $[u, v]$ trimming on the surface
     - Degenerate Edges are required when the $[u, v]$ mapping collapses like at the apex of a cone (note that the pcurve is needed to be fully defined using the Edge's t range)
     - An Edge may be found in a Loop twice (with opposite senses) and with different pcurves. For example a closed cylindrical surface at the seam – one pcurve would represent the beginning of the period where the other is the end of the periodic range.
     - Types: Open or Closed (comes back on itself)

EGADS Topology Objects

- Face
  - A surface bounded by one or more Loops with associated senses
  - Only one outer Loop (sense = 1) and any number of inner Loops (sense = -1). Note that under very rare conditions a Loop may be found in more than 1 Face – in this case the one marked with sense = +/- 2 must be used in a reverse manner.
  - All Loops must be Closed
  - Loop(s) must not contain reference geometry for Planar surfaces
  - If the surface is not a Plane then the Loop's reference Object must match that of the Face
  - Type is the orientation of the Face based on surface's $U \otimes V$:
    - SFORWARD or SREVERSE when the orientations are opposed

    Note that this is coupled with the Loop's orientation (i.e. an outer Loop traverses the Face in a right-handed manner defining the outward direction)

EGADS Topology Objects

- Shell
  - A collection of one or more connected Faces that if Closed segregates regions of 3-Space
  - All Faces must be properly oriented
  - Non-manifold Shells can have more than 2 Faces sharing an Edge
  - Types: Open (including non-manifold) or Closed
- SolidBody
  - A manifold collection of one or more Closed Shells with associated senses
  - There may be only one outer Shell (sense = 1) and any number of inner Shells (sense = -1)
  - Edges (except Degenerate) are found exactly twice (sense = ± 1)

EGADS Topology Objects

- Body – including SolidBody
  - Container used to aggregate Topology
  - Connected to support non-manifold collections at the Model level
  - *Owns* all the Objects contained within
  - Types:
    - A WireBody contains a single Loop
    - A FaceBody contains a single Face – IGES import
    - A SheetBody contains a single Shell which can be either non-manifold or manifold (though usually a manifold Body of this type is promoted to a SolidBody)
- Model
  - A collection of Bodies – becomes the *Owner* of contained Objects
  - Returned by SBO & Sew Functions
  - Read and Written by EGADS

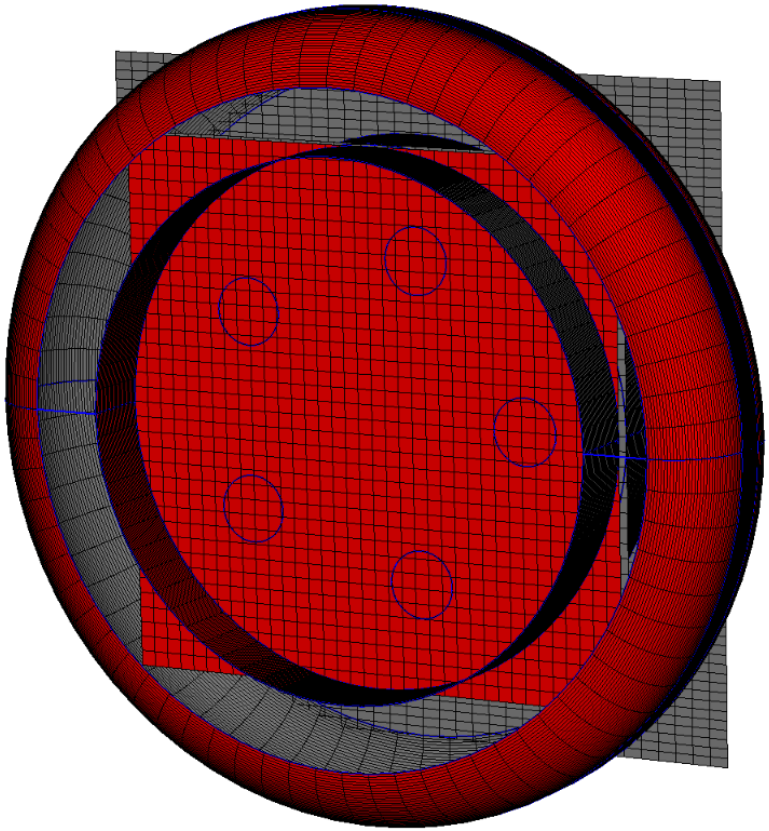
EGADS Topology Objects

- Helper Functions
  - makeLoop
    - Connects unrelated (via Nodes) Edges from a list
    - Uses input tolerance to match entities
    - Result may be multiple Loops
  - makeFace
    - From Closed Planar Loop
    - From surface with limits
  - sewFaces
    - Connects Faces with unrelated Topology
    - Uses input tolerance to match entities
    - Returns a Model – may have multiple Bodies
    - Can connect in a nonmanifold manner

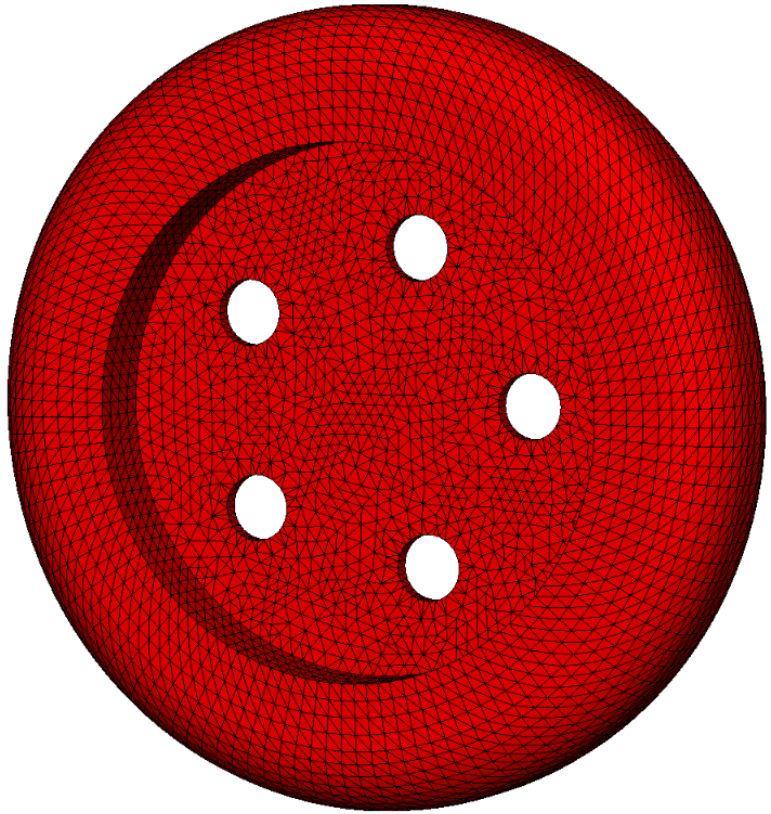
EGADS Tessellation Objects

- Geometry
  - Unconnected discretization of a range of the Object
    - Polyline for curves at constant t increments
    - Regular grid for surfaces at constant increments (isoclines)
- Body Topology
  - Connected and trimmed tessellation including:
    - Polyline for Edges
    - Triangulation for Faces
    - Optional Quadrilateral Patching for Faces
  - Ownership and Geometric Parameters for Vertices
  - Adjustable parameters for side length and curvature (x2)
  - Watertight
  - Exposed per Face/Edge or Global indexing

EGADS Tessellation Objects



from $ESP_ROOT/bin/vGeom



from $ESP_ROOT/bin/vTess

The EGADS API

- Function names begin with "EG_" – or –
  "IG_" for the FORTRAN bindings
- Functions almost always return an integer *error code*
- *Object-based* – procedural, usually with the first argument an **ego**
- Signatures usually have the inputs first, then output argument(s)
- Some outputs may be pointers to lists of *things*
  `EG_free` needs to be used when marked as "freeable"
- **ego**s have:
  - *Owner*: Context, Body, or Model
  - Reference Objects (objects they depend upon)
- When a Body is made, all included Objects are copied – not referenced

See `$ESP_ROOT/doc/EGADS/egads.pdf` for a detailed description of all of the functions.
See `$ESP_ROOT/include/egads.h` for a complete listing of the functions.
See `$ESP_ROOT/include/egadsErrors.h` for a list of the return code `define`s.

The EGADS API – *Ownership*

- Deleting Objects
  - Use the function "EG_deleteObject" (or "ig_deleteobject")
  - The Object must be reference *free* – i.e. not used by another
    - Delete in the opposite order of creation
    - If in a Body, delete the Body (unless the Body is in a Model)
  - "EG_deleteObject" on a Context does not delete the Context
    - Deletes all Objects in the Context that are not in a Body
    - Use "EG_close" to delete all objects in a Context (and the Context)
- Another Rule
  - A Body can only be in one Model
    - Copy the Body of interest, then include the copy in the new Model

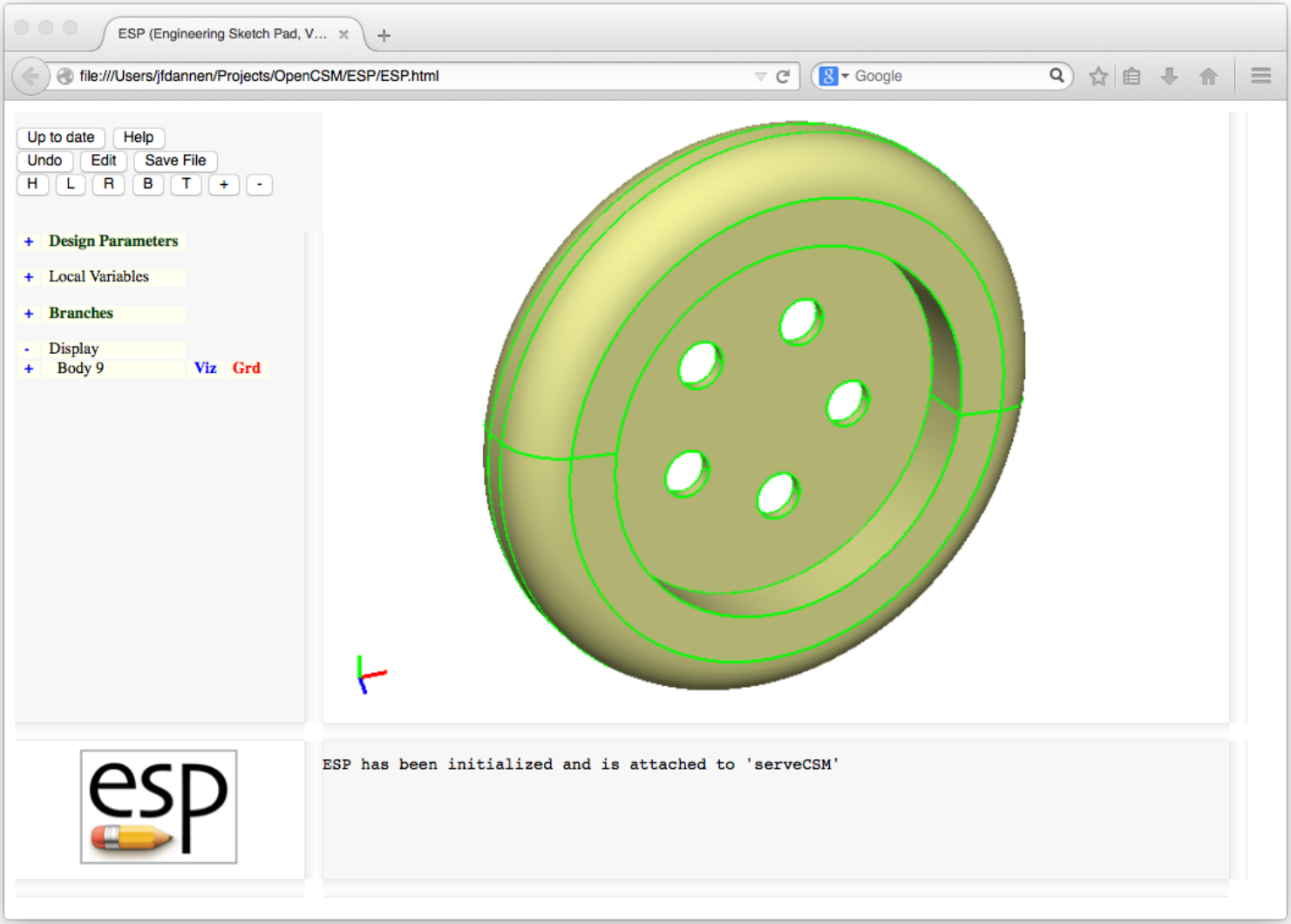
Steps to Writing a UDP/UDF

- **Draw a picture**
- Define input and output parameters
  - name (case-insensitive)
  - type (`ATTRSTRING`, `ATTRINT`, `-ATTRINT`, `ATTRREAL`, `-ATTRREAL`, `ATTRREALSEN`)
  - size
  - default value(s)
- Build the Body (stand-alone)
  - bottom-up
  - top-down
  - combination
- Test stand-alone with `vTess`
- Write a `.csm` file
- Test the UDP/UDF

UDP/UDF Defines & Entry Points

```
#define NUMUDPARGS num          /* number of inputs and outputs */
#define NUMUDPINPUTBODYS num    /* number of input bodies - UDF only */


int
udpExecute(ego object,          /* (in)  EGADS Context -- UDP
                                         EGADS Model   -- UDF */
           ego *ebody,          /* (out) Body pointer */
           int *nMesh,          /* (out) number of associated meshes */
           char *string[])      /* (out) error message */


int
udpSensitivity(ego ebody,       /* (in)  Body pointer */
               int npnt,        /* (in)  number of points */
               int entType,     /* (in)  OCSM entity type */
               int entIndex,    /* (in)  OCSM entity index (bias-1) */
               double uvs[],    /* (in)  parametric coords for eval */
               double vels[])   /* (out) velocities */
```

Tire UDP: Finished Product

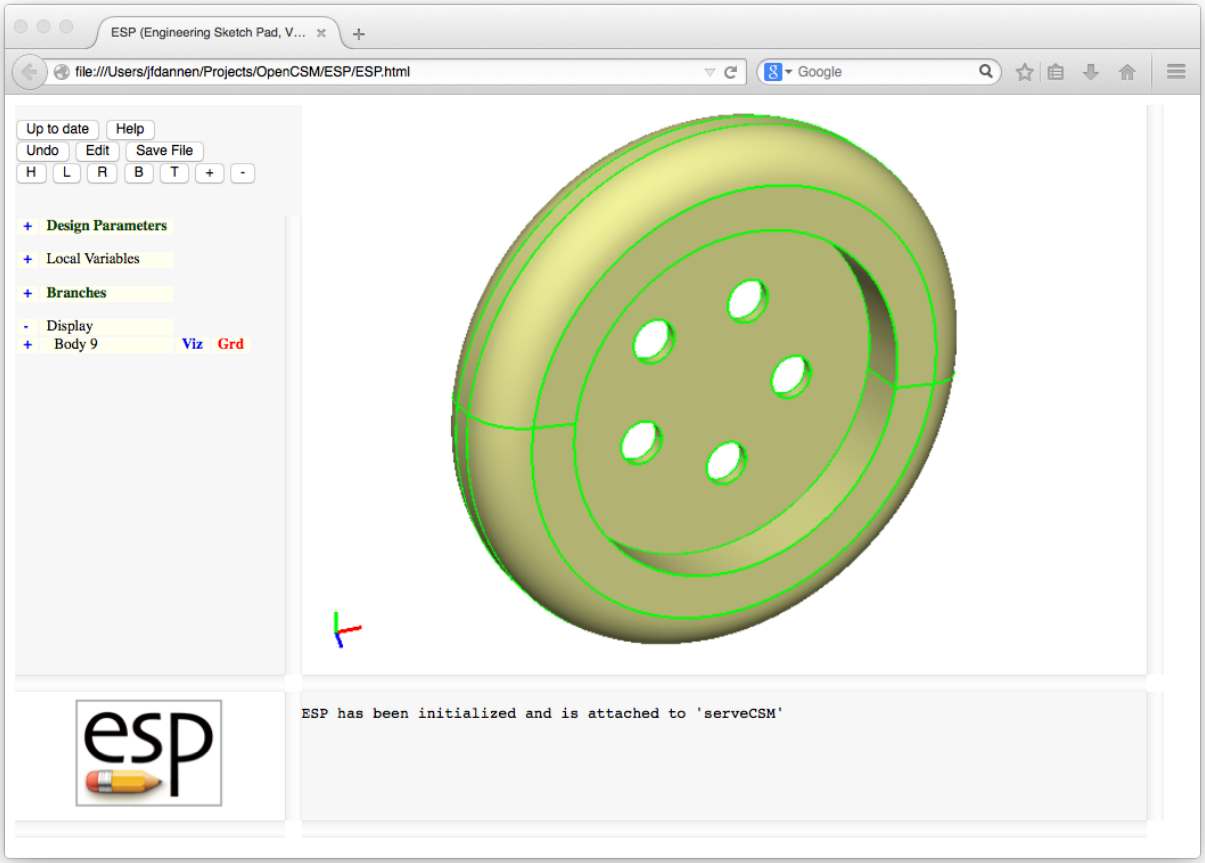


Tire UDP: Code Walk-through

- cd to `$ESP_ROOT/doc/UDP_UDF/data`
- Source file is `udpTire.c`
- To build under LINUX/OSX
  - `make`
- To build under Windows
  - `nmake -f NMakefile`
- To run stand-alone
  - `tire`
  - `$ESP_ROOT/bin/vTess tire.egads`
    - open browser on `$ESP_ROOT/bin/wv.html`
- To run in `ESP`
  - `$ESP_ROOT/bin/serveCSM tire.csm`

Tire UDP: Inputs and Outputs

Example of both *Bottom Up* and *Top Down* Construction



Name	Description
`width`	width
`minrad`	minimum radius
`maxrad`	maximum radius
`filletrad`	fillet radius at outside
`platethick`	wheel thickness
`bolts`	number of bolt holes
`patternrad`	radius of bolt circle
`boltrad`	radius of bolt holes
`volume`	volume (output)

Programming Example – Preamble

```
#define NUMUDPARGS 9
#include "udpUtilities.h"

/* shorthands for accessing argument values and velocities */
#ifdef UDP
   #define WIDTH(IUDP)       ((double *) (udps[IUDP].arg[0].val))[0]
   #define MINRAD(IUDP)      ((double *) (udps[IUDP].arg[1].val))[0]
   #define MAXRAD(IUDP)      ((double *) (udps[IUDP].arg[2].val))[0]
   #define FILLETRAD(IUDP)   ((double *) (udps[IUDP].arg[3].val))[0]
   #define PLATETHICK(IUDP)  ((double *) (udps[IUDP].arg[4].val))[0]
   #define PATTERN(IUDP)     ((double *) (udps[IUDP].arg[5].val))[0]
   #define BOLTS(IUDP)       ((double *) (udps[IUDP].arg[6].val))[0]
   #define BOLTRAD(IUDP)     ((double *) (udps[IUDP].arg[7].val))[0]
   #define VOLUME(IUDP)      ((double *) (udps[IUDP].arg[8].val))[0]
   /* data about possible arguments */
   static char  *argNames[NUMUDPARGS] = {"width",  "minrad", "maxrad", "fillrad", "platethick", "p
   static int    argTypes[NUMUDPARGS] = {ATTRREAL, ATTRREAL, ATTRREAL, ATTRREAL,  ATTRREAL,     AT
   static int    argIdefs[NUMUDPARGS] = {0,        0,        0,        0,         0,            0,
   static double argDdefs[NUMUDPARGS] = {0.,       0.,       0.,       0.,        0.,           0.

   #include "udpUtilities.c"
#else
   #define WIDTH(IUDP)       5.0
   #define MINRAD(IUDP)      8.0
   #define MAXRAD(IUDP)     12.0
   #define FILLETRAD(IUDP)   2.0
   #define PLATETHICK(IUDP)  0.5
   #define PATTERN(IUDP)     4.0
   #define BOLTS(IUDP)       5.0
   #define BOLTRAD(IUDP)     1.0
   #define VOLUME(IUDP)      myVolume
 #endif
```

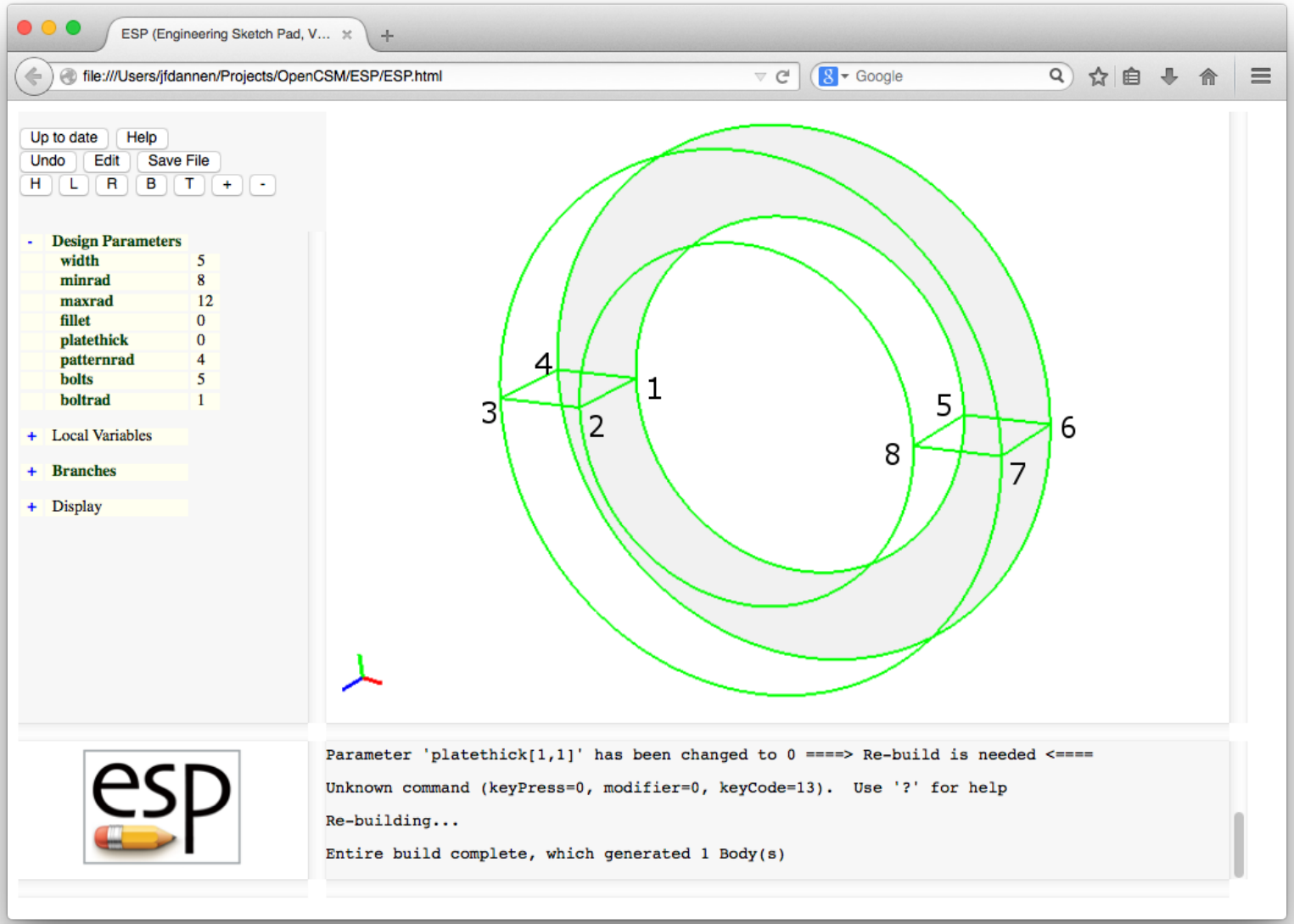
Programming Example – Stand-alone tester

```
int main(int  argc, char *argv[])
{
    int  status, nMesh;
    char *string;
    ego  context, ebody, emodel;

    status = EG_open(&context);
    printf("EG_open -> status=%d\n", status);
    if (status < 0) exit(EXIT_FAILURE);

    /* call the execute routine */
    status = udpExecute(context, &ebody, &nMesh, &string);
    printf("udpExecute -> status=%d\n", status);
    if (status < 0) exit(EXIT_FAILURE);
    EG_free(string);

    /* make and dump the model */
    status = EG_makeTopology(context, NULL, MODEL, 0, NULL,
                             1, &ebody, NULL, &emodel);
    printf("EG_makeTopology -> status=%d\n", status);
    if (status < 0) exit(EXIT_FAILURE);
    status = EG_saveModel(emodel, "tire.egads");
    printf("EG_saveModel -> status=%d\n", status);
    if (status < 0) exit(EXIT_FAILURE);

    /* cleanup */
    status = EG_deleteObject(emodel);
    printf("EG_close -> status=%d\n", status);
    status = EG_close(context);
    printf("EG_close -> status=%d\n", status);
    return EXIT_SUCCESS;
}
```

Tire UDP: Strategy (1)

- Draw a *sketch*, with Nodes, Edges, and Faces numbered
- Define the inputs and outputs
  - check size (scalar vs. multi-valued)
  - check validity
- Build basic tire from bottom up
  - 8 Nodes
  - 8 Edges (linear) at the equator
    - generate a linear curve
    - inverse evaluate at Nodes to get t_{beg} and t_{end}
    - make the Edge
  - 8 Edges (circular)
    - generate the circular curve
    - inverse evaluate at Nodes to get t_{beg} and t_{end}
    - ensure $t_{\text{end}} > t_{\text{beg}}$ by increasing t_{beg} by 2π if needed
    - make the Edge
  - ...

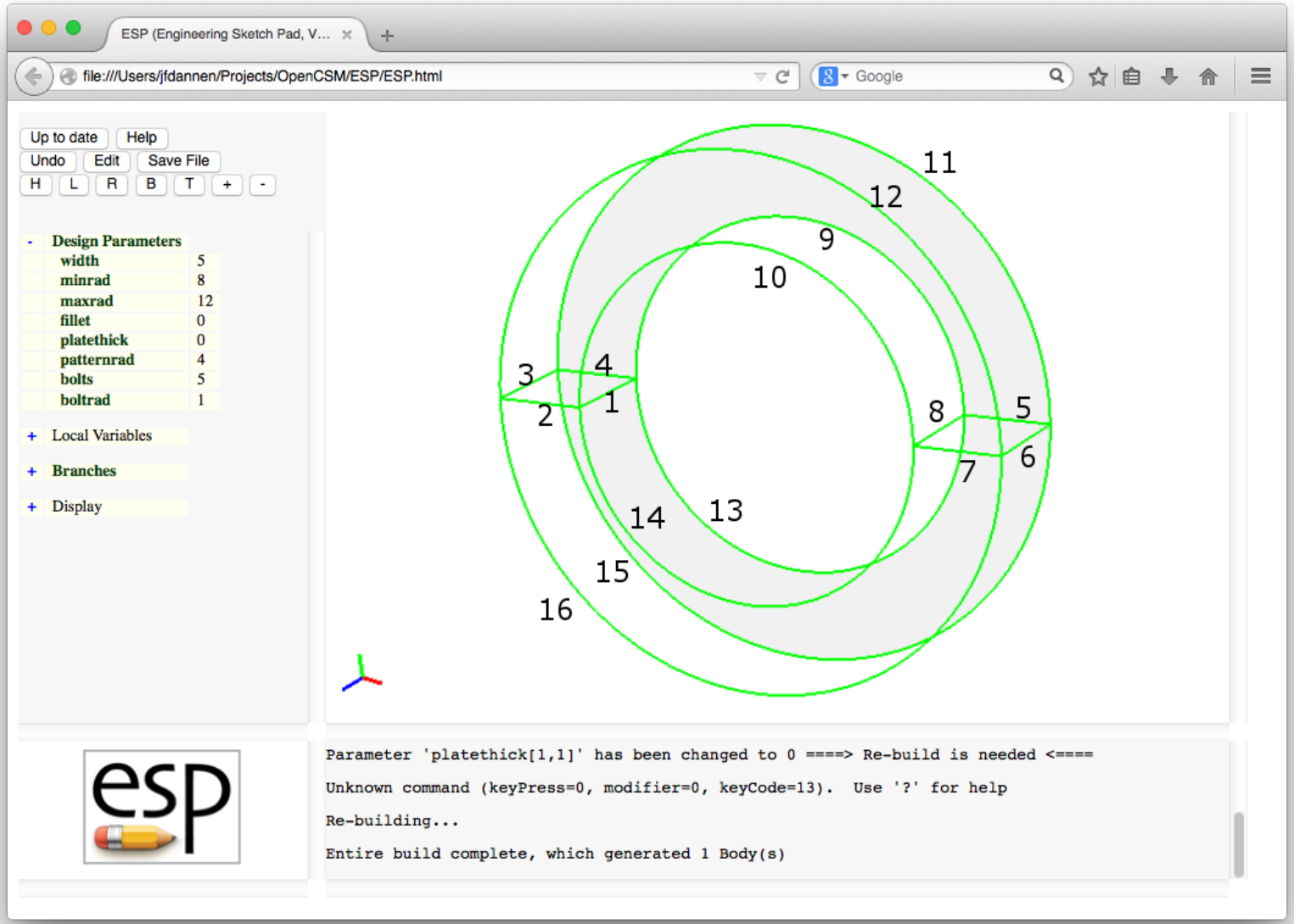
Tire UDP: Node Numbers



Programming Example – Nodes

```
/* Node locations */

node1[0] = -MINRAD(0);  node1[1] = 0;  node1[2] = -WIDTH(0) / 2;
node2[0] = -MINRAD(0);  node2[1] = 0;  node2[2] =  WIDTH(0) / 2;
node3[0] = -MAXRAD(0);  node3[1] = 0;  node3[2] =  WIDTH(0) / 2;
node4[0] = -MAXRAD(0);  node4[1] = 0;  node4[2] = -WIDTH(0) / 2;
node5[0] =  MINRAD(0);  node5[1] = 0;  node5[2] = -WIDTH(0) / 2;
node6[0] =  MAXRAD(0);  node6[1] = 0;  node6[2] = -WIDTH(0) / 2;
node7[0] =  MAXRAD(0);  node7[1] = 0;  node7[2] =  WIDTH(0) / 2;
node8[0] =  MINRAD(0);  node8[1] = 0;  node8[2] =  WIDTH(0) / 2;

/* make the Nodes */

status = EG_makeTopology(context, NULL, NODE, 0, node1, 0, NULL, NULL, &enodes[0]);
if (status != EGADS_SUCCESS) goto cleanup;
status = EG_makeTopology(context, NULL, NODE, 0, node2, 0, NULL, NULL, &enodes[1]);
if (status != EGADS_SUCCESS) goto cleanup;
status = EG_makeTopology(context, NULL, NODE, 0, node3, 0, NULL, NULL, &enodes[2]);
if (status != EGADS_SUCCESS) goto cleanup;
status = EG_makeTopology(context, NULL, NODE, 0, node4, 0, NULL, NULL, &enodes[3]);
if (status != EGADS_SUCCESS) goto cleanup;
status = EG_makeTopology(context, NULL, NODE, 0, node5, 0, NULL, NULL, &enodes[4]);
if (status != EGADS_SUCCESS) goto cleanup;
status = EG_makeTopology(context, NULL, NODE, 0, node6, 0, NULL, NULL, &enodes[5]);
if (status != EGADS_SUCCESS) goto cleanup;
status = EG_makeTopology(context, NULL, NODE, 0, node7, 0, NULL, NULL, &enodes[6]);
if (status != EGADS_SUCCESS) goto cleanup;
status = EG_makeTopology(context, NULL, NODE, 0, node8, 0, NULL, NULL, &enodes[7]);
if (status != EGADS\_SUCCESS) goto cleanup;
```

Edge Numbers for Tire UDP



Programming Example – Edges (1)

```
/* make (linear) Edge 1 */

data[0] = node1[0];
data[1] = node1[1];
data[2] = node1[2];
data[3] = node2[0] - node1[0];
data[4] = node2[1] - node1[1];
data[5] = node2[2] - node1[2];
status  = EG_makeGeometry(context, CURVE, LINE, NULL, NULL, data, &ecurve[0]);
if (status != EGADS_SUCCESS) goto cleanup;

status = EG_invEvaluate(ecurve[0], node1, &trange[0], data);
if (status != EGADS_SUCCESS) goto cleanup;
status = EG_invEvaluate(ecurve[0], node2, &trange[1], data);
if (status != EGADS_SUCCESS) goto cleanup;

elist[0] = enodes[0];
elist[1] = enodes[1];
status   = EG_makeTopology(context, ecurve[0], EDGE, TWONODE, trange, 2, elist, NULL,
                           &eedges[0]);
if (status != EGADS_SUCCESS) goto cleanup;
```

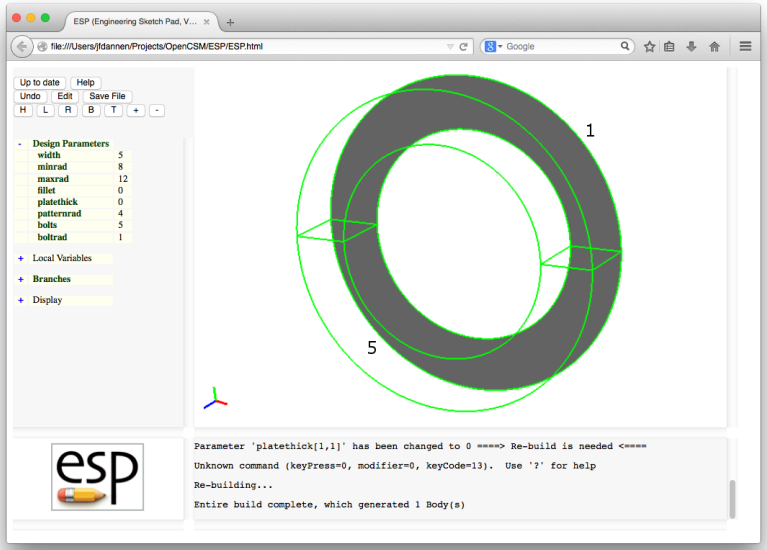
Programming Example – Edges (2)

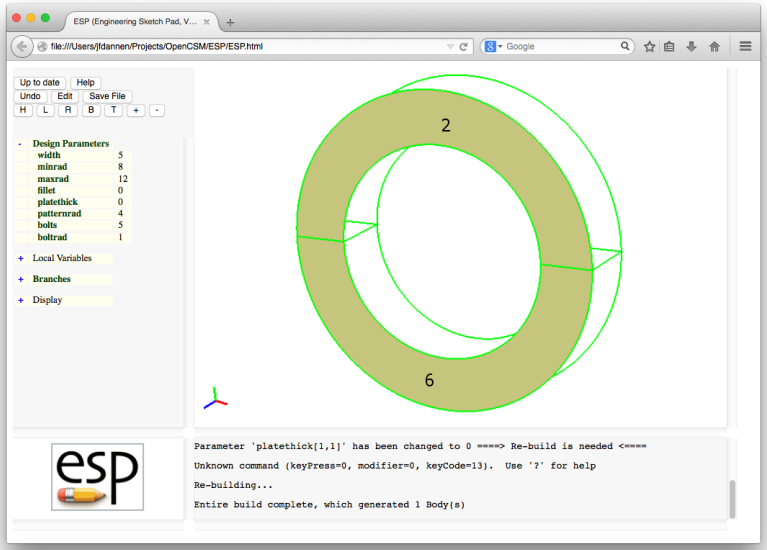
```
/* data used in creating the arcs */

axis1[0] = 1;   axis1[1] = 0;   axis1[2] = 0;
axis2[0] = 0;   axis2[1] = 1;   axis2[2] = 0;
axis3[0] = 0;   axis3[1] = 0;   axis3[2] = 1;
cent1[0] = 0;   cent1[1] = 0;   cent1[2] = -WIDTH(0) / 2;
cent2[0] = 0;   cent2[1] = 0;   cent2[2] =  WIDTH(0) / 2;

/* make (circular) Edge 9 */

data[0] = cent1[0];   data[1] = cent1[1];   data[2] = cent1[2];
data[3] = axis1[0];   data[4] = axis1[1];   data[5] = axis1[2];
data[6] = axis2[0];   data[7] = axis2[1];   data[8] = axis2[2];   data[9] = MINRAD(0);

status = EG_makeGeometry(context, CURVE, CIRCLE, NULL, NULL, data, &ecurve[8]);
if (status != EGADS_SUCCESS) goto cleanup;


status = EG_invEvaluate(ecurve[8], node5, &trange[0], data);
if (status != EGADS_SUCCESS) goto cleanup;

status = EG_invEvaluate(ecurve[8], node1, &trange[1], data);
if (status != EGADS_SUCCESS) goto cleanup;
if (trange[0] > trange[1]) trange[1] += TWOPI;   /* ensure trange[1] > trange[0] */

elist[0] = enodes[4];
elist[1] = enodes[0];
status   = EG_makeTopology(context, ecurve[8], EDGE, TWONODE, trange, 2, elist, NULL,
                           &eedges[8]);
if (status != EGADS_SUCCESS) goto cleanup;
```

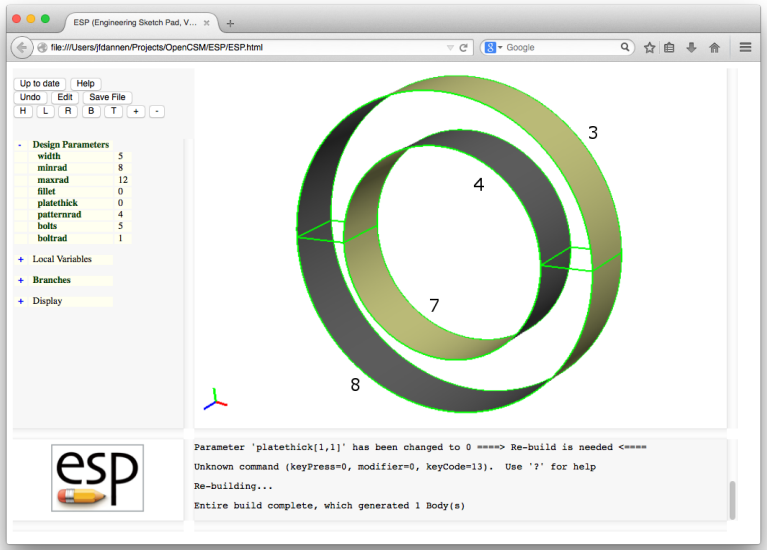
Tire UDP: Strategy (2)

- Continue bottom up build
  - 4 Faces (planar)
    - make a Loop of 4 Edges
    - make the (planar) Face
  - 4 Faces (cylindrical)
    - make cylindrical surface
    - make a PCurve for each Edge that bounds Face
    - make a Loop of 4 Edges and 4 PCurves
    - make the (cylindrical) Face
  - 1 Shell that combines the 8 Faces
  - 1 Solid Body from the Shell

Tire UDP: Face Numbers







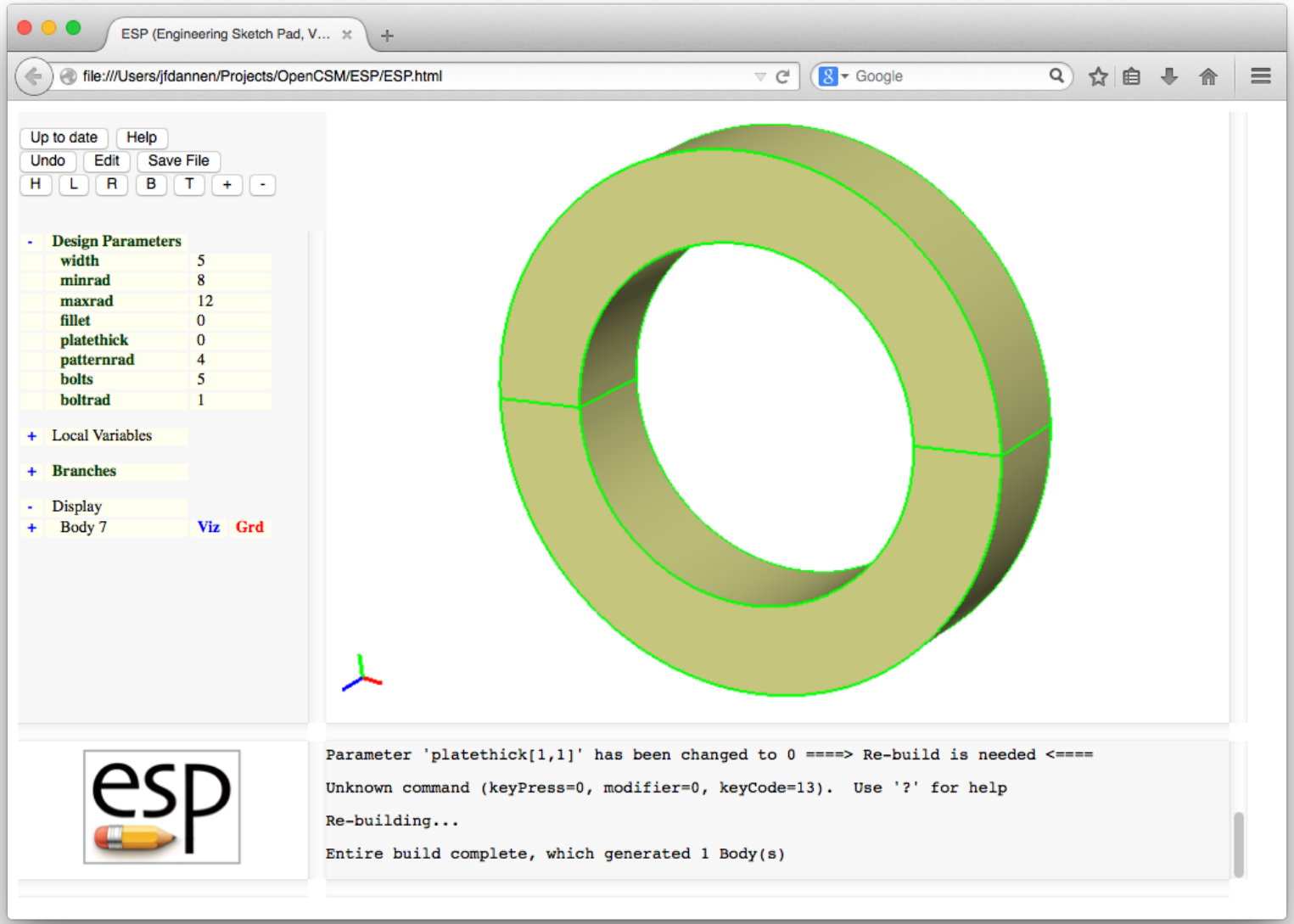
Programming Example – Faces (1)

```
/* make the outer cylindrical surface */

data[0] = cent1[0];   data[1]  = cent1[1];   data[2]  = cent1[2];
data[3] = axis1[0];   data[4]  = axis1[1];   data[5]  = axis1[2];
data[6] = axis2[0];   data[7]  = axis2[1];   data[8]  = axis2[2];
data[9] = axis3[0];   data[10] = axis3[1];   data[11] = axis3[2];   data[12] = MAXRAD(0);
status  = EG_makeGeometry(context, SURFACE, CYLINDRICAL, NULL, NULL, data, &esurface[0]);
if (status != EGADS_SUCCESS) goto cleanup;

/* make the inner cylindrical surface */

data[0] = cent1[0];   data[1]  = cent1[1];   data[2]  = cent1[2];
data[3] = axis1[0];   data[4]  = axis1[1];   data[5]  = axis1[2];
data[6] = axis2[0];   data[7]  = axis2[1];   data[8]  = axis2[2];
data[9] = axis3[0];   data[10] = axis3[1];   data[11] = axis3[2];   data[12] = MINRAD(0);
status  = EG_makeGeometry(context, SURFACE, CYLINDRICAL, NULL, NULL, data, &esurface[1]);
if (status != EGADS_SUCCESS) goto cleanup;

/* make (planar) Face 1 */

sense[0] = SFORWARD;   sense[1] = SREVERSE;   sense[2] = SFORWARD;   sense[3] = SFORWARD;
elist[0] = eedges[3];  elist[1] = eedges[8];  elist[2] = eedges[4];  elist[3] = eedges[10];
status   = EG_makeTopology(context, NULL, LOOP, CLOSED, NULL, 4, elist, sense, &eloop);
if (status != EGADS_SUCCESS) goto cleanup;

status = EG_makeFace(eloop, SFORWARD, NULL, &efaces[0]);
if (status != EGADS_SUCCESS) goto cleanup;
```

Programming Example – Faces (2)

```
/* make (cylindrical) Face 3 */

status = EG_otherCurve(esurface[0], ecurve[2], 0, &epcurve[0]);
if (status != EGADS_SUCCESS) goto cleanup;

status = EG_otherCurve(esurface[0], ecurve[10], 0, &epcurve[1]);
if (status != EGADS_SUCCESS) goto cleanup;

status = EG_otherCurve(esurface[0], ecurve[5], 0, &epcurve[2]);
if (status != EGADS_SUCCESS) goto cleanup;

status = EG_otherCurve(esurface[0], ecurve[11], 0, &epcurve[3]);
if (status != EGADS_SUCCESS) goto cleanup;

sense[0] = SFORWARD;   sense[1] = SREVERSE;   sense[2] = SFORWARD;   sense[3] = SFORWARD;
elist[0] = eedges[2];  elist[1] = eedges[10]; elist[2] = eedges[5];  elist[3] = eedges[11];
elist[4] = epcurve[0]; elist[5] = epcurve[1]; elist[6] = epcurve[2]; elist[7] = epcurve[3];
status = EG_makeTopology(context, esurface[0], LOOP, CLOSED, NULL, 4, elist, sense, &eloop);
if (status != EGADS_SUCCESS) goto cleanup;

status = EG_makeTopology(context, esurface[0], FACE, SREVERSE, NULL, 1, &eloop, sense,
                         &efaces[2]);
if (status != EGADS_SUCCESS) goto cleanup;
:
:

 /* make the shell and initial Body */
status = EG_makeTopology(context, NULL, SHELL, CLOSED, NULL, 8, efaces, NULL, &eshell);
if (status != EGADS_SUCCESS) goto cleanup;

status = EG_makeTopology(context, NULL, BODY, SOLIDBODY, NULL, 1, &eshell, NULL, &ebody1);
if (status != EGADS_SUCCESS) goto cleanup;
```

Tire UDP after Bottom-up Build

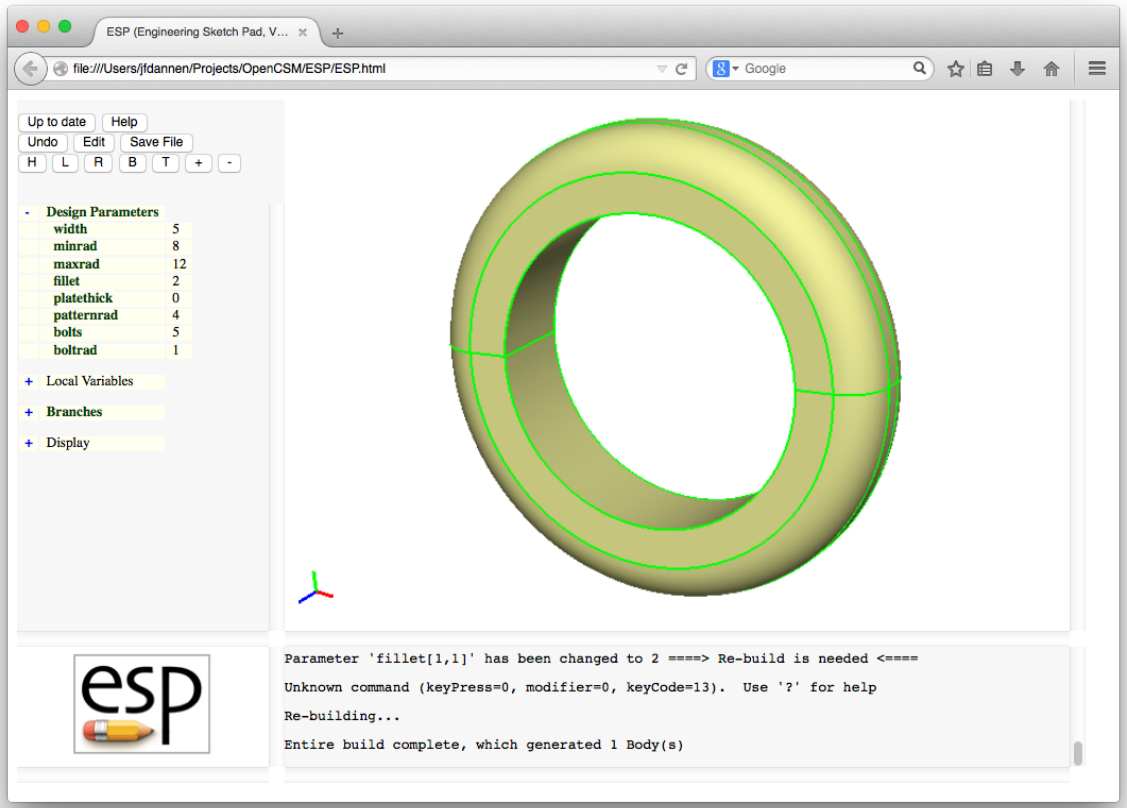


Tire UDP: Strategy (3)

- Modify the Body top-down
  - fillet on outer Edges
    - identify the 4 Edges
  - add wheel
    - cylinder that is “unioned” with the tire
  - add pattern of holes
    - cylinders that are “subtracted” from the wheel
- Compute and return the “output” variables
- Note: this entire UDP could have been written top-down, but was broken up to show the steps needed in bottom-up construction

Programming Example – Rounding the Tire

```
/* add fillets if desired (result is ebody2) */
if (FILLETRAD(0) > 0.0) {
  elist[0] = eedges[10]; elist[1] = eedges[11]; elist[2] = eedges[14]; elist[3] = eedges[15];
  status = EG_filletBody(ebody1, 4, elist, FILLETRAD(0), &ebody2, NULL);
  if (status != EGADS_SUCCESS) goto cleanup;
  status = EG_deleteObject(ebody1);
  if (status != EGADS_SUCCESS) goto cleanup;
} else {
  ebody2 = ebody1;
}
```



Programming Example – The Wheel

```
if (PLATETHICK(0) > 0.0) {
  data[0] = 0;   data[1] = 0;   data[2] =  PLATETHICK(0) / 2;
  data[3] = 0;   data[4] = 0;   data[5] = -PLATETHICK(0) / 2;
  data[6] = (MINRAD(0) + MAXRAD(0)) / 2;
  status = EG_makeSolidBody(context, CYLINDER, data, &ebody3);
  if (status != EGADS_SUCCESS) goto cleanup;

  status = EG_solidBoolean(ebody2, ebody3, FUSION, &emodel);
  if (status != EGADS_SUCCESS) goto cleanup;

  status = EG_deleteObject(ebody2);
  if (status != EGADS_SUCCESS) goto cleanup;
  status = EG_deleteObject(ebody3);
  if (status != EGADS_SUCCESS) goto cleanup;
  status = EG_getTopology(emodel, &eref, &oclass, &mtype, data, &nchild, &echilds, &senses);
  if (status != EGADS_SUCCESS) goto cleanup;

  if (oclass != MODEL || nchild != 1) {
    printf("No model or are returning more than one body ochild = %d, nchild = %d/n",
           oclass, nchild);
    status = -999;
    goto cleanup;
  }

  status = EG_copyObject(echilds[0], NULL, &source);
  if (status != EGADS_SUCCESS) goto cleanup;
  status = EG_deleteObject(emodel);
  if (status != EGADS_SUCCESS) goto cleanup;
```

Programming Example – Bolt Holes

```
/* add bolt holes */
for (i = 0; i < NINT(BOLTS(0)); i++) {
    data[0] = PATTERN(0) * cos(i * (2 * PI / BOLTS(0)));
    data[1] = PATTERN(0) * sin(i * (2 * PI / BOLTS(0)));
    data[2] = PLATETHICK(0) / 2;
    data[3] = PATTERN(0) * cos(i * (2 * PI / BOLTS(0)));
    data[4] = PATTERN(0) * sin(i * (2 * PI / BOLTS(0)));
    data[5] = -PLATETHICK(0) / 2;
    data[6] = BOLTRAD(0);

    status = EG_makeSolidBody(context, CYLINDER, data, &ebody4);
    if (status != EGADS_SUCCESS) goto cleanup;

    status = EG_solidBoolean(source, ebody4, SUBTRACTION, &emodel);
    if (status != EGADS_SUCCESS) goto cleanup;

    status = EG_deleteObject(source);
    if (status != EGADS_SUCCESS) goto cleanup;
    status = EG_deleteObject(ebody4);
    if (status != EGADS_SUCCESS) goto cleanup;

    status = EG_getTopology(emodel, &eref, &oclass, &mtype, data, &nchild, &echilds2,
                &senses);
    if (status != EGADS_SUCCESS) goto cleanup;

    if (oclass != MODEL || nchild != 1) {
       printf("Not a model or are returning more than one body ochild = %d, nchild = %d/n",
            oclass, nchild);
       status = -999;
       goto cleanup;
    }
```

Programming Example – Finish Up

```
            status = EG_copyObject(echilds2[0], NULL, &source);
            if (status != EGADS_SUCCESS) goto cleanup;

            status = EG_deleteObject(emodel);
            if (status != EGADS_SUCCESS) goto cleanup;
        }
        *ebody = source;
    } else {
        *ebody = ebody2;
    }

    /* set the output value(s) */
    status = EG_getMassProperties(*ebody, data);
    if (status != EGADS_SUCCESS) {
        goto cleanup;
    }
    VOLUME(0) = data[0];

    /* remember this model (body) */
#ifdef UDP
    udps[numUdp].ebody = *ebody;
#else
    printf("myVolume = %f\n", myVolume);
#endif

cleanup:
    if (status != EGADS_SUCCESS)
        *string = udpErrorStr(status);

    return status;
}
```

Programming Example