Computational Aircraft Prototype Syntheses

Training Session 7
Meshing for CFD II: Pointwise

ESP v1.18

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Overview

- Pointwise and GeomToMesh.glf
- Pointwise invsicid meshing
  - Suggested parameters
  - Proximity detection
- Pointwise viscous meshing
  - Suggested parameters
  - Viscous boundary layer mesh generation
- Suggested Exercises

Pointwise Overview

- Pointwise: commercial software available for Windows, Linux, and Mac.
- General purpose mesh generator for high quality structured, unstructured, and hybrid meshes
- T-Rex extrusion for generation of boundary layer resolving hybrid meshes.
- Glyph: a TCL/TK based scripting language to automate repetitive tasks.

GeomToMesh.glf Overview

- GeomToMesh.glf: glyph script for creating unstructured volume meshes given a clean EGADS geometry file.
- Vision: script to automatically generate a valid, high quality unstructured mesh given clean, closed geometry.
- Using geometry attributions, the scripts will attempt to create a mesh that matches the user's intent.
- Source Box for increased viscous off body resolution
- Elevate on Export generates higher-order curved meshes (not yet in CAPS)

Pointwise Terminology

- Edge: Line connecting two vertexes

Connector

- A collection of mesh vertexes on an `EDGE`.
- `CAPS` requires only one connector per `EDGE`.
- Pointwise supports multiple connectors per `EDGE`.

Domain

- Surface elements on an `FACE` bounded by a set of connectors
- `CAPS` requires one domain per `FACE`
- Pointwise supports “Quilting” where one domain spans multiple `FACES`

Block

- Volume region bounded by a set of domains

Pointwise AIM Inputs and Outputs

Pointwise AIM Documentation

Transport Geometry EGADS Files

- Use `pyCAPS` to export geometry to EGADS files
- Explore meshing parameters without rebuilding geometry
- DANGER: Decouples geometric and analysis parameters
  - getGeometryVal and getGeometryOutVal are read only

Execute: EGADS/egadsCFD.py

```
# Change to Inviscid CFD view
transport.setGeometryVal("VIEW:Concept"    , 0)
transport.setGeometryVal("VIEW:CFDInviscid", 1)
transport.setGeometryVal("VIEW:CFDViscous" , 0)

# Enable just wing
transport.setGeometryVal("COMP:Wing"    , 1)
transport.setGeometryVal("COMP:Fuse"    , 0)
transport.setGeometryVal("COMP:Htail"   , 0)
transport.setGeometryVal("COMP:Vtail"   , 0)
transport.setGeometryVal("COMP:Pod"     , 0)
transport.setGeometryVal("COMP:Control", 0)

# Save egads file of the geometry
print("==> Generating CFDInviscid_Wing")
transport.saveGeometry("CFDInviscid_Wing.egads")
```

CFDInviscid_Wing.egads
CFDInviscid_WingPod.egads
CFDInviscid_Transport.egads
CFDViscous_Wing.egads
CFDViscous_WingPod.egads
CFDViscous_Transport.egads

Pointwise Execution

- Pointwise GeomToMesh.glf script available via $CAPS_GLYPH environment variable
- Windows: also uses PW_HOME environment variable
- Try multiple times in case server license is not available

session07/pointwise_01_Defaults.py

```
####### Run pointwise #################
currentDirectory = os.getcwd()   # Get current working directory
os.chdir(pointwise.analysisDir)  # Move into test directory

CAPS_GLYPH = os.environ["CAPS_GLYPH"]
for i in range(60):
    if "Windows" in platform.system():
        PW_HOME = os.environ["PW_HOME"]
        os.system(’"’ + PW_HOME + ’\\win64\\bin\\tclsh.exe ’ + CAPS_GLYPH + \
                  ’\\GeomToMesh.glf" caps.egads capsUserDefaults.glf’)
    else:
        os.system("pointwise -b " + CAPS_GLYPH + "/GeomToMesh.glf caps.egads capsUserDefaults.glf")

    time.sleep(1) # let the harddrive breathe
    if os.path.isfile(’caps.GeomToMesh.gma’) and os.path.isfile(’caps.GeomToMesh.ugrid’): break
    time.sleep(20) # wait and try again

os.chdir(currentDirectory)       # Move back to top directory
#######################################
```

GeomToMesh.glf Default Values

- GeomToMeshDefaults.glf contains meshing parameters that control the mesh characteristics
- The default parameter settings mirror values in Pointwise interactive mode
- GeomToMesh.glf input: CAD file (egads for instance) and optional “UserDefault.glf”
- The parameters in the “UserDefaults.glf” file will override the settings in the GeomToMeshDefaults.glf

Execute: session07/pointwise_01_Defaults.py

GeomToMesh.glf Suggested Inviscid Values

- Steve Karman: “The values discussed in the following slides are, to some extent, personal preferences evolved over years of experience.”
- These parameters resolve geometry curvature and create high quality surface meshes
- The volume mesh exhibits smooth gradation of element size

session07/pointwise_02_InviscidWing.py

```
# Connector level
pointwise.setAnalysisVal("Connector_Turn_Angle"     , 10)
pointwise.setAnalysisVal("Connector_Turn_Angle_Hard", 70)
pointwise.setAnalysisVal("Connector_Source_Spacing" , True)

# Domain level
pointwise.setAnalysisVal("Domain_Algorithm"   , "AdvancingFront")
pointwise.setAnalysisVal("Domain_Max_Layers"  , 15)
pointwise.setAnalysisVal("Domain_TRex_ARLimit", 40.0)
pointwise.setAnalysisVal("Domain_Decay"       , 0.8)

# Block level
pointwise.setAnalysisVal("Block_Boundary_Decay"      , 0.8)
pointwise.setAnalysisVal("Block_Edge_Max_Growth_Rate", 1.5)
```

GeomToMesh.glf Suggested Inviscid Values

- Connector parameters control the mesh operations on `EDGE`s
- `EDGE` length and curvature influences the mesh resolution and distribution
- Source Spacing enables proximity checking between connectors

session07/pointwise_02_InviscidWing.py

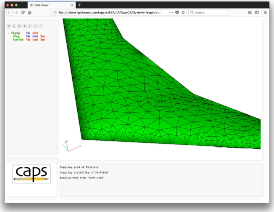
```
# Connector level
pointwise.setAnalysisVal("Connector_Turn_Angle"     , 10)
pointwise.setAnalysisVal("Connector_Turn_Angle_Hard", 70)
pointwise.setAnalysisVal("Connector_Source_Spacing" , True)
```

GeomToMesh.glf Suggested Inviscid Values

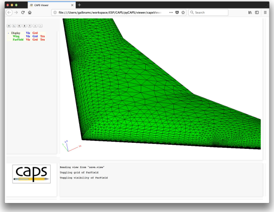
- Domain parameters control the mesh operations on `FACE`s
- Max Layers enables T-Rex surface boundary layer
    - Clustering to high curvature and sharp regions of the geometry

session07/pointwise_02_InviscidWing.py

```
# Domain level
pointwise.setAnalysisVal("Domain_Algorithm"   , "AdvancingFront")
pointwise.setAnalysisVal("Domain_Max_Layers"  , 15)
pointwise.setAnalysisVal("Domain_TRex_ARLimit", 40.0)
pointwise.setAnalysisVal("Domain_Decay"       , 0.8)
```



```
Toggling grid of FarField
Toggling visibility of FarField
Reading view from "save.view"
```



```
Reading view from "save.view"
Toggling grid of FarField
Toggling visibility of FarField
```

GeomToMesh.glf Suggested Inviscid Values

- Block parameters control the mesh operation in the volume, including the extruded viscous mesh portion
- Block_Boundary_Decay: Rate of element size increase away from boundaries
- Block_Edge_Max_Growth_Rate: Controls growth rate along connectors and gradation of the volume mesh

session07/pointwise_02_InviscidWing.py

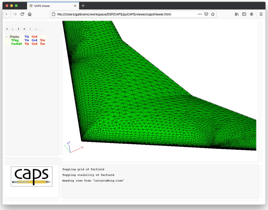
```
# Block level
pointwise.setAnalysisVal("Block_Boundary_Decay"      , 0.8)
pointwise.setAnalysisVal("Block_Edge_Max_Growth_Rate", 1.5)
```

Leading Edge Spacing: Connector_Turn_Angle

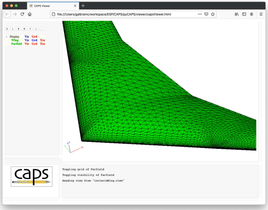
- Turning Angle resolves EDGEs to match the specified degree
- Lower angles increases EDGE resolution in high curvature regions

session07/pointwise_03_TurnAngle.py

```python
# Demonstrate the impact of Connector_Turn_Angle
for conTurnAngle in [5, 10, 20]:
    # Modify the turn angle
    pointwise.setAnalysisVal("Connector_Turn_Angle", conTurnAngle)
```


CAPS Viewer
file:///Users/galbramc/workspace/ESP/CAPS/pyCAPS/viewer/capsViewer.html
Display Viz Grd
Wing Viz Grd Trn
Farfield Viz Grd Trn
caps

```
Toggling grid of Farfield
Toggling visibility of Farfield
Reading view from "invisciWing.view"
```


CAPS Viewer
file:///Users/galbramc/workspace/ESP/CAPS/pyCAPS/viewer/capsViewer.html
Display Viz Grd
Wing Viz Grd Trn
Farfield Viz Grd Trn
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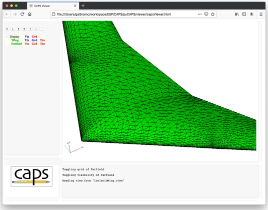

CAPS Viewer
file:///Users/galbramc/workspace/ESP/CAPS/pyCAPS/viewer/capsViewer.html
Display Viz Grd
Wing Viz Grd Trn
Farfield Viz Grd Trn
caps

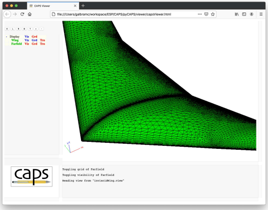
```
Toggling grid of Farfield
Toggling visibility of Farfield
Reading view from "invisciWing.view"
```

Trailing Edge Spacing: Connector_Turn_Angle_Hard

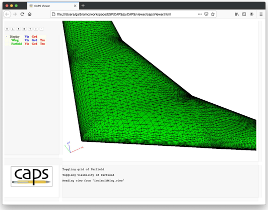
- Turning Angle Hard resolves `EDGE` with acute angle between connected `FACE`s
- Lower angles increases resolution

session07/pointwise_04_TurnAngleHard.py

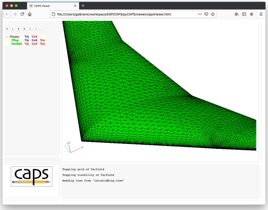
```python
# Demonstrate the impact of Connector_Turn_Angle
for conTurnAngleHard in [10, 30, 50]:
    # Modify the hard turn angle
    pointwise.setAnalysisVal("Connector_Turn_Angle_Hard", conTurnAngleHard)
```



```
Toggling grid of Farfield
Toggling visibility of Farfield
Reading view from "invisciWing.view"
```



```
Toggling grid of Farfield
Toggling visibility of Farfield
Reading view from "invisciWing.view"
```



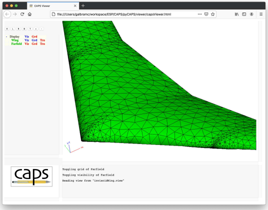
```
Toggling grid of Farfield
Toggling visibility of Farfield
Reading view from "invisciWing.view"
```

Impact of Domain_Decay

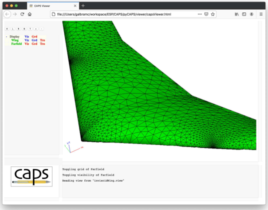
- Domain decay controls gradation of element sizes away from the EDGEs a surface mesh patch.
- Values near 1.0 give gradual increase in element size.
- Values (0.5 or less) gives rapid increase is element size.

session07/pointwise_05_DomainDecay.py

```python
# Demonstrate the impact of Domain_Decay
for domDecay in [0.1, 0.6, 0.95]:
    # Modify the domain decay
    pointwise.setAnalysisVal("Domain_Decay", domDecay)
```


CAPS Viewer
file:///Users/galbramc/workspace/ESP/CAPS/pyCAPS/viewer/capsViewer.html
Display Viz Grd
Wing Viz Grd Trn
Farfield Viz Grd Trn

```
Toggling grid of Farfield
Toggling visibility of Farfield
Reading view from "inviscidWing.view"
```


CAPS Viewer
file:///Users/galbramc/workspace/ESP/CAPS/pyCAPS/viewer/capsViewer.html
Display Viz Grd
Wing Viz Grd Trn
Farfield Viz Grd Trn

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Toggling grid of Farfield
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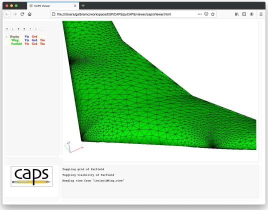
Reading view from "inviscidWing.view"
```


CAPS Viewer
file:///Users/galbramc/workspace/ESP/CAPS/pyCAPS/viewer/capsViewer.html
Display Viz Grd
Wing Viz Grd Trn
Farfield Viz Grd Trn

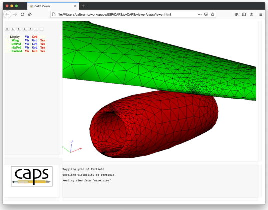
```
Toggling grid of Farfield
Toggling visibility of Farfield
Reading view from "inviscidWing.view"
```

Proximity Detection

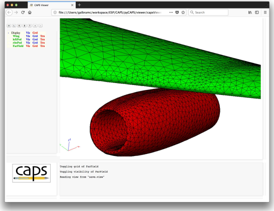
- Pod includes **EDGE** geometry close to the wing leading edge
- Connector Source Spacing enables connectors-to-connector proximity detection
- The proximity test also uses Block level parameters

session07/pointwise_06_ConnectorProximity.py

```
# Demonstrate the impact of Connector_Source_Spacing
for conSourceSpace in [False, True]:
    # Modify the source spacing
    pointwise.setAnalysisVal("Connector_Source_Spacing", conSourceSpace)
```



```
Toggling grid of Farfield
Toggling visibility of Farfield
Reading view from "save.view"
```



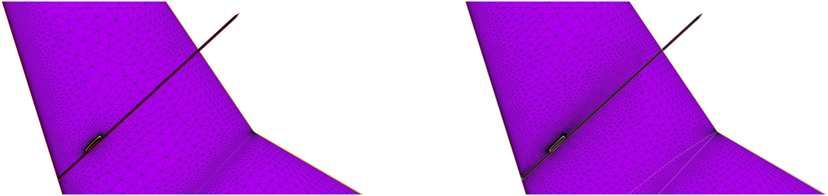
```
Toggling grid of Farfield
Toggling visibility of Farfield
Reading view from "save.view"
```

Proximity Detection

- Domain-to-domain proximity detection enabled with
  Connector_Adapt_Sources
  Domain_Adapt
- FACEs must be attributed with

```
ATTRIBUTE PW:DomainAdaptSource $true
ATTRIBUTE PW:DomainAdaptTarget $true
```

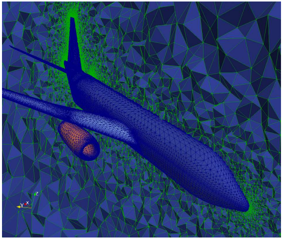
- Source domains will refine Target domains
- A single domain can be tagged both source and target

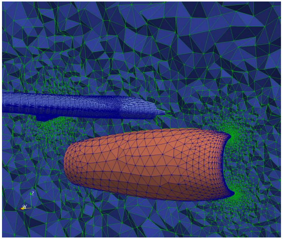


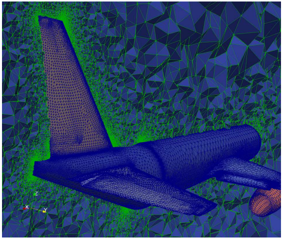
Full Inviscid Transport Example

- Inviscid surface mesh for the full transport configuration using suggested parameters
  - ∼ 6 min
  - 730k Nodes
  - 4.2M Elements

session07/pointwise_07_InviscidTransport.py







Overview

- Pointwise and GeomToMesh.glf

- Pointwise invsicid meshing
  - Suggested parameters
  - Proximity detection

- Pointwise viscous meshing
  - Suggested parameters
  - Viscous boundary layer mesh generation

- Suggested Exercises

GeomToMesh.glf Suggested Viscous Values

- Recommended viscous values are similar to the inviscid
- Block level parameters to control boundary layer meshing

session07/pointwise_08_ViscousWing.py

```
# Connector level
pointwise.setAnalysisVal("Connector_Turn_Angle"      , 10)
pointwise.setAnalysisVal("Connector_Prox_Growth_Rate", 1.2)
pointwise.setAnalysisVal("Connector_Source_Spacing"  , True)

# Domain level
pointwise.setAnalysisVal("Domain_Algorithm"   , "AdvancingFront")
pointwise.setAnalysisVal("Domain_Max_Layers"  , 15)
pointwise.setAnalysisVal("Domain_Growth_Rate" , 1.25)
pointwise.setAnalysisVal("Domain_TRex_ARLimit", 40.0)
pointwise.setAnalysisVal("Domain_Decay"       , 0.8)

# Block level
pointwise.setAnalysisVal("Block_Boundary_Decay"      , 0.8)
pointwise.setAnalysisVal("Block_Collision_Buffer"    , 1.0)
pointwise.setAnalysisVal("Block_Max_Skew_Angle"      , 160.0)
pointwise.setAnalysisVal("Block_Edge_Max_Growth_Rate", 1.5)
pointwise.setAnalysisVal("Block_Full_Layers"         , 1)
pointwise.setAnalysisVal("Block_Max_Layers"          , 100)

# Set wall spacing for capsGroup = Wing
viscousWall  = {"boundaryLayerSpacing" : 0.001}
pointwise.setAnalysisVal("Mesh_Sizing", ("Wing", viscousWall))
```

GeomToMesh.glf Suggested Viscous Values

- The suggested connector attributes very similar to inviscid values.
- Proximity growth rate has been slightly reduced.

session07/pointwise_08_ViscousWing.py

```
# Connector level
pointwise.setAnalysisVal("Connector_Turn_Angle"      , 10)
pointwise.setAnalysisVal("Connector_Prox_Growth_Rate", 1.2)
pointwise.setAnalysisVal("Connector_Source_Spacing"  , True)
```

GeomToMesh.glf Suggested Viscous Values

- The suggested domain attributes also similar to inviscid values.
- The growth rate has been slightly reduced.

session07/pointwise_08_ViscousWing.py

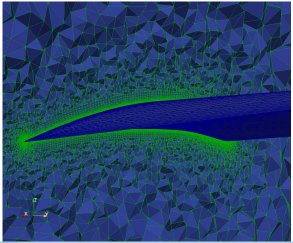
```
# Domain level
pointwise.setAnalysisVal("Domain_Algorithm"   , "AdvancingFront")
pointwise.setAnalysisVal("Domain_Max_Layers"  , 15)
pointwise.setAnalysisVal("Domain_Growth_Rate" , 1.25)
pointwise.setAnalysisVal("Domain_TRex_ARLimit", 40.0)
pointwise.setAnalysisVal("Domain_Decay"       , 0.8)
```

GeomToMesh.glf Suggested Viscous Values

- Increased collision buffer to allow gap between fronts
- Skew angle stops T-Rex locally when elements exceed angle
- Full Layers is the desired minimum number of full viscous layers
- Max Layer is upper bounds on the number of layers
- T-Rex automatically halts locally when elements approach isotropy

session07/pointwise_08_ViscousWing.py

```
# Block level
pointwise.setAnalysisVal("Block_Boundary_Decay"      , 0.8)
pointwise.setAnalysisVal("Block_Collision_Buffer"    , 1.0)
pointwise.setAnalysisVal("Block_Max_Skew_Angle"      , 160.0)
pointwise.setAnalysisVal("Block_Edge_Max_Growth_Rate", 1.5)
pointwise.setAnalysisVal("Block_Full_Layers"         , 1)
pointwise.setAnalysisVal("Block_Max_Layers"          , 100)
```

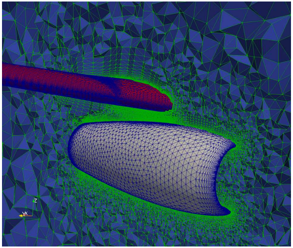


Colliding Boundary Layers

- Viscous extrusion when "PW:WallSpacing" attribute on FACEs
  - Set with Mesh_Sizing boundaryLayerSpacing using capsGroup
  - boundaryLayerSpacing scaled by capsMeshLength
- Boundary layer wall spacings can differ between capsGroup

session07/pointwise_09_ViscousWingPod.py

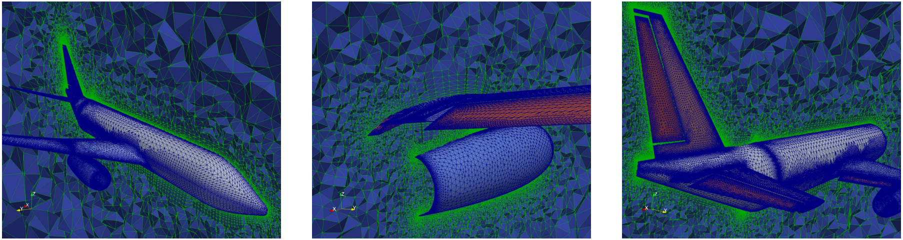
```
# Set wall spacing for capsGroup = Wing and capsGroup = Pod
wingWall = {"boundaryLayerSpacing" : 0.001}
podWall  = {"boundaryLayerSpacing" : 0.003}
pointwise.setAnalysisVal("Mesh_Sizing", [("Wing", wingWall),
                                         ("Pod", podWall)])
```



Full Transport Example

- Viscous surface mesh for the full transport configuration using suggested parameters[1]
  - ∼ 20 min
  - 2.3M Nodes
  - 13.6M Elements

session07/pointwise_10_ViscousTransport.py



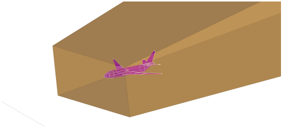
[1] NOTE: Unreasonably coarse boundary layers in examples

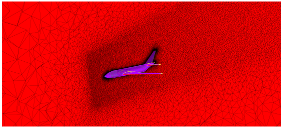
Source Box

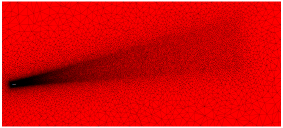
- Box is 20% larger than bounding box of all viscous surfaces
- Length Scaled multiplied along the direction vector
- Widens using the Angle parameter
- Scalar size field grows from surface size along the box

session07/pointwise_11_SourceBox.py

```
# General source box parameters
pointwise.setAnalysisVal("Gen_Source_Box_Length_Scale", 2.0) # Double size in Box Direction
pointwise.setAnalysisVal("Gen_Source_Box_Direction"   , [ 0.9848077, 0, 0.1736482 ])
pointwise.setAnalysisVal("Gen_Source_Box_Angle"       , 10.0)
pointwise.setAnalysisVal("Gen_Source_Growth_Factor"   , 40.0)
```

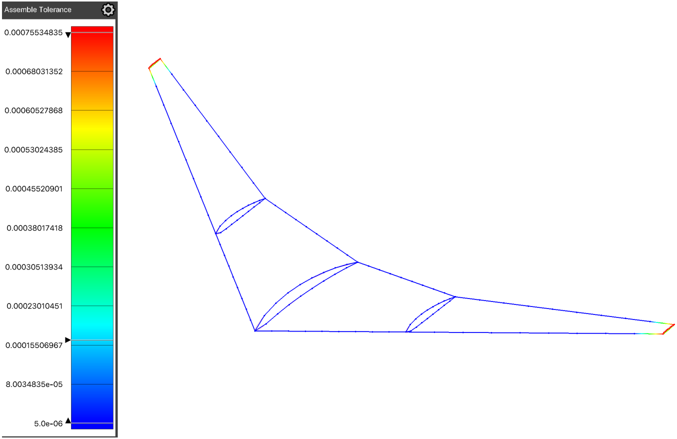






Full Disclosure: Poor Assemble Tolerance

- EGADS files in Pointwise may have poor assemble tolerance
- Can cause meshing failures or errors exporting to CAPS
- Fix exists and will be in future Pointwise release



Inputs Scaled by capsMeshLength

Mesh_Sizing Parameters

- nodeSpacing: Spacing around a NODE
- minSpacing, maxSpacing, avgSpacing: EDGE or FACE
- maxDeviation: EDGE or FACE deviation
- boundaryLayerSpacing: FACE initial boundary layer spacing

Global Input Parameters

- Domain_Min_Edge: Domain minimum Edge length
- Domain_Max_Edge: Domain maximum Edge length
- Domain_Wall_Spacing: Initial boundary layer spacing on FACEs with

```
ATTRIBUTE PW:WallSpacing $Wall
```

Primary Mesh Resolution Parameters

Surface Mesh Resolution

- Connector_Turn_Angle: High curvature of connector
- Connector_Prox_Growth_Rate: Connector-to-connector prox.
- Connector_Turn_Angle_Hard: Acute angles between `FACE`s
- Domain_TRex_ARLimit: Spanwise resolution of surface TRex
- Block_Edge_Max_Growth_Rate: Growth rate along connectors and gradation of volume mesh

Volume Mesh Resolution

- Block_Boundary_Decay: Rate of element size increase away from boundaries
- Block_Growth_Rate : Growth rate of viscous boundary layer

Suggested Exercises

Inviscid Mesh Sequence

- For the InviscidTransport, generate surface meshes with approximate element counts of:
  - 150,000
  - 250,000
  - 300,000

Domain-to-Domain Proximity Inviscid Wing with Pods

- Add combinations of Source and Target attributes to the Wing and/or Pod in ESP/viewCFDInviscid.udc (do not use EGADS/CFDInviscid_WingPod.egads)

```
ATTRIBUTE PW:DomainAdaptSource $true
ATTRIBUTE PW:DomainAdaptTarget $true
```

- Toggle Connector_Adapt_Sources and Domain_Adapt

Suggested Exercises Cont.

Other AIM Inputs

- Explore the impact of Pointwise AIM input parameters
  - Connector, Domain, Block inputs

- Create your own (optionally share it `galbramc@mit.edu`)