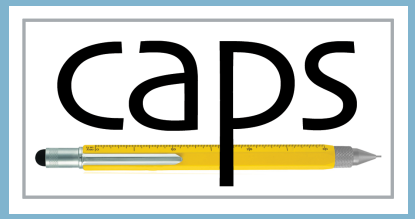
Computational Aircraft Prototype Syntheses



Training Session 5
Meshing for CFD: AFLR

ESP v1.26

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Overview

- AFLR4 surface mesh generation
  - Mesh length scaling (`capsMeshLength`)
  - Edge spacing controls
  - Proximity Detection
- AFLR3 volume mesh generation
  - Inviscid mesh generation (linking Surface_Mesh)
  - Viscous boundary layer mesh generation
- Suggested Exercises

AFLR Overview

Advancing-Front/Local-Reconnection Grid Generator

- AFLR mesh generator suite by Prof. David Marcum at Mississippi State
  - AFLR2 – 2D unstructured meshes
  - AFLR3 – 3D unstructured meshes with boundary layers
  - AFLR4 – CAD surface meshes
- AFLR2/AFLR3 developed over past decades
- AFLR4 extensive development as part of `CAPS` project
  - Actively under development

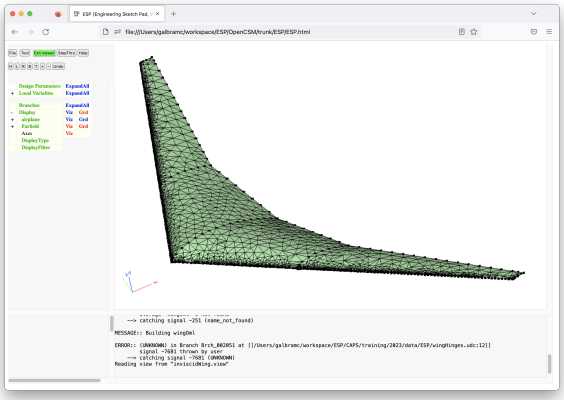
AFLR4/AFLR3 AIM Documentation

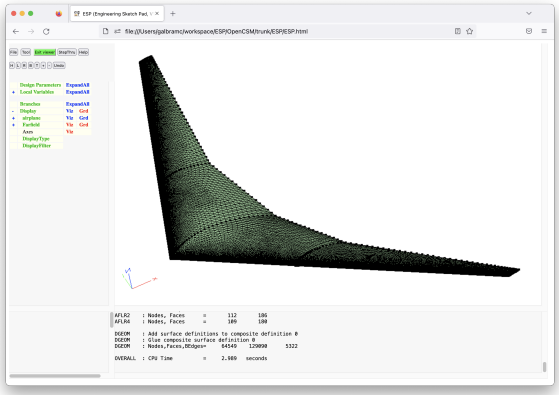
AFLR Execution and Surface Tessellations

- AFLR generates meshes in memory
- geometry.view shows surface tessellation after runAnalysis

session05/01_aflr4_InviscidWing.py

```
# Create aflr4 aim
aflr4 = capsProblem.analysis.create(aim = "aflr4AIM",
                                    name = "aflr4")

# View the bodies
aflr4.geometry.view()

# Mark capsMesh == Farfield with a Farfield bcType
aflr4.input.Mesh_Sizing = {"Farfield": {"bcType":"Farfield"}}

# Run AIM analysis
aflr4.runAnalysis()

# View the surface tessellation
aflr4.geometry.view()
```





AFLR Farfield Growth Factor

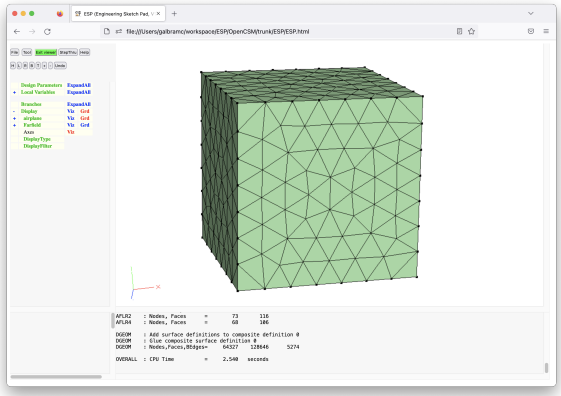
- Farfield boundary set via "Mesh_Sizing", or tagged with

  `ATTRIBUTE AFLR_GBC $FARFIELD_UG3_GBC`

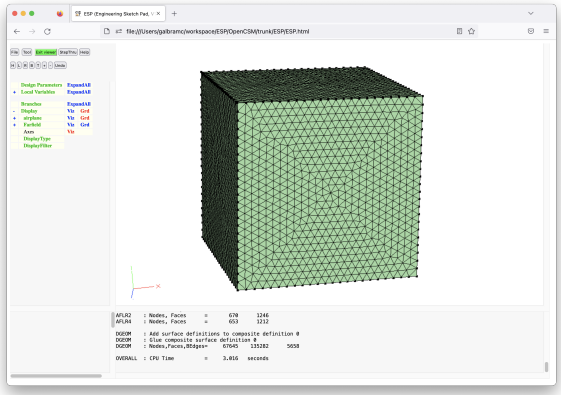
- "Mesh_Sizing" via `capsMesh` attributes on `FACE/EDGE/NODE`
- ff_cdfr – Far field element factor

session05/02_aflr4_Farfield.py

```
# Mark capsMesh == Farfield with a Farfield bcType
aflr4.input.Mesh_Sizing = {"Farfield": {"bcType":"Farfield"}}

# Farfield growth factor
aflr4.input.ff_cdfr = 1.4

# Run AIM
aflr4.runAnalysis()

# View the surface tessellation
aflr4.geometry.view()

# Reduce Farfield growth factor
aflr4.input.ff_cdfr = 1.1
```



aflr4.input.ff_cdfr = 1.4



aflr4.input.ff_cdfr = 1.1

Mesh Length Scaling

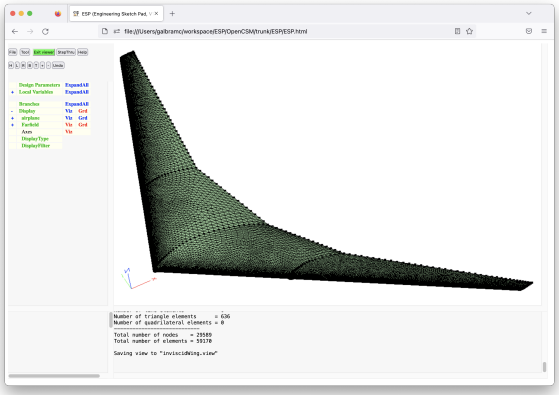
- AFLR4 reference length (ref_len) bounds element sizes
- Rule of thumb: characteristic length of geometry
  - Mean Aerodynamic Chord, diameter of fuselage, etc.
- CAPS: reference length computed from `capsMeshLength`

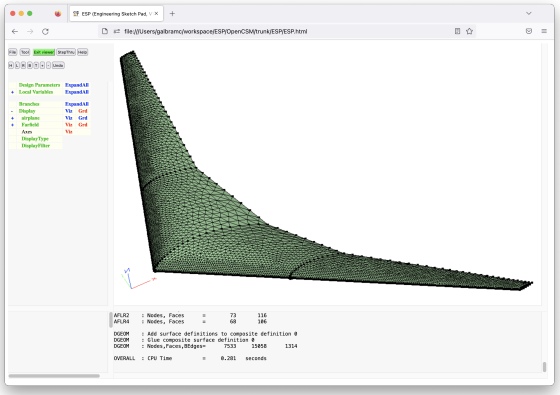
  `ATTRIBUTE capsMeshLength wing:mac`

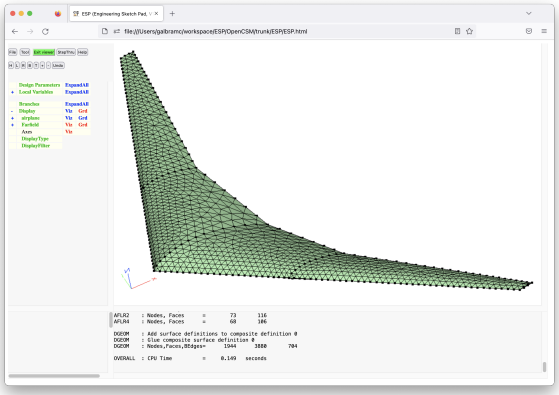
session05/03_aflr4_MeshLength.py

```
# Scaling factor to compute AFLR4 'ref_len' parameter via
# ref_len = capsMeshLength * Mesh_Length_Factor
aflr4.input.Mesh_Length_Factor = 5

# Relative scale of maximum spacing bound relative to ref_len
# max_spacing = max_scale * ref_len
aflr4.input.max_scale = 0.1

# Relative scale of minimum spacing bound relative to ref_len
# min_spacing = min_scale * ref_len
aflr4.input.min_scale = 0.01

# Absolute scale of minimum spacing bound for proximity
# abs_min_spacing = abs_min_scale * ref_len
aflr4.input.abs_min_scale = 0.001
```

Mesh Length Scaling







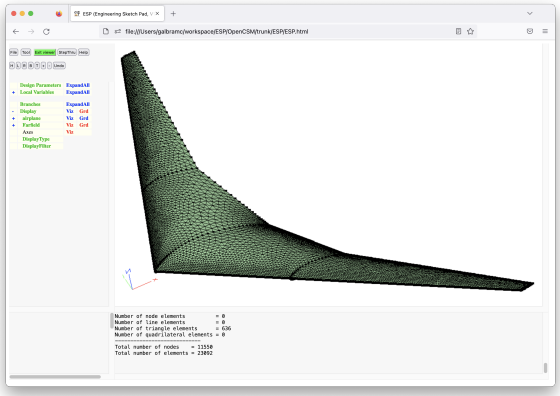
session05/03_aflr4_MeshLength.py

```
# Use mesh length factor to make a series of coarser meshes (not a family)
for Length_Factor in [1, 3, 9]:
    aflr4.input.Mesh_Length_Factor = Length_Factor

    # Run AIM
    aflr4.runAnalysis()

    # View the surface tessellation
    aflr4.geometry.view()
```

Edge Weight for Large Face-to-Face Angles

- Increase resolution of "sharp" edges (e.g. trailing edges)
- Set via "Mesh_Sizing", or attribute applied to `FACE`s

```
ATTRIBUTE AFLR4_Edge_Scale_Factor_Weight 1
```



session05/04_aflr4_EdgeWeight.py

```
# Edge mesh spacing can be scaled on surfaces based on
# discontinuity level between adjacent surfaces on both sides of the edge.
# The level of discontinuity potentially reducing the edge spacing.
# The edgeWeight scale factor weight is used as an interpolation weight
# between the unmodified spacing and the modified spacing.
aflr4.input.Mesh_Sizing = {"leftWing": {"edgeWeight":1.0},
                           "Farfield": {"bcType":"Farfield"}}
```

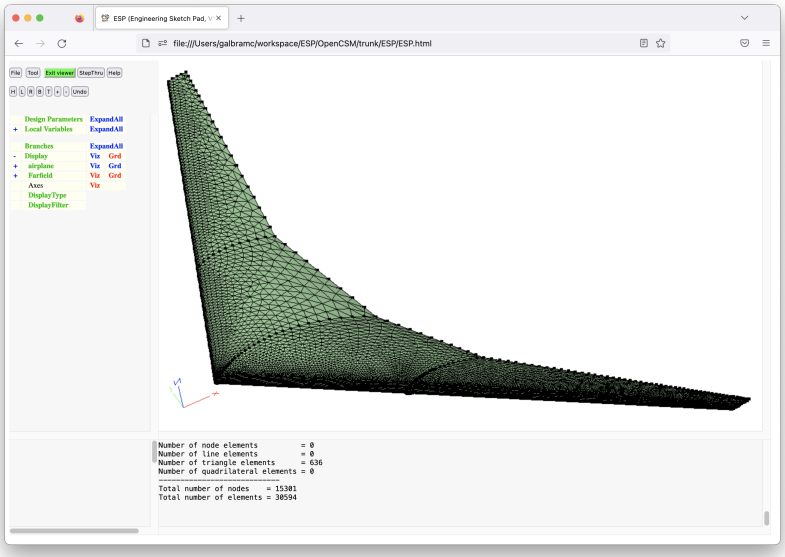
FACE/EDGE Local Mesh Scaling

- Increase/Decrease resolution on FACE/EDGE
- Set via "Mesh_Sizing", or attribute applied FACE/EDGE

```
ATTRIBUTE AFLR4_Scale_Factor 0.25
```

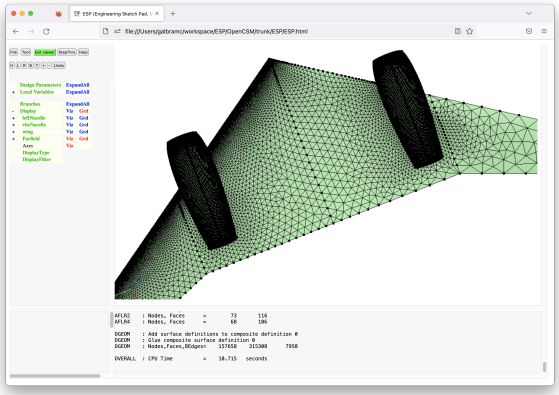
session05/05_aflr4_ScaleFactor.py

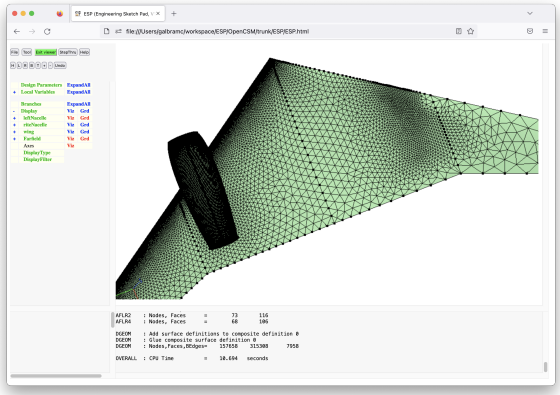
```
# Apply a local scaling factor to capsMesh="leftWing"
aflr4.input.Mesh_Sizing = {"riteWing": {"scaleFactor":4.00},
                           "leftTE"  : {"scaleFactor":0.125},
                           "leftWing": {"scaleFactor":0.5},
                           "Farfield": {"bcType":"Farfield"}}
```



Proximity Detection

- Proximity detection imprints meshes from close bodies on each other
- Wing coarsened to illustrate imprinting
- Individual bodies treated as separate components

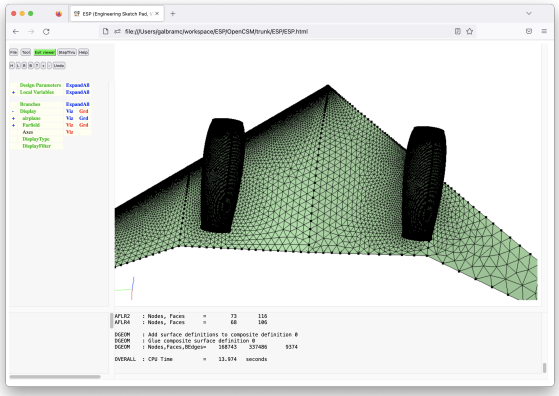


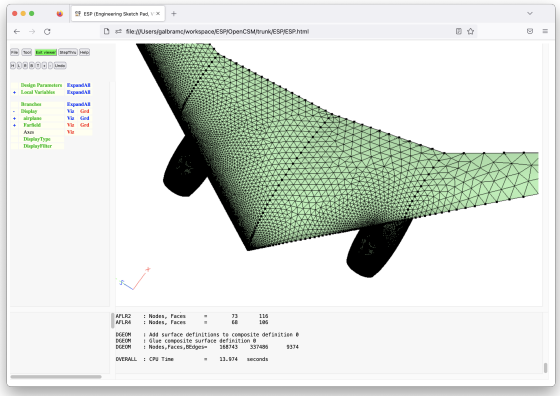


session05/06_aflr4_Proximity.py

```
# Set mesh sizing parmeters
aflr4.input.Mesh_Sizing = {"Farfield": {"bcType":"Farfield"},
                           "leftWing": {"scaleFactor":50},
                           "Nacelle" : {"scaleFactor":0.5}}
```

Proximity Sensing Single Body Components





- `AFLR4_Cmp_ID FACE` attribute distinguishes components

ESP/viewCFDViscous.udc

```
SET       AFLR4_Cmp_Fuse      1
SET       AFLR4_Cmp_Wing      2
SET       AFLR4_Cmp_Htail     3
SET       AFLR4_Cmp_Vtail     4
SET       AFLR4_Cmp_Nacelle   5
SET       AFLR4_Cmp_Pylon     6
SET       AFLR4_Cmp_Farfield  7
```

```
FACE HAS    tagComp=leftWing  tagType=upper
SET         capsGroup=Wing
SET         capsBound=upperWing
SET         capsMesh=leftWing
SET         AFLR4_Cmp_ID=!AFLR4_Cmp_Wing
```

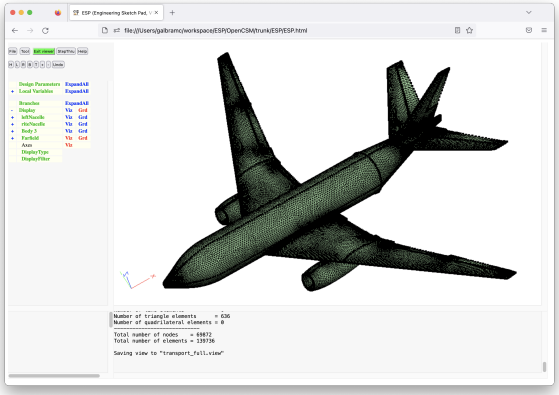
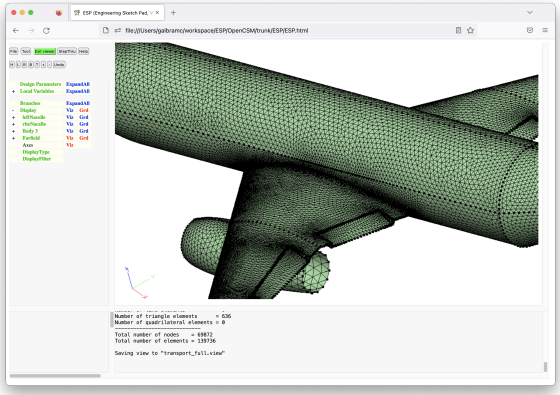
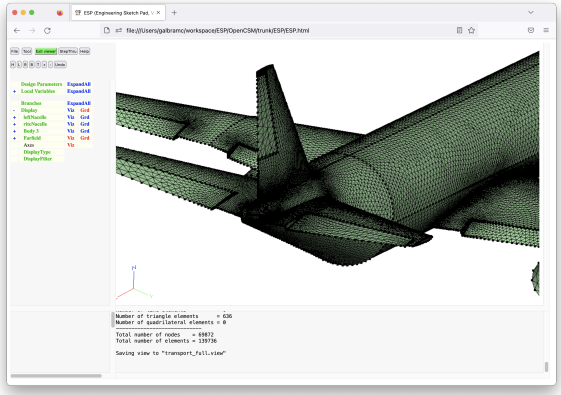
```
FACE HAS    tagComp=leftNacelle
SET         capsGroup=Nacelle
SET         capsMesh=Nacelle
SET         AFLR4_Cmp_ID=!AFLR4_Cmp_Nacelle
```

Execute: session05/07_aflr4_ProximityComponents.py

Full Inviscid Transport

- Inviscid surface mesh for the full transport configuration
  - ~10 s
  - 70k Nodes
  - 140k Triangles

Execute: session05/08_aflr4_InviscidTransport.py

Overview

- AFLR4 surface mesh generation
  - Mesh length scaling (`capsMeshLength`)
  - Edge spacing controls
  - Proximity Detection

- AFLR3 volume mesh generation
  - Inviscid mesh generation (linking Surface_Mesh)
  - Viscous boundary layer mesh generation

- Suggested Exercises

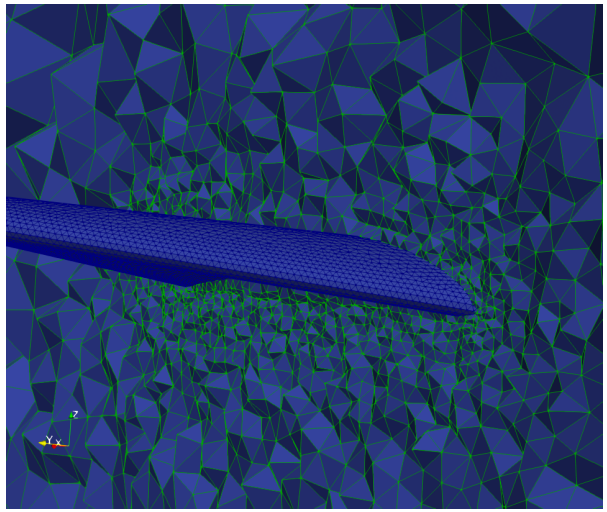
AFLR3 Volume Mesh and linking Surface_Mesh

Surface Mesh Transfer

- AFLR4 AIM output Surface_Mesh is linked to AFLR3 AIM input Surface_Mesh
- Transfers surface mesh from AFLR4 to AFLR3

session05/09_aflr4_aflr3_InviscidWing.py

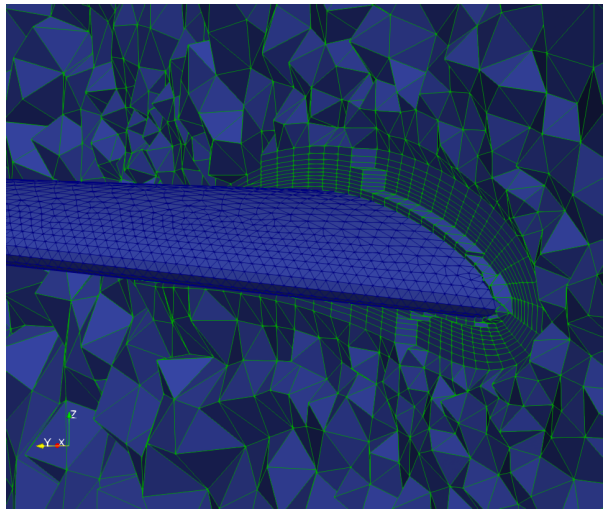
```
# Create AFLR3 AIM to generate the volume mesh
aflr3 = capsProblem.analysis.create(aim  = "aflr3AIM",
                                    name = "aflr3")

# Link the aflr4 Surface_Mesh as input to aflr3
aflr3.input["Surface_Mesh"].link(aflr4.output["Surface_Mesh"])

# Dump VTK files for visualization
aflr3.input.Proj_Name   = "TransportWing"
aflr3.input.Mesh_Format = "VTK"

# Run AIM
aflr3.runAnalysis()
```



AFLR3 Boundary Layer Volume Mesh generation

- Boundary layer meshes are required for viscous CFD
- AFLR3 "grows" boundary layer meshes from viscous surfaces

- Global boundary layer parameter (automatically ignores Farfield)
- Mesh_Gen_Input_String to add any AFLR3 command line flags



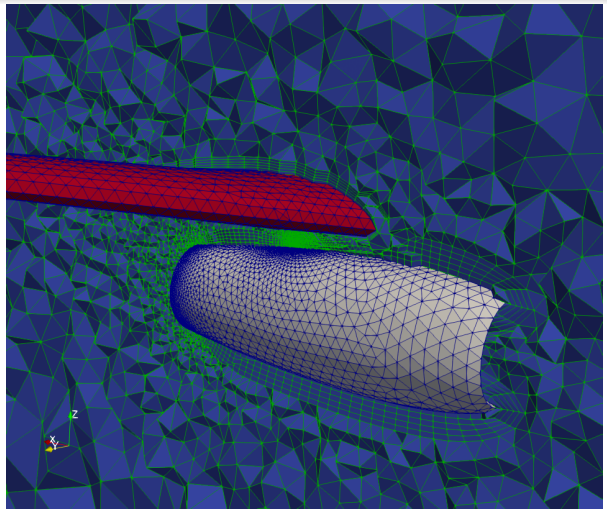
session05/10_aflr4_aflr3_ViscousWing.py

```
# Specify boundary layer maximum layers.
# Initial spacing and minimum thickness are scaled by capsMeshLength
aflr3.input.BL_Max_Layers      = 10
aflr3.input.BL_Initial_Spacing = 0.01
aflr3.input.BL_Thickness       = 0.1

# Specify prism boundary layer elements
aflr3.input.Mesh_Gen_Input_String = "-blc"
```

AFLR3 Boundary Layer Volume Mesh generation

- Boundary layer meshes are required for viscous CFD
- AFLR3 "grows" boundary layer meshes from viscous surfaces

- `capsMesh` wise boundary layers parameters
- Properly treats colliding layers



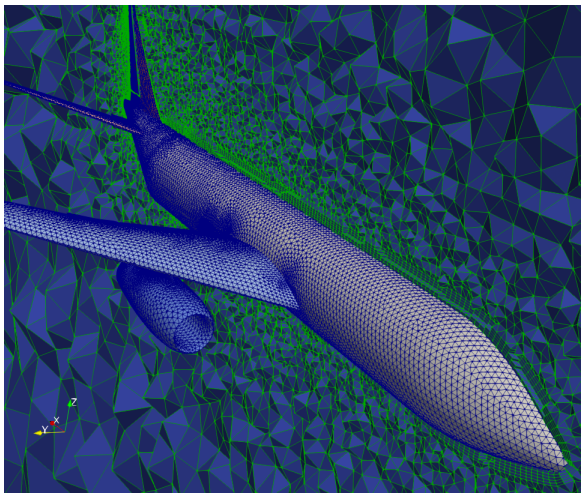
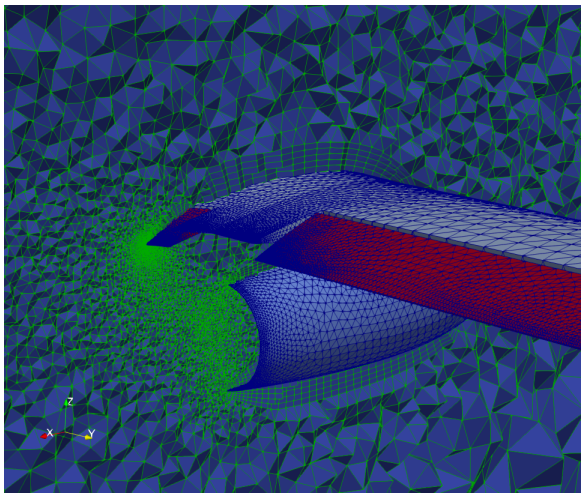
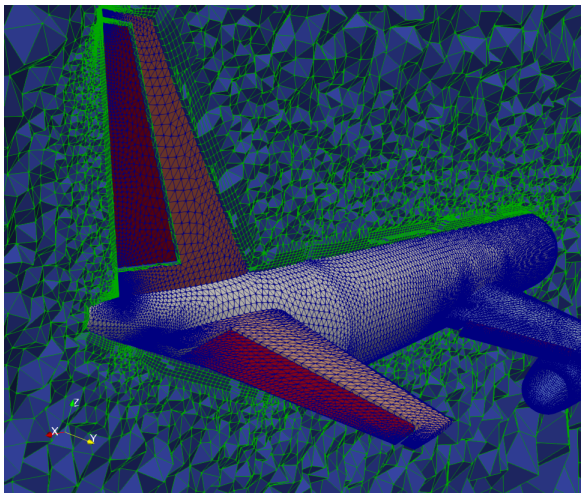
session05/11_aflr4_aflr3_ViscousWingPod.py

```
# Specify boundary layer maximum layers.
aflr3.input.BL_Max_Layers = 10

# Specify prism boundary layer elements
aflr3.input.Mesh_Gen_Input_String = "-blc"

# Set mesh sizing parameters
aflr3.input.Mesh_Sizing = {"leftWing" : {"boundaryLayerSpacing":0.01, "boundaryLayerThickness":0.1},
                           "riteWing" : {"boundaryLayerSpacing":0.01, "boundaryLayerThickness":0.1},
                           "Nacelle"  : {"boundaryLayerSpacing":0.02, "boundaryLayerThickness":0.1}}
```

Full Viscous Transport

- Viscous mesh for full transport configuration
  - ~1.0 min
  - 380k Nodes
  - 1.8M Elements

Execute: session05/12_aflr4_aflr3_ViscousTransport.py

Suggested Exercises

curv_factor

- Explore the impact of AFLR4 “curv_factor”

Inviscid Transport

- Make the surface mesh finer for the engine pods of the InviscidTransport
- Coarsen the fuselage surface mesh for the InviscidTransport without coarsening the wing/tail surfaces

Suggested Exercises Cont.

Inviscid Mesh Sequence

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