Generation of Unstructured Hexahedron-Dominated Conforming Mesh Using Two-Boundary Marching Method

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Why Hexahedrons

- It is known that cell-centered based flow solvers consume most of time on the source terms of the species and particle transport equations.
- A tetrahedral mesh increases the element count 4 to 10 fold over a hexahedral mesh with similar number of vertices in the domain.
  Hexahedrons provide directional sizing without losing accuracy. (i.e. normal to the wall)

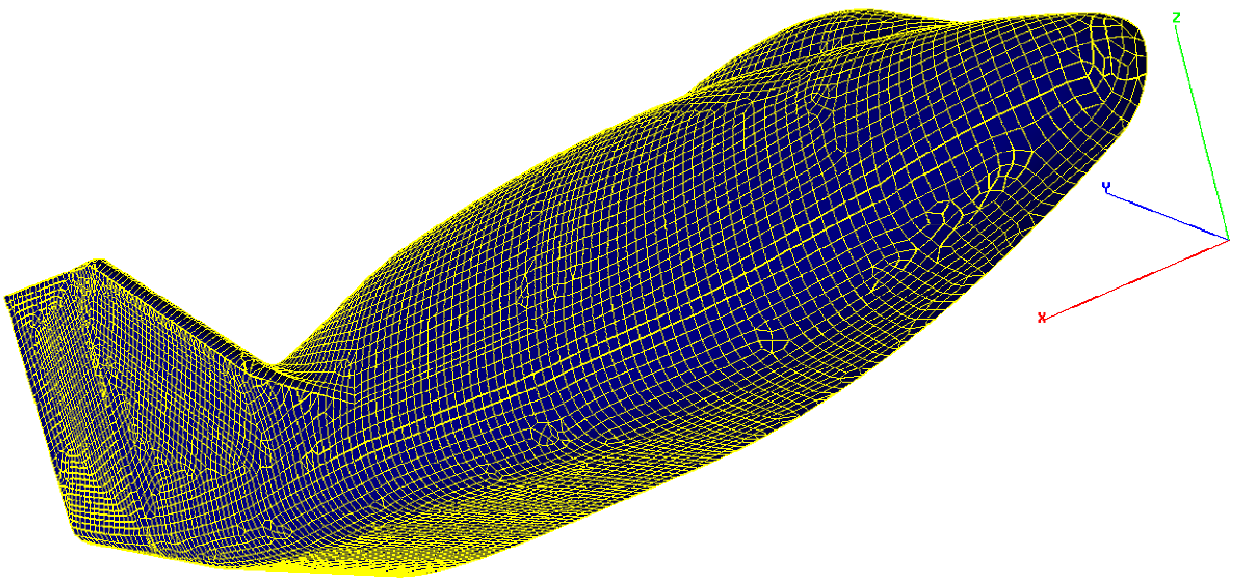
A Unified Approach to Generate Unstructured Hexahedron

- Unstructured overset-hexahedron mesh (8th International Meshing Roundtable 1999).
- Unstructured all-hexahedron mesh (AIAA 2001-1097).
- Unstructured mostly-hexahedron mesh (TFAWS 2008).

Preprocessing of Unified Approach(1)

- Surface Grid Generation --Quadrilateral Shell Element

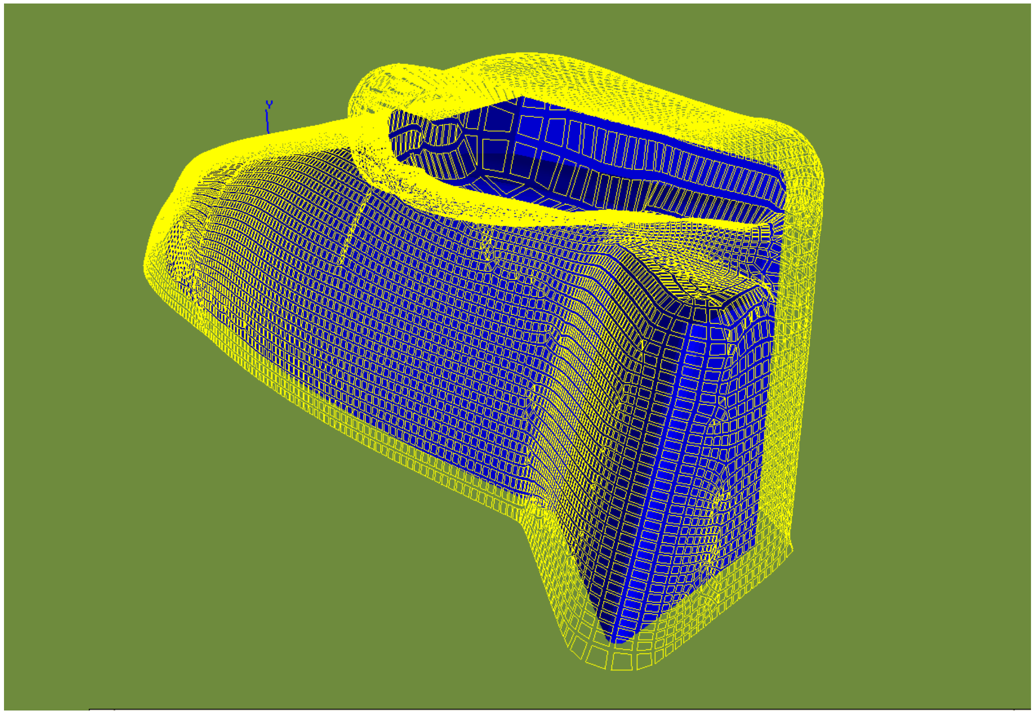
Quadrilateral dominated mesh
(X-38 crew return spacecraft)



Preprocessing of Unified Approach(2)

- Generation of marching grid from the surface mesh (i.e. hair grid or radiated grid)

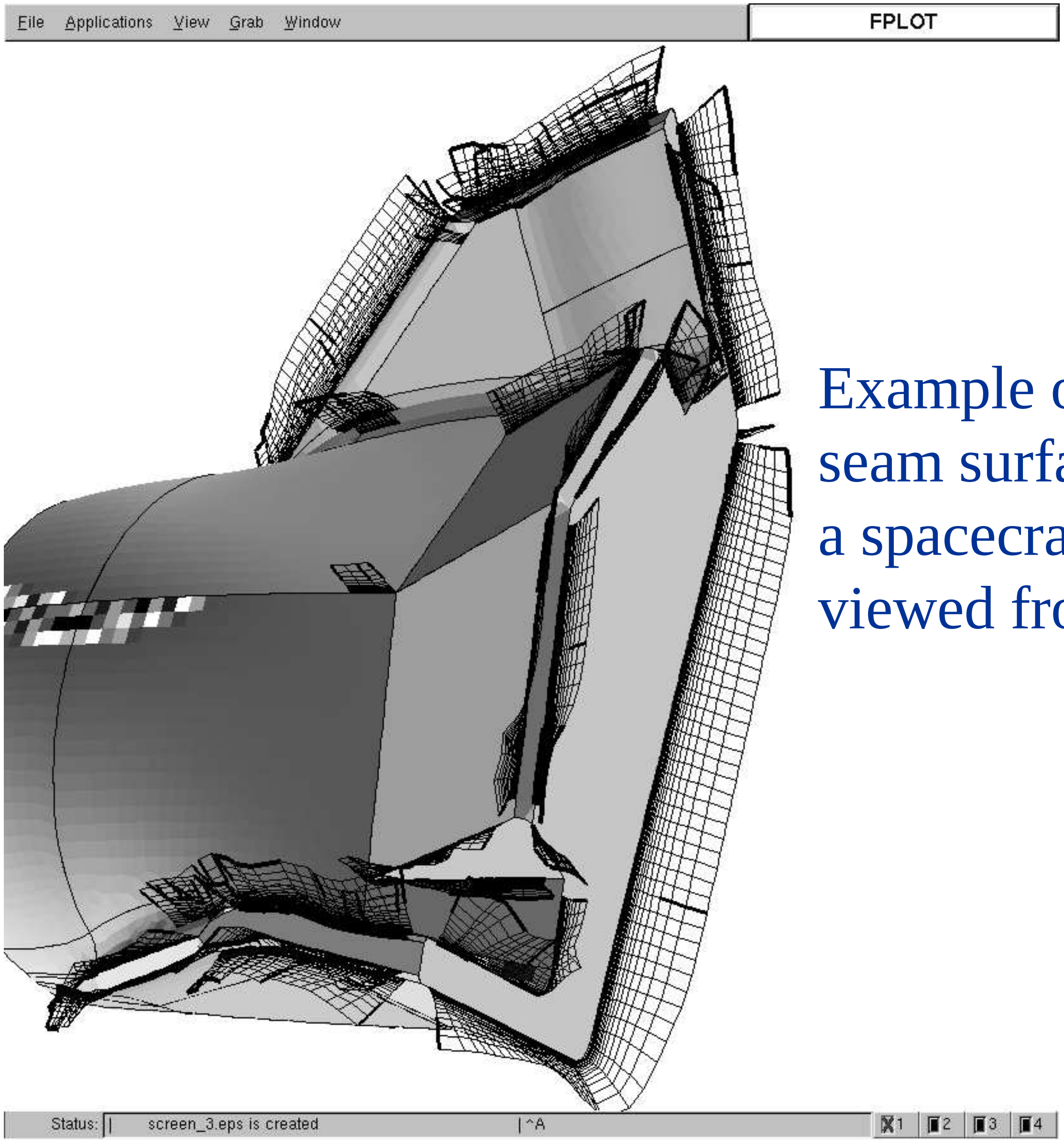
Wireframe view of the grown hair grid around the X-38 (shaded area denotes the surface of the body).



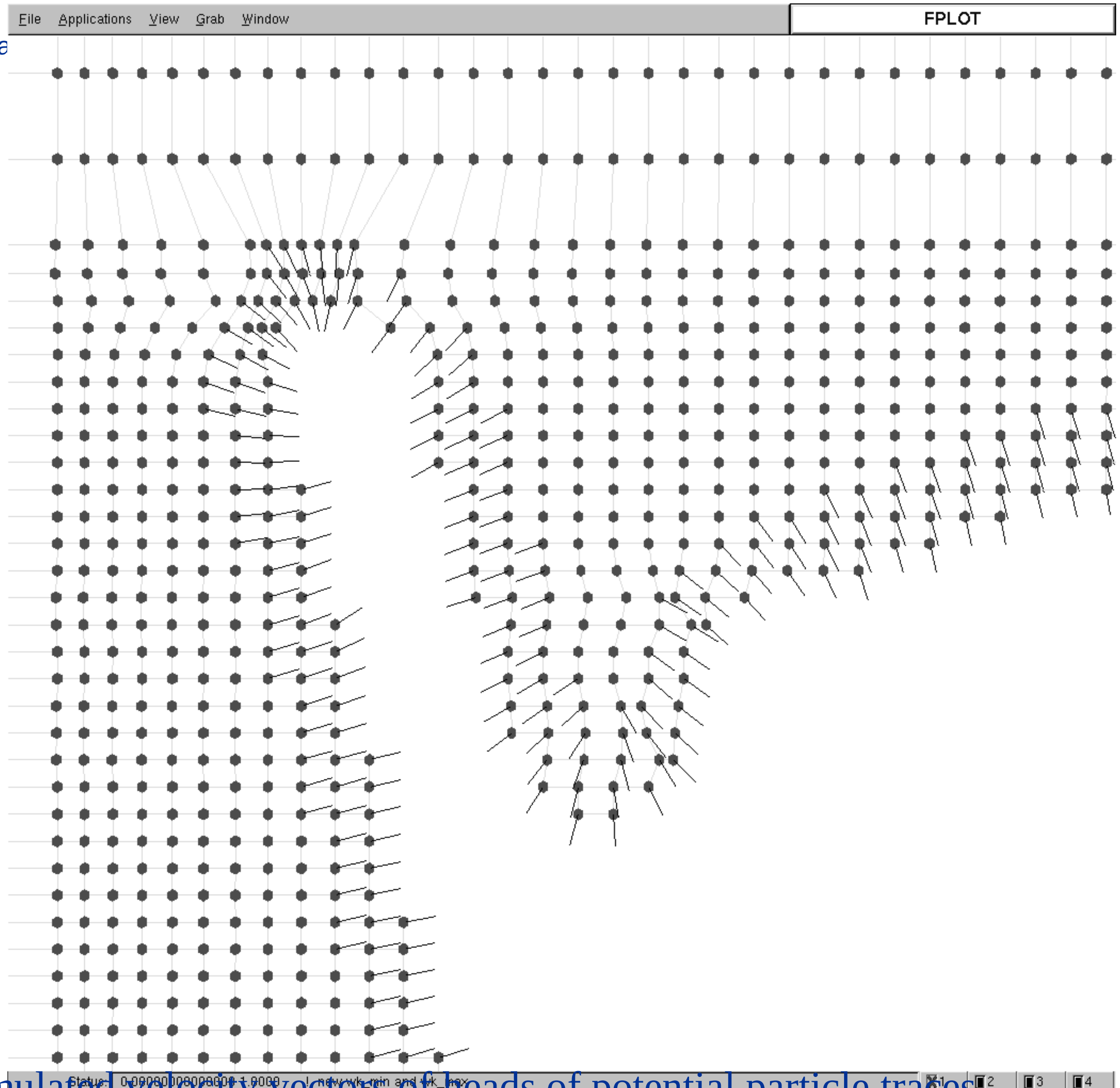
Preprocessing of Unified Approach(3)

- Core grid generation

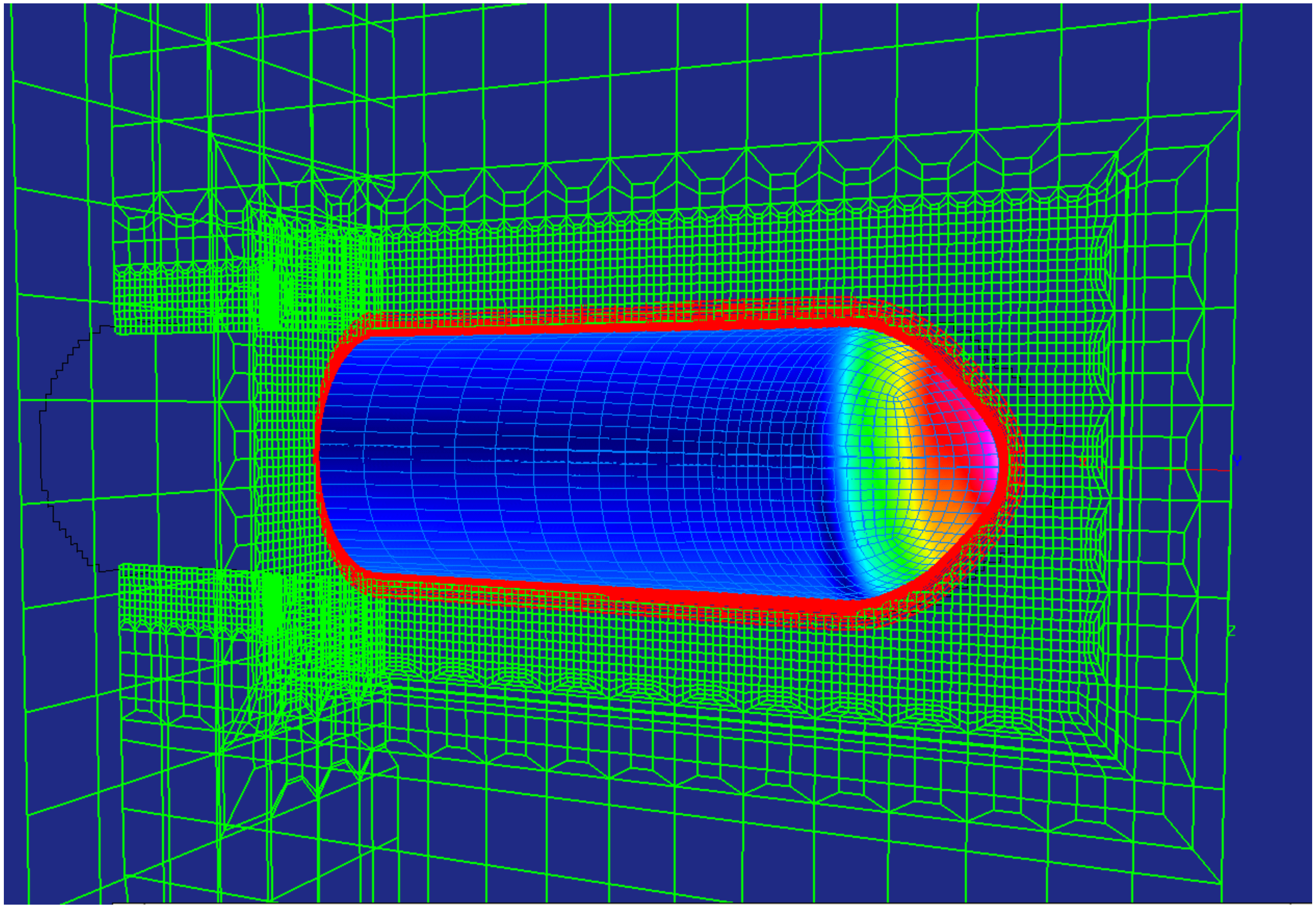
1. Identify the geometric discontinuities as seam curves
2. Identify seam corners
3. Initial core grid must encompasses the domain to be gridded.
4. Enhance initial core grid with the help of seam curves and seam corners. (such as grid relocation, adaptive mesh refinement, etc)
5. Apply hole cutting to blank out the unnecessary grid points.



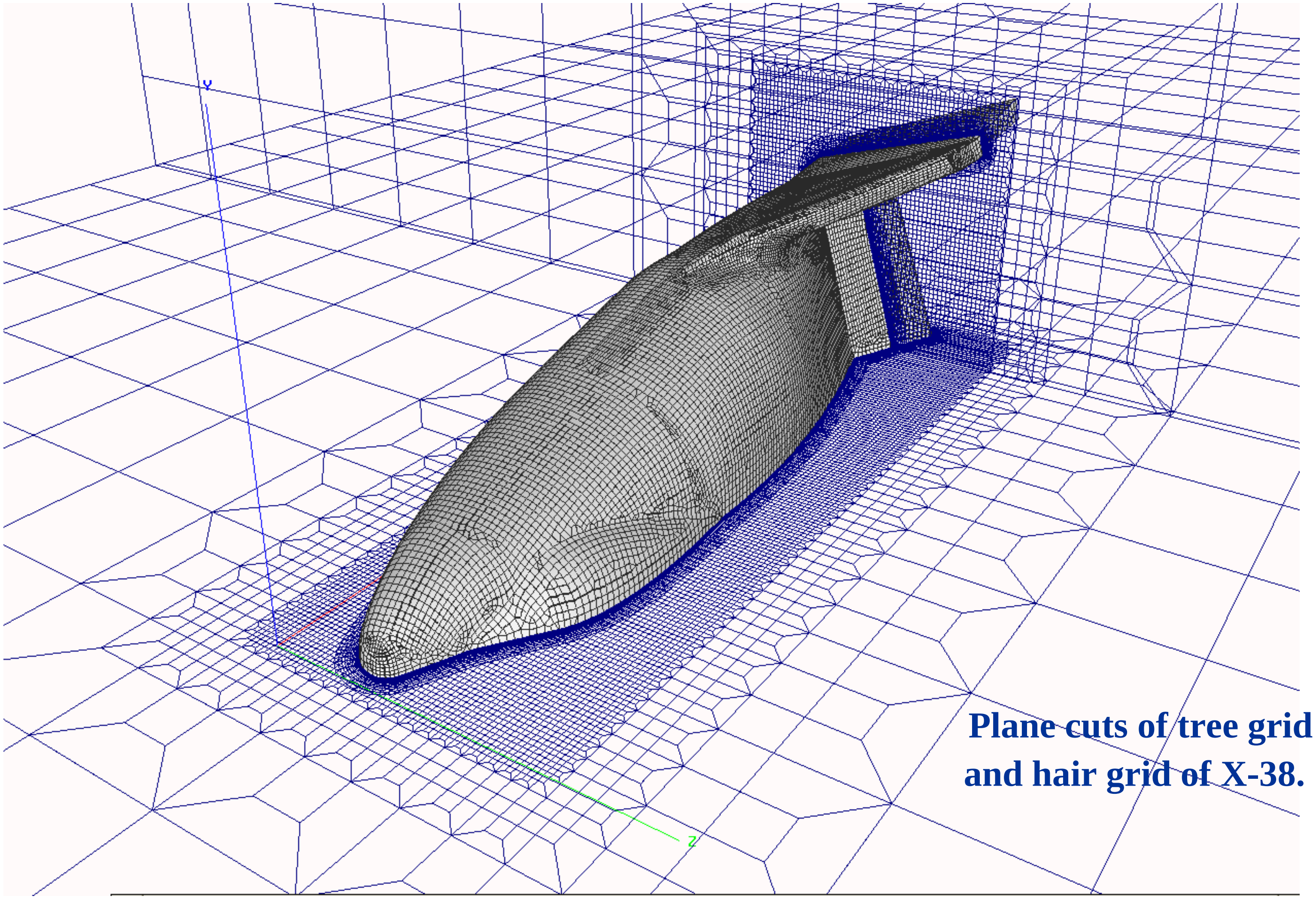
Example of
seam surfaces of
a spacecraft
viewed from after body.



Simulated velocity vectors of heads of potential particle traces:
(1) velocity of points that are not overlapped by radiated marching grid is set to zero.
(2) points inside the solid have been blanked out.
(3) Only farthest fringe points from the first layer of the radiated marching grid will be chosen as the heads of the particle traces.

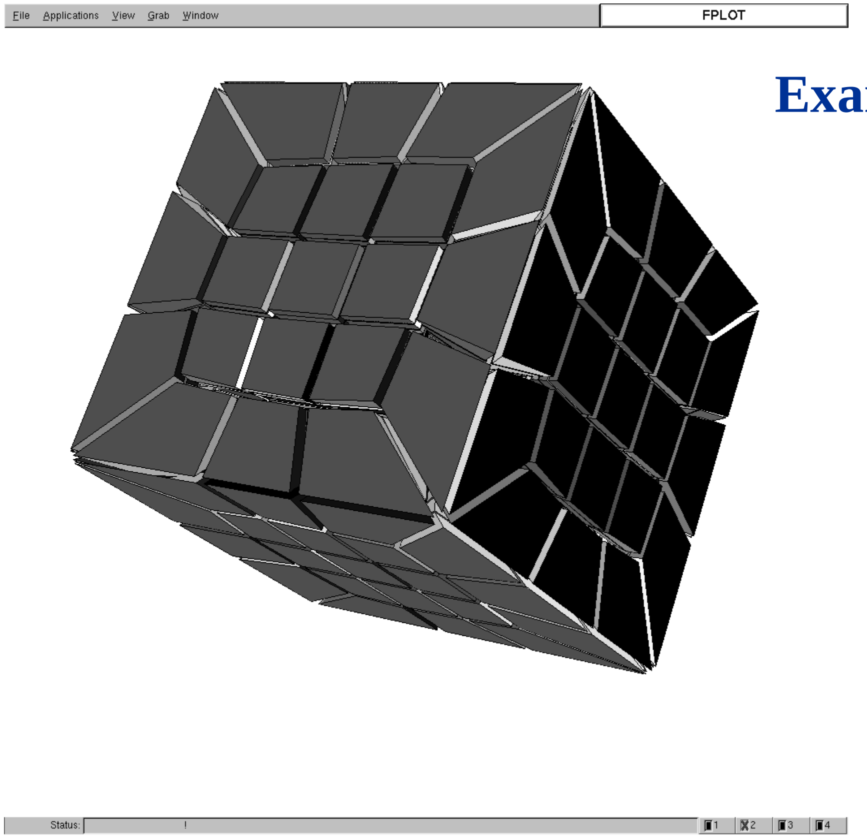


Example (1) of overset hexahedron ---
Plane cuts of tree/core grid and hair grid for an ogive cylinder.

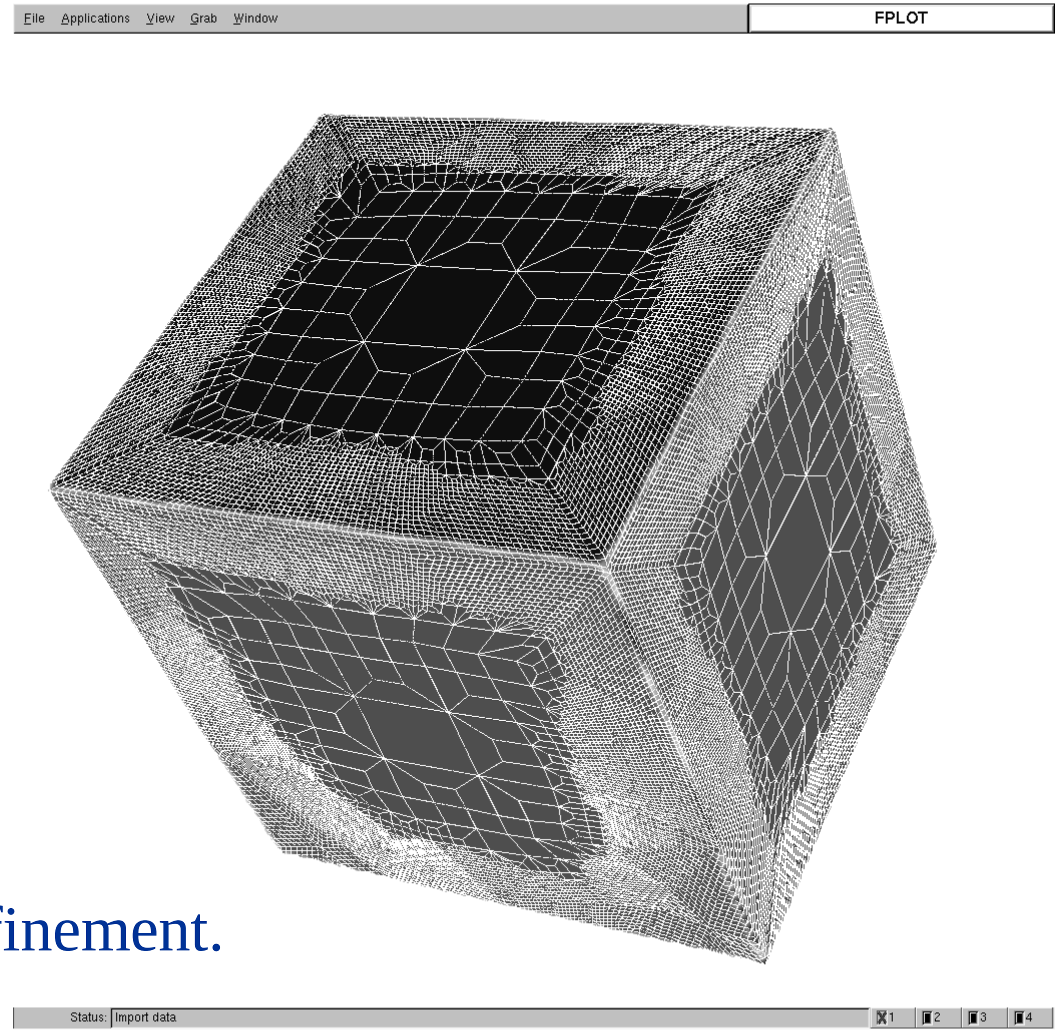


Plane cuts of tree grid and hair grid of X-38.

Example (2) of overset hexahedron ---X-38

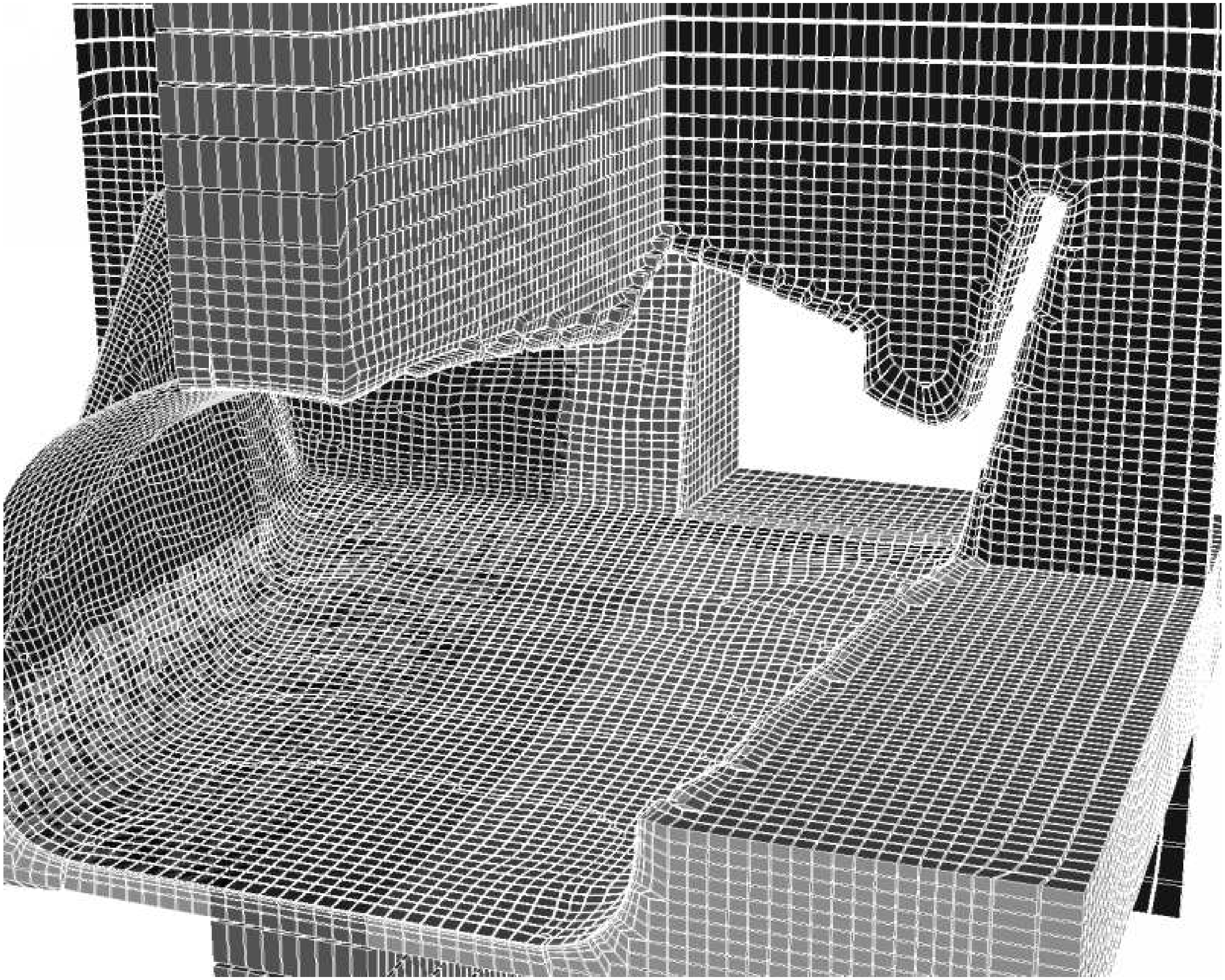


Example (1) of all-hexahedron mesh



Seam corners and curves
captured via adaptive mesh refinement.

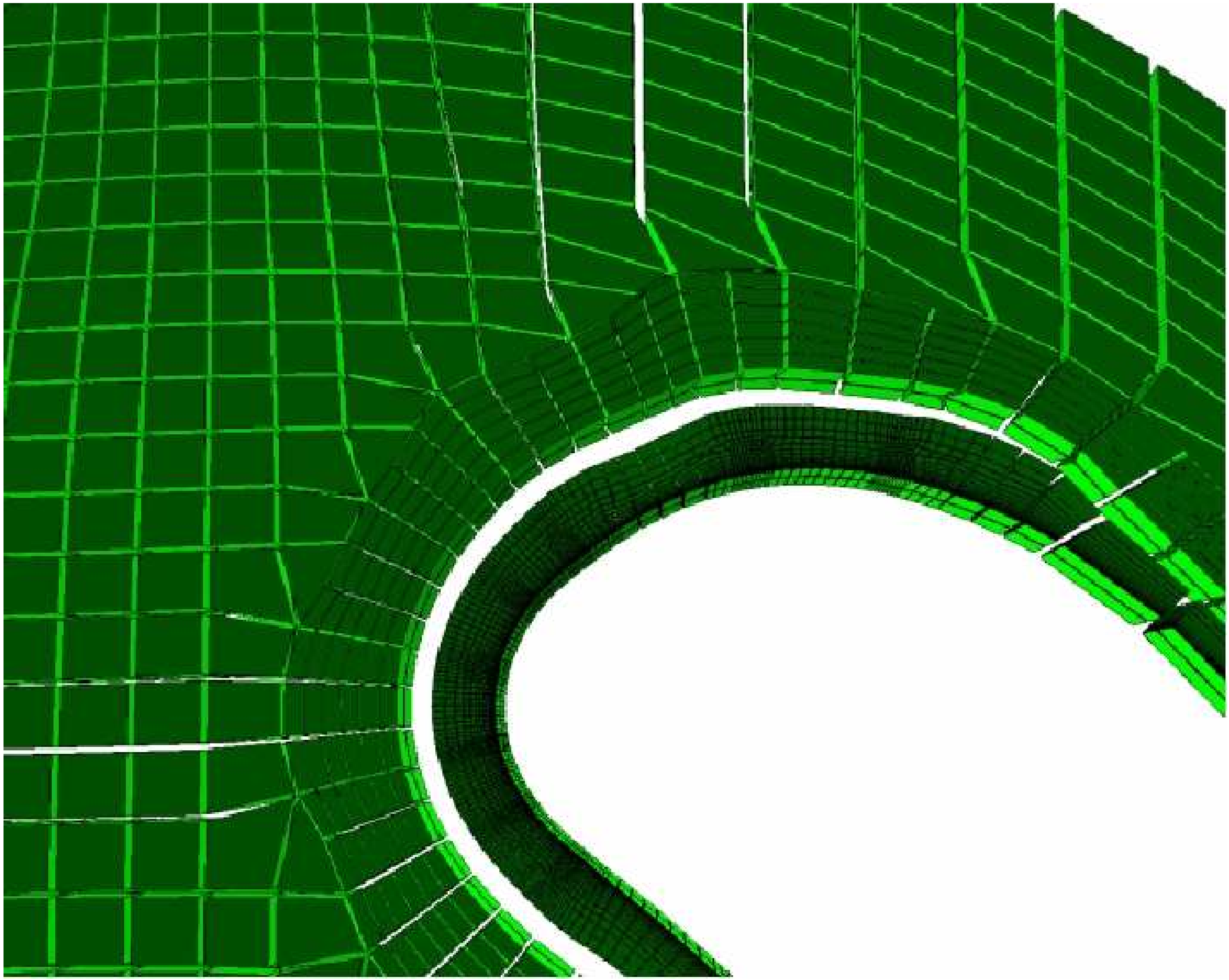
Example (2) of all-hexahedron ---X-38



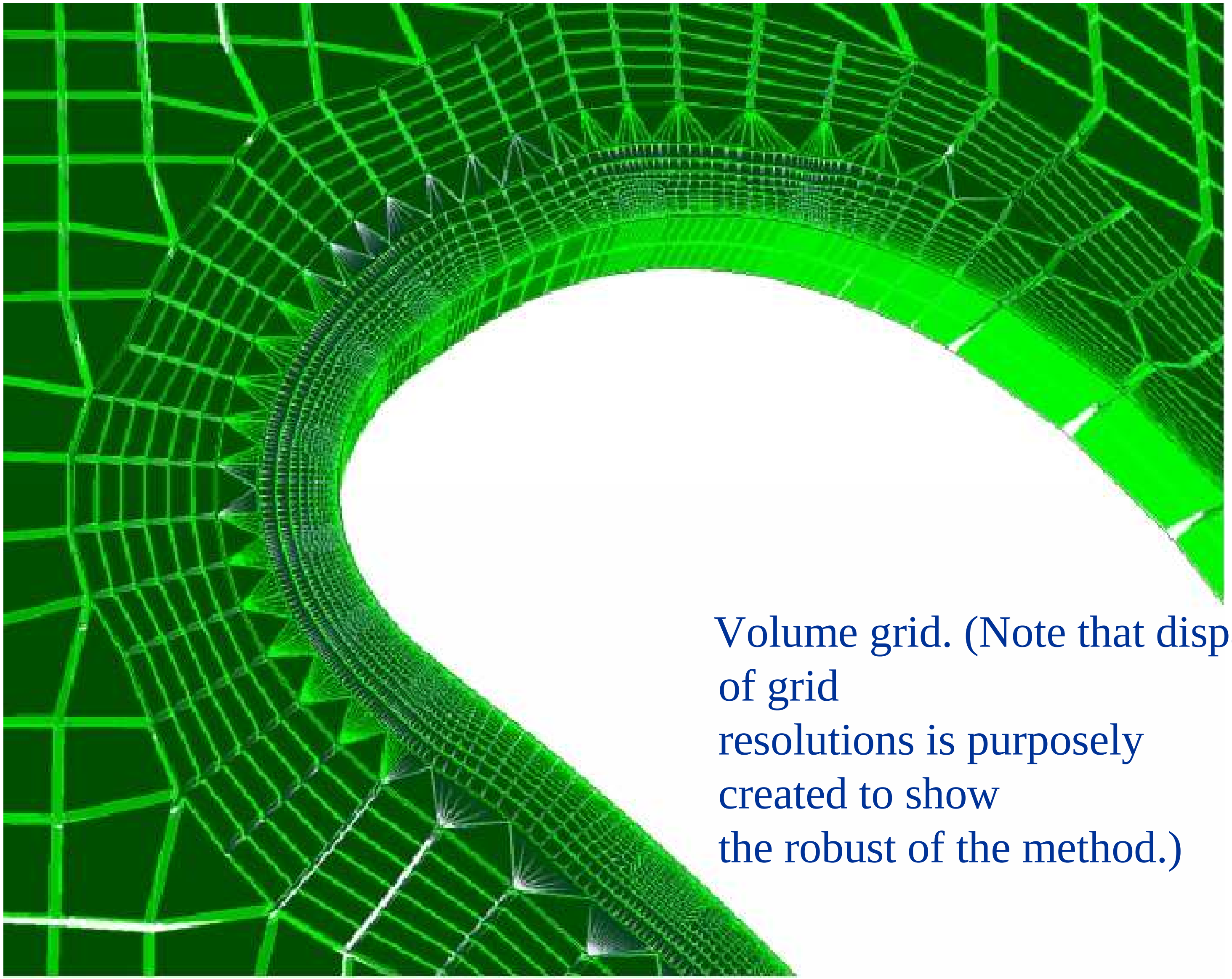
A combination of quadrilateral surface elements and internal hexahedrons

Two-Boundary Marching Method

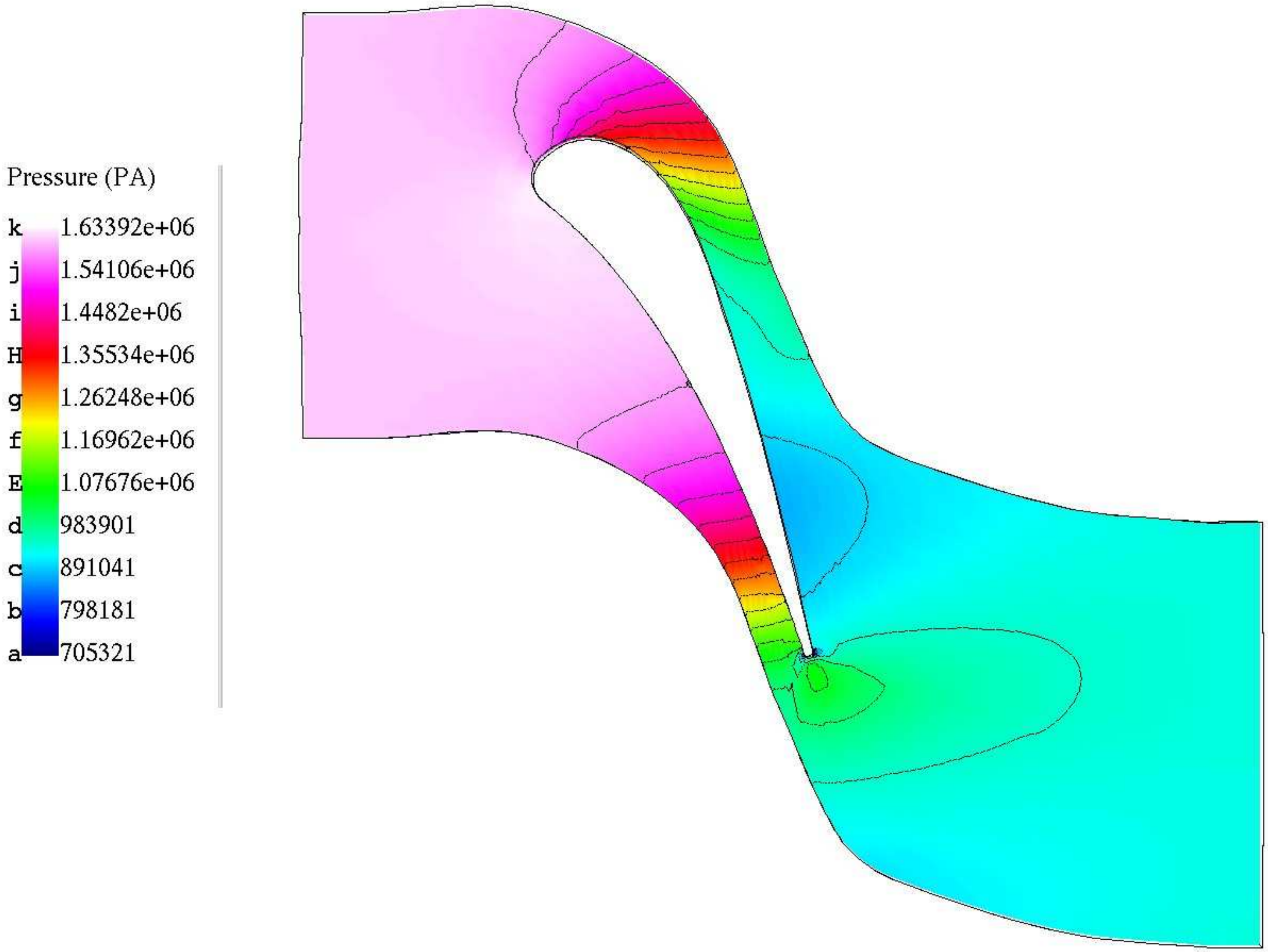
- Generates marching grid from the turbine surface
- Generates passage grid influenced by turbine marching grid
- Builds particle trace grid guided by turbine marching grid. it terminates before reaching turbine surface.
- A thin space is formed between two marching grids
- Volume grid is generated in the thin space using an advancing front method by partitioning the sub domains into pyramids, tetrahedrons and wedges



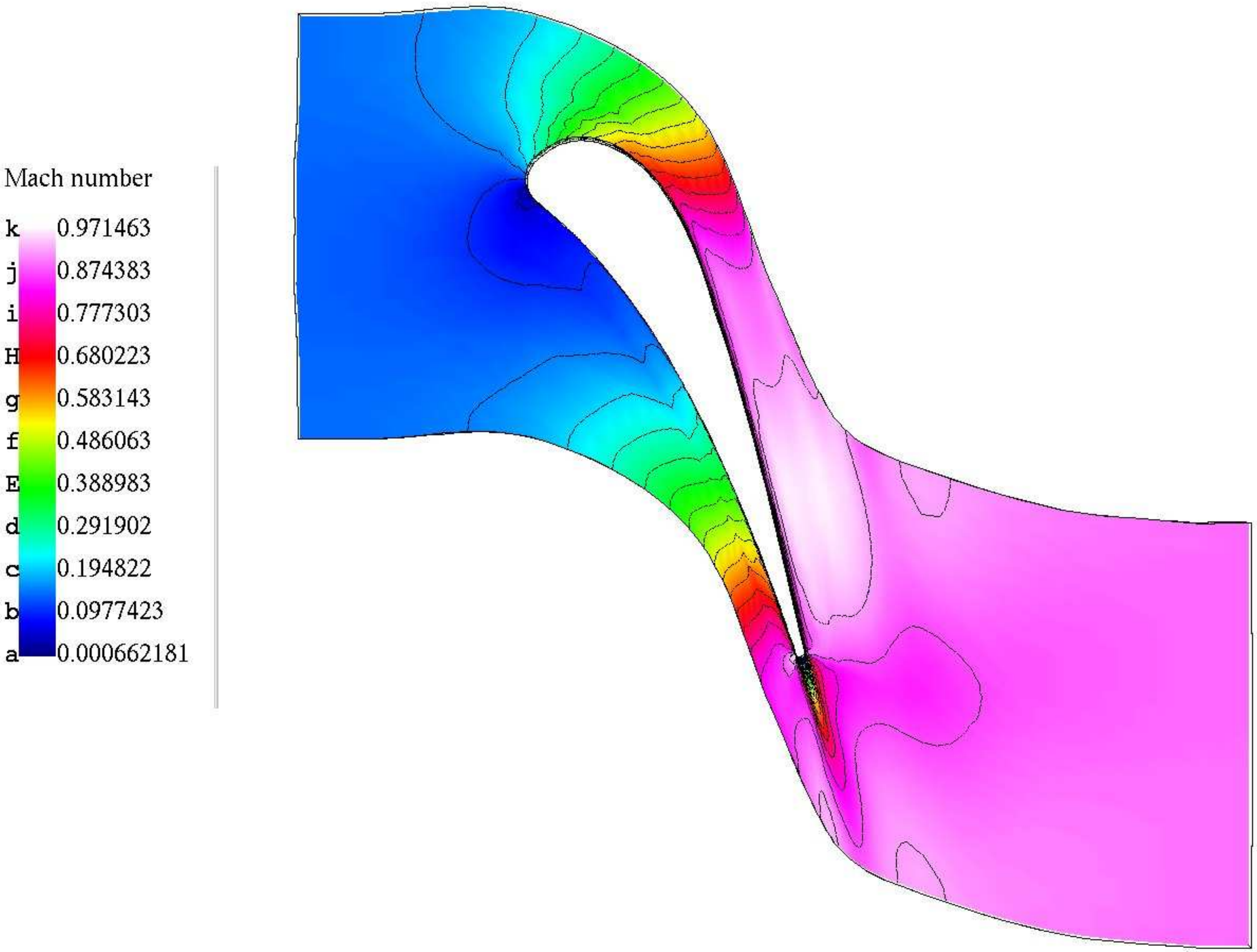
A thin space between surface marching grid and particle trace grid.



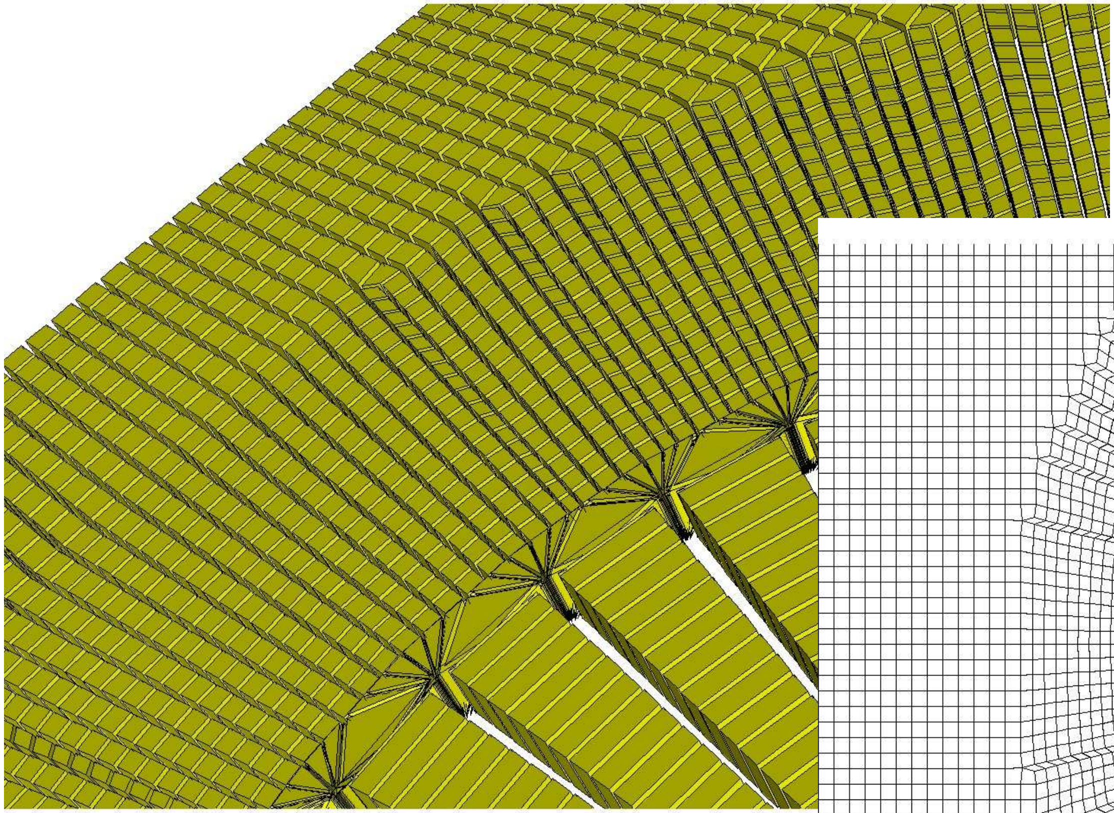
Volume grid. (Note that disparity of grid
resolutions is purposely
created to show
the robust of the method.)



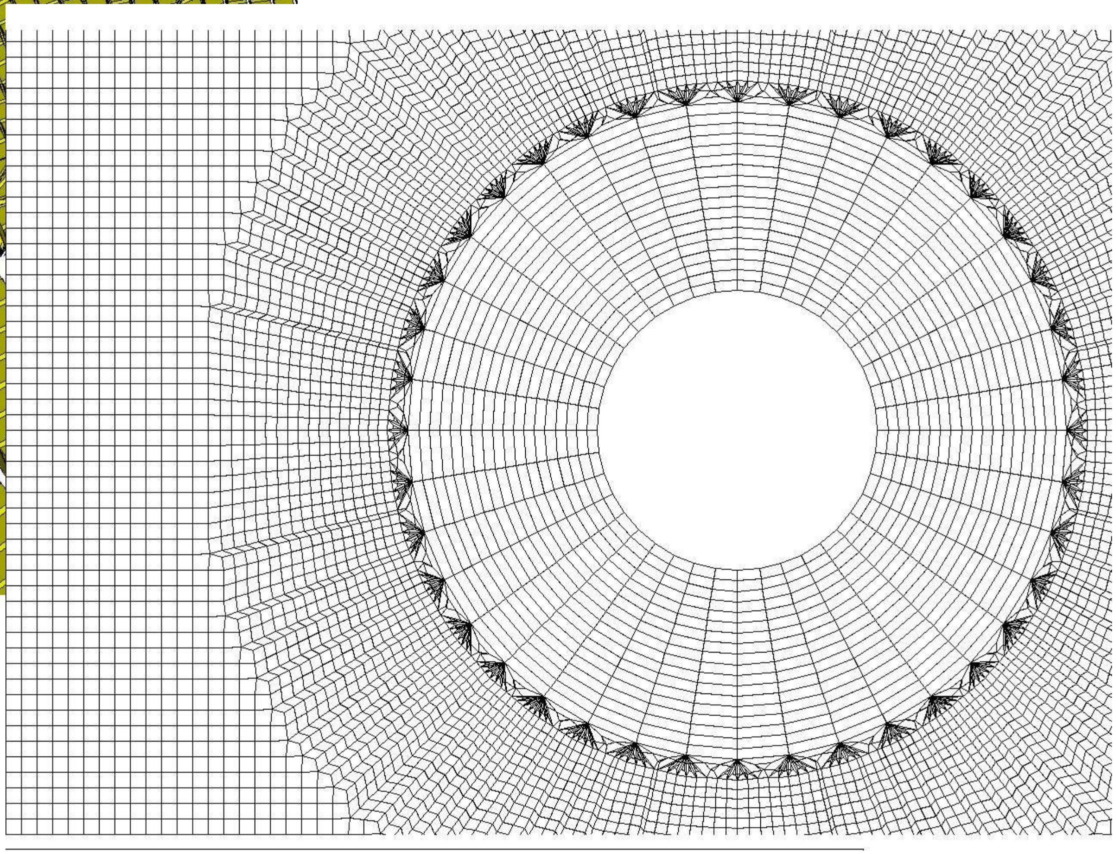
Static pressure contours of a turbine blade with hybrid meshes.



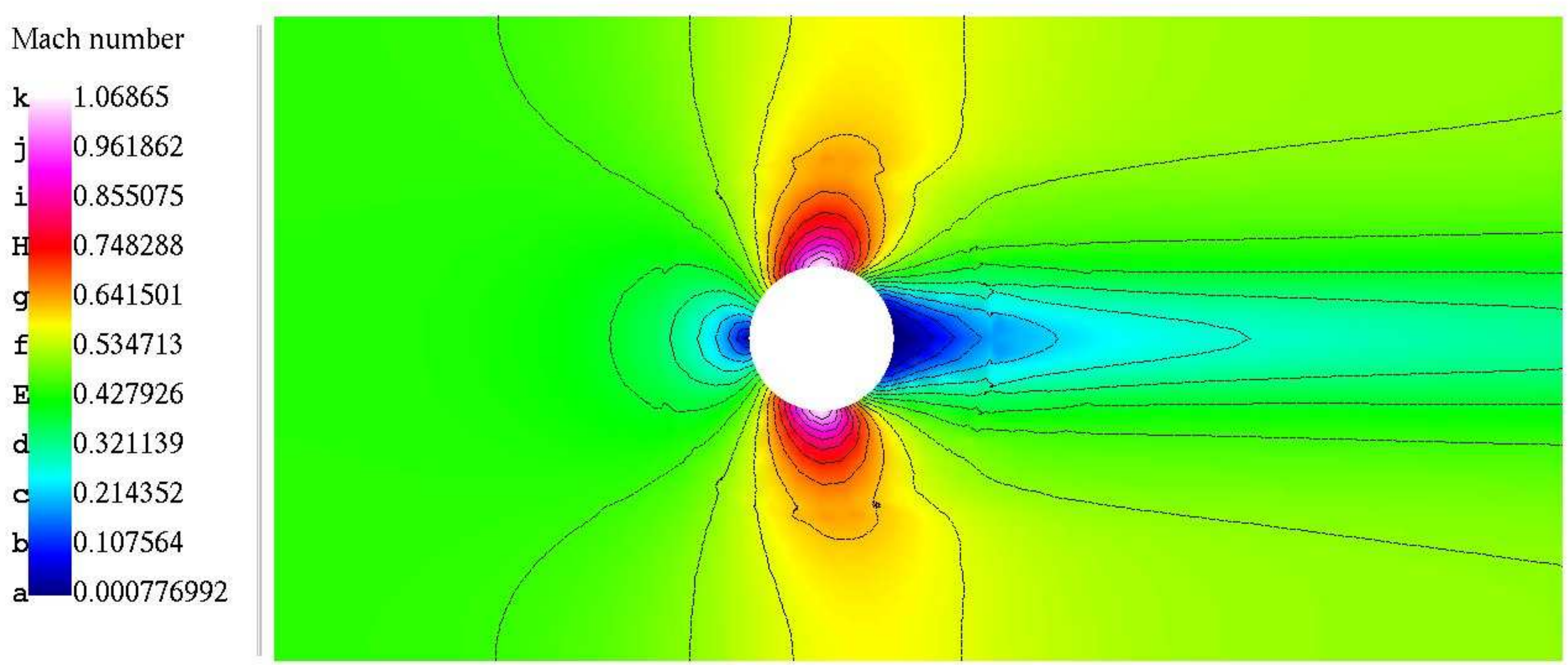
A plane-cut view of Mach number.



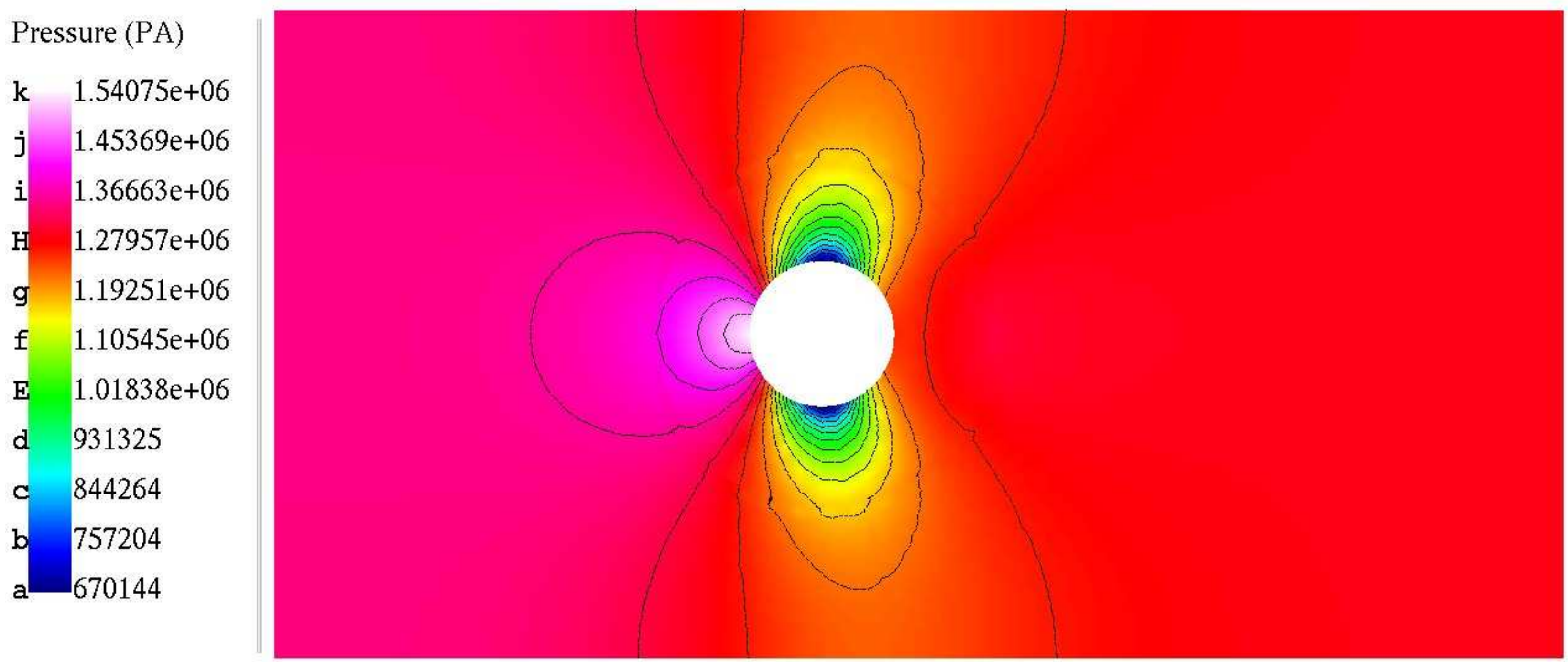
A 3d mesh plot that shows hexahedrons, pyramids, wedges and tetrahedrons.



Mesh transition from hexahedron to pyramid and tetrahedron and back to hexahedron.



Plot of Mach number contour.
The contour lines that pass through the transition mesh show the influence of changing mesh types.



Plot of pressure contour.
The contour lines that pass through the transition meshes display slight imperfection.

Concluding remarks

- A hexahedron mesh generation method has been modified to create hybrid meshes by merging surface marching grids and inside out grid-based meshes via an advancing front method.
- This mesh generation is part of a unified approach to generate unstructured (1) overset-hexahedron, (2) all-hexahedron, (3) mostly-hexahedral meshes.
- More realistic geometries will be used to generate the third type of meshes.