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Overset Meshing in ANSYS Fluent

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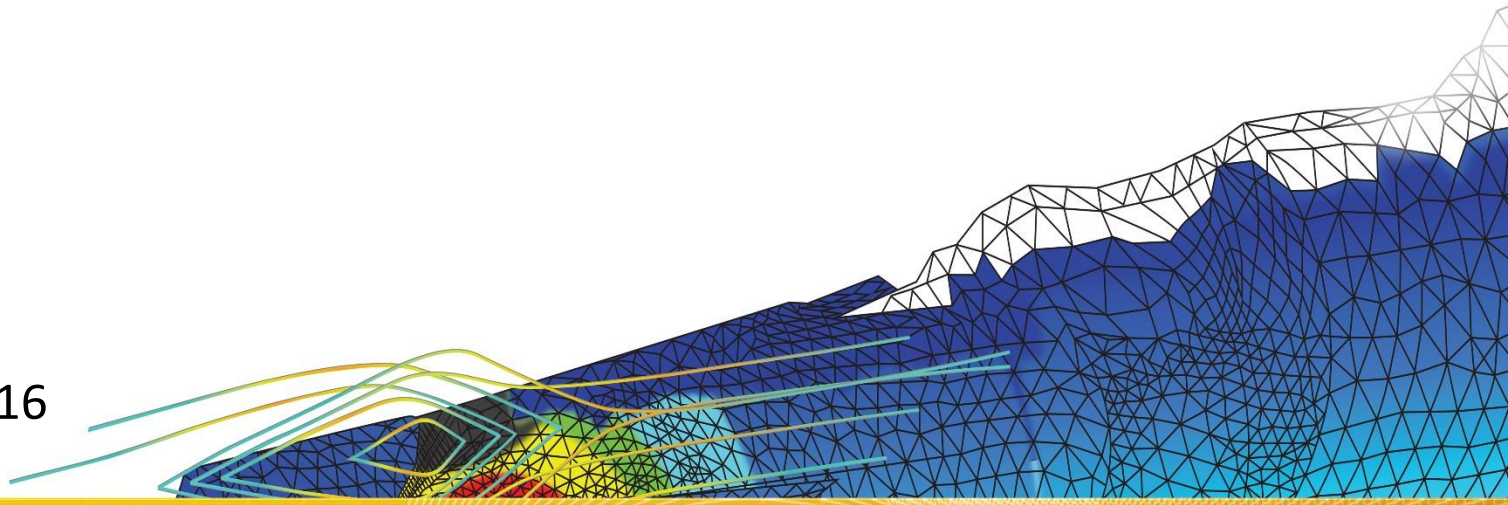
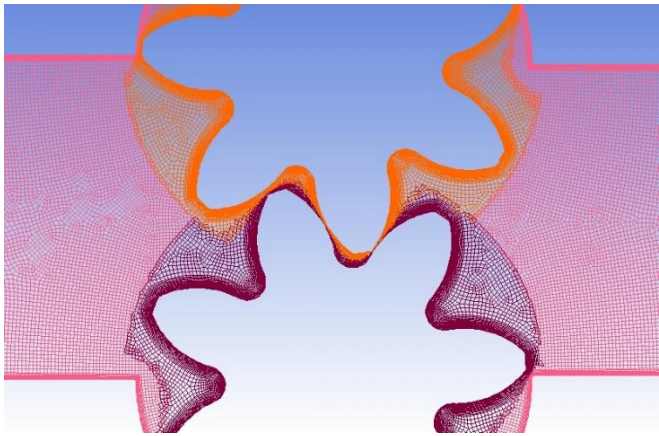
Thomas Scheidegger

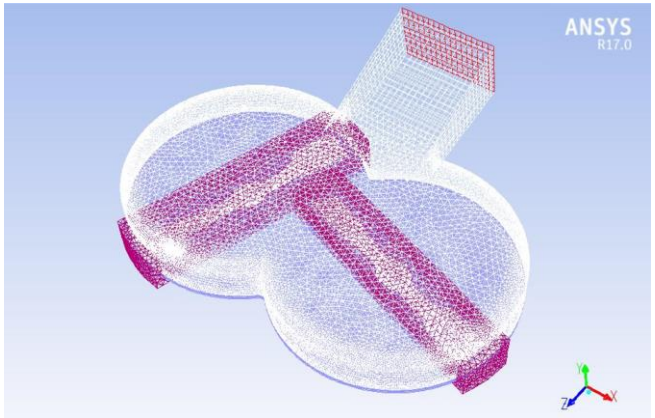
October 20, 2016



Motivation for Overset Meshing in ANSYS Fluent

- **Extending current capabilities**
  - **Better handling of relative mesh motion with small gaps (gears, pumps)**
- **Ease of use**
  - **Perceived simplified mesh generation for complex geometries**
  - **Avoid remeshing failures and setup issues as in dynamic mesh**
  - **Easier configuration changes and part swapping**
- **Solution quality**
  - **Overset grids maintain grid quality during mesh motion**
  - **Locally structured meshes in a generally unstructured grid**





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Overset in ANSYS Fluent

- **Fluent 17.0 (2016)**
  - **Pressure-based solver**
    - **Coupled scheme for pressure-velocity coupling**
    - **Steady-state and transient**
  - **k-eps and standard k-w turbulence models**
  - **Single phase and Volume of Fluid (VOF) multiphase**
  - **All element (polyhedra) and mesh types**
  - **Adaptive mesh refinement**
  - **Fully parallel**

- **Fluent 18.0**
  - **Density-based solver**
  - **Dynamic Mesh (rigid and deforming)**

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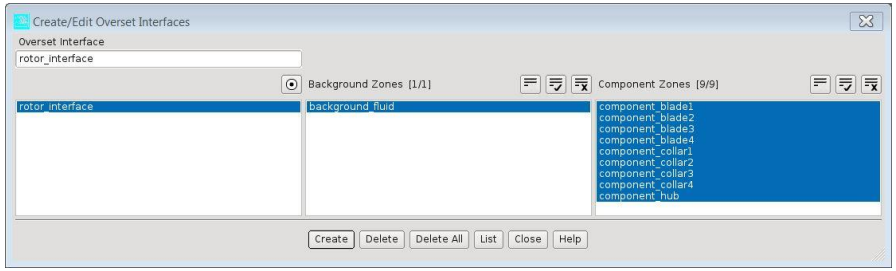
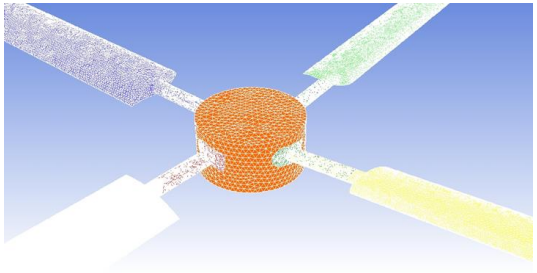
Overset in ANSYS Fluent

- **User interface with minimal input required to handle all supported topologies**
  - **No connectivity information required**
  - **Requires automatic detection of matching (overlapping) geometry**
  - **User specifies set of background and component grids to be paired in overset interface**





  - **Optional inputs**
    - **Global grid priorities to favor zones in the assembly process**
    - **Local cell priorities to favor cells based on size or boundary distance**

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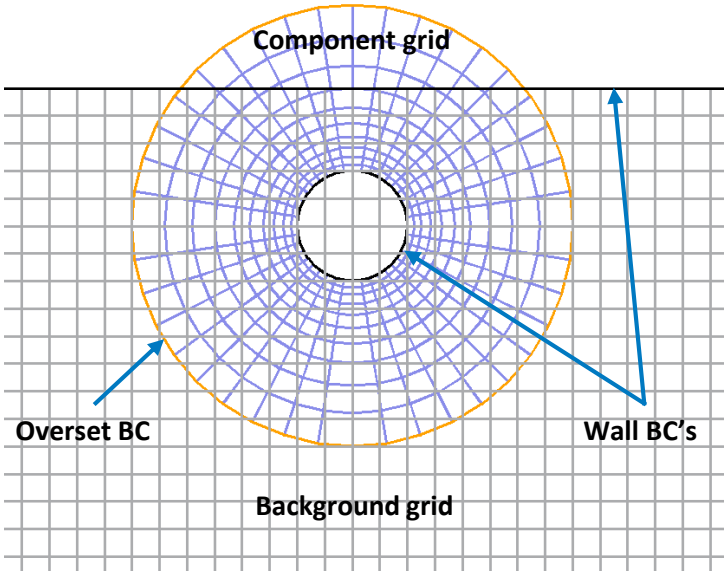
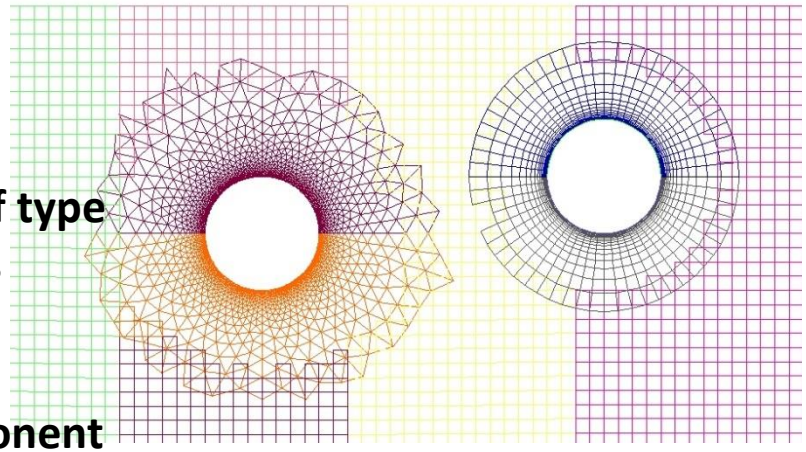
Overset in ANSYS Fluent



- **Overset interface**
  - Pairs multiple component grids with multiple background grids
  - Needs to have at least one background and one component grid
- **Background grid**
  - Cell zone which does not have a boundary zone of type overset. Multiple background grids have to be conformally connected.
- **Component grid**
  - Cell zone which has at least one boundary of type overset. Component grids can be conformal.
- **Overset boundary**
  - Boundary condition to designate that component grids are intended to communicate with other grids



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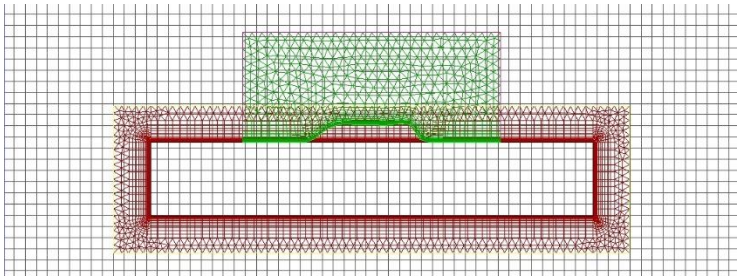
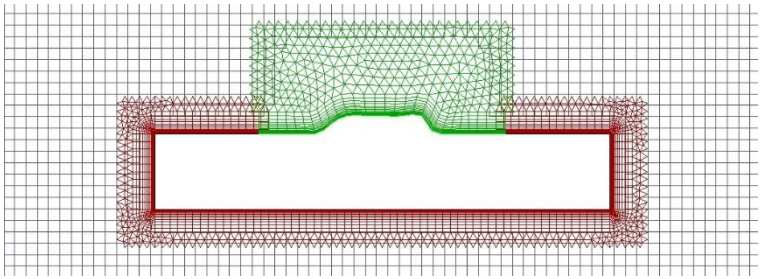
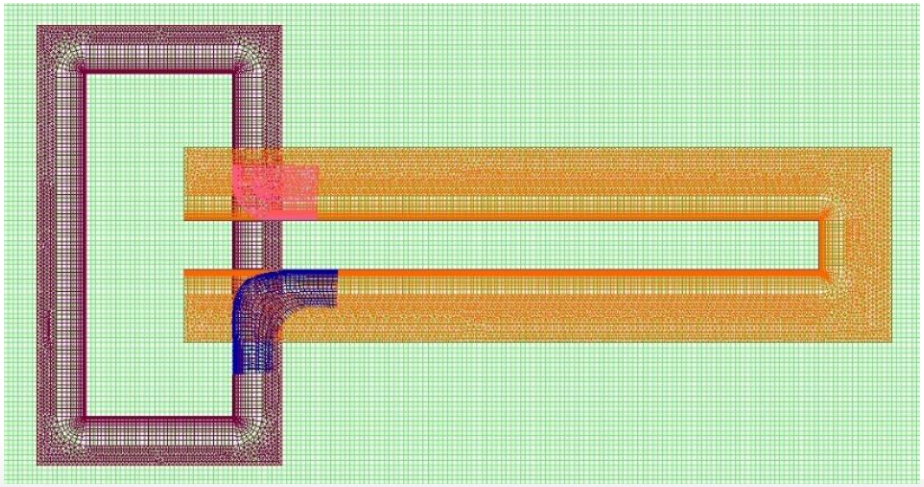
Overset in ANSYS Fluent

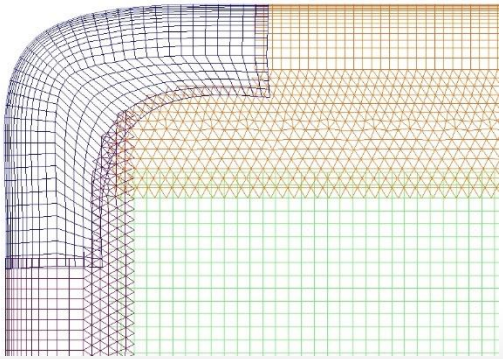
- **Overlapping boundaries**
  - **Automatic detection of matching/overlapping geometry of same boundary condition type (wall, symmetry, inlet…) during hole cutting**





- **Intersecting wall boundaries require collar grids**
  - **Collar grids generate boundary overlaps and remove the actual intersection**





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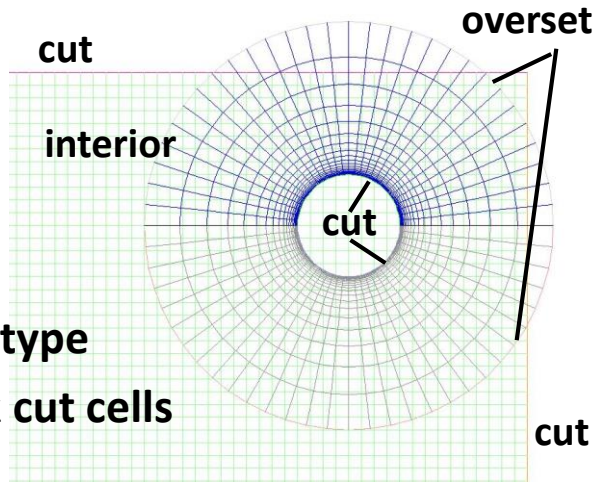
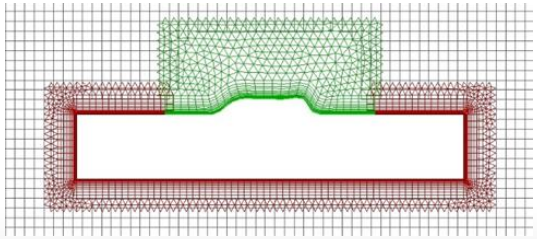
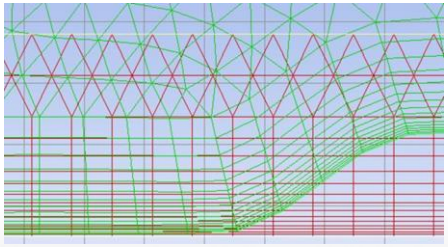
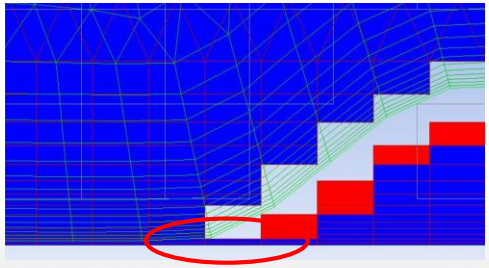
Hole Cutting



- **Direct hole cutting**
  - Face zones are identified as of *cut*, *overset*, or *interior* type
  - Faces of cut zones cut faces of interior zones and mark cut cells
    - Face candidates filled into kd-tree
    - Overlapping cut faces are considered to belong to the same geometry and do not cut
      - Requires robust marking/protection of overlapping cut faces. Tolerances based on adjacent cell height and local feature angles.
    - All face types triangulated for fast tri-tri intersection test
  - Cells outside the computational domain are marked by flood filling
    - Requires reliable marking of seed cells
    - Requires sufficient matching of overlapping cut zones (no leaks)
      - Thin-cut correction to prevent leaks in inflation layers







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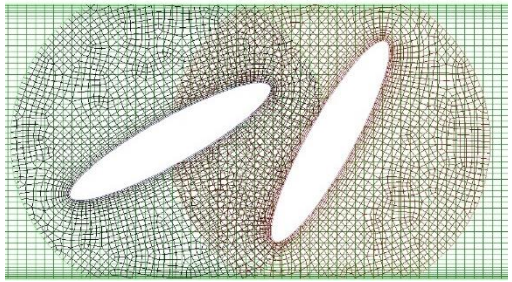
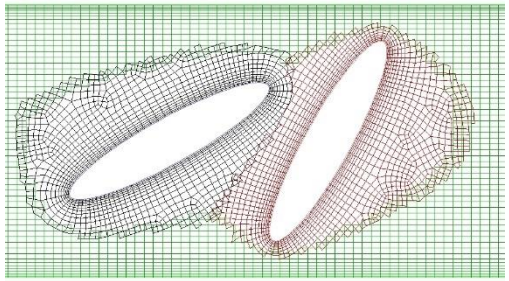
Overlap Minimization

- **Reduce overlap by converting additional cells into dead cells**
  - **Mark temporary receptor cells on maximum overlap grid**
  - **Flood fill additional receptor cells if cell finds valid donor cell with**
    - **Higher grid priority (optional), or**
    - **Higher cell donor priority**
      - **Inverse of local average cell size or boundary distance**
      - **Grid priority overrides cell donor priority**
    - **Bounding cell search using octree and neighbor walk**
      - **Cached bounding cells with moving mesh**
  - **Remove solve cell islands (due to irregular unstructured grids)**
    - **Flood fill solve cells from cut face zones and convert unreached solve cells to receptors, if permissible**
  - **Convert unnecessary receptors to dead cells**





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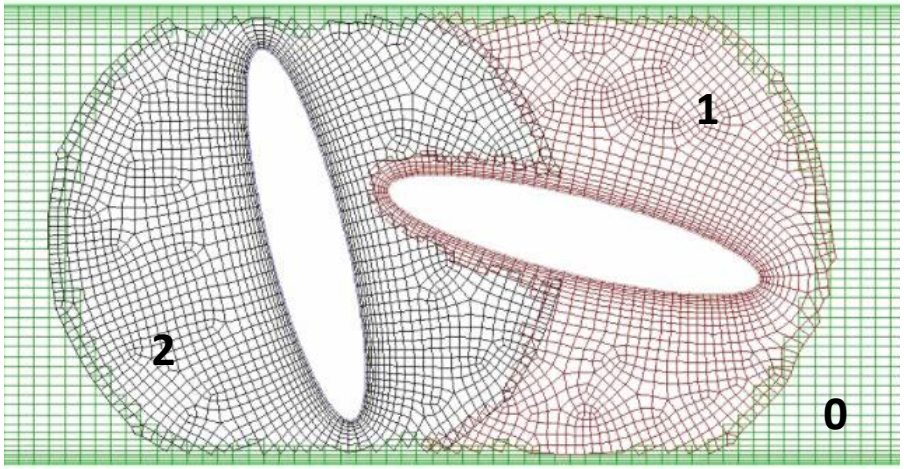
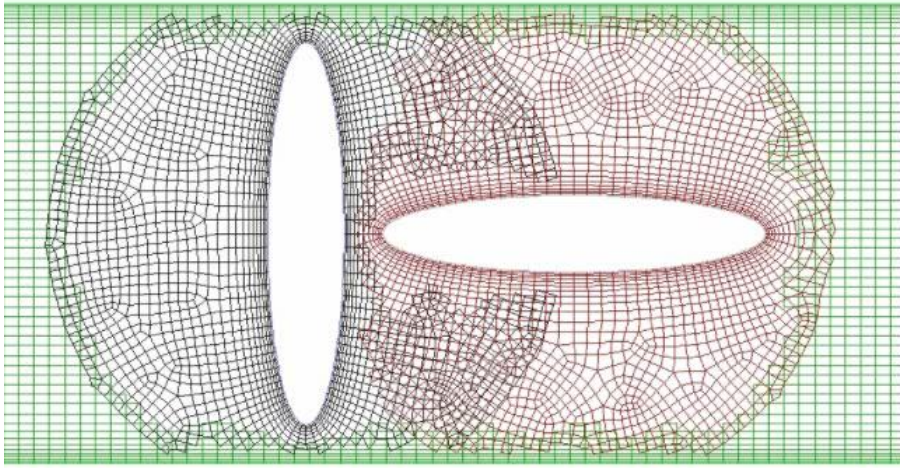
Overlap Minimization

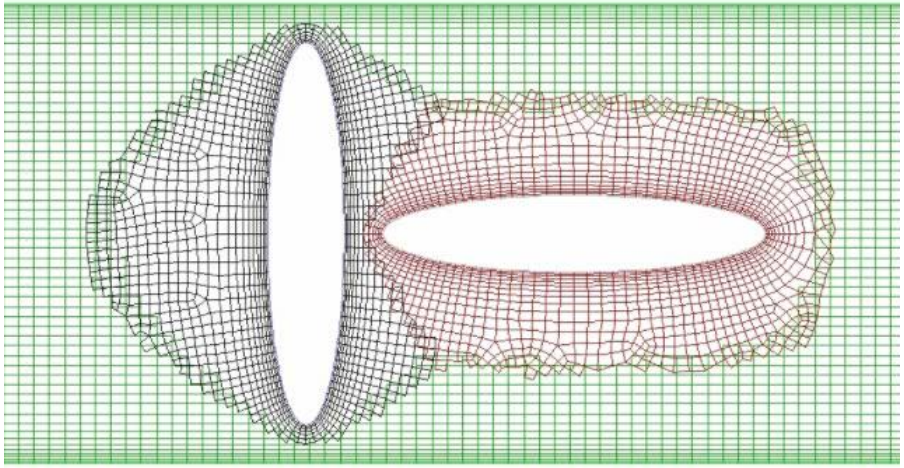
- **Cell donor and grid priorities**
  - **Can be combined**



Grid priorities



Cell size based donor priority



Boundary distance based donor priority

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Donor Search

- **Bounding cell with highest cell donor priority is principal donor**
  - **Byproduct of overlap minimization**
  - **Cache bounding cells in moving mesh simulations**
    - **Starting point for neighbor walk**
  - **Donor stencil includes face or node connected cells**
  - **If only receptor cell is found, option to accept closest connected solve cell**
    - **Reduces orphan cells where overlap is minimal**
  - **In transient simulations, exclude donors which were dead cells in previous time step**

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Parallel Overset Meshing

- **General implementation to allow any available partitioning method**
  - **Replicating mesh as "extended zones" as needed in order to make hole cutting, overlap minimization, and donor search local operations**
    - **Face and cell zones replicated based on overlapping axis-aligned bounding boxes**
      - **Cut face zones extended for hole cutting**
      - **Component and background cell zones extended for minimization and donor search**
  - **Parallel performance depends on partitioning**
    - **Size of extended zones → intersection time**
    - **Size of parallel neighborhood → solution exchanges**
    - **Distribution of solve cells → solver scaling**

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Parallel Overset Meshing

- **Partitioning Methods**
  - **Metis default partitioner**
  - **Option to include overset donor-receptor connectivity in partitioning (Metis-DR)**
  - **Option for model-weighted partitioning to distribute solve cells evenly (Metis-MWP)**
    - **Default for steady state calculations**
  - **Periodic repartitioning of domain for moving mesh**

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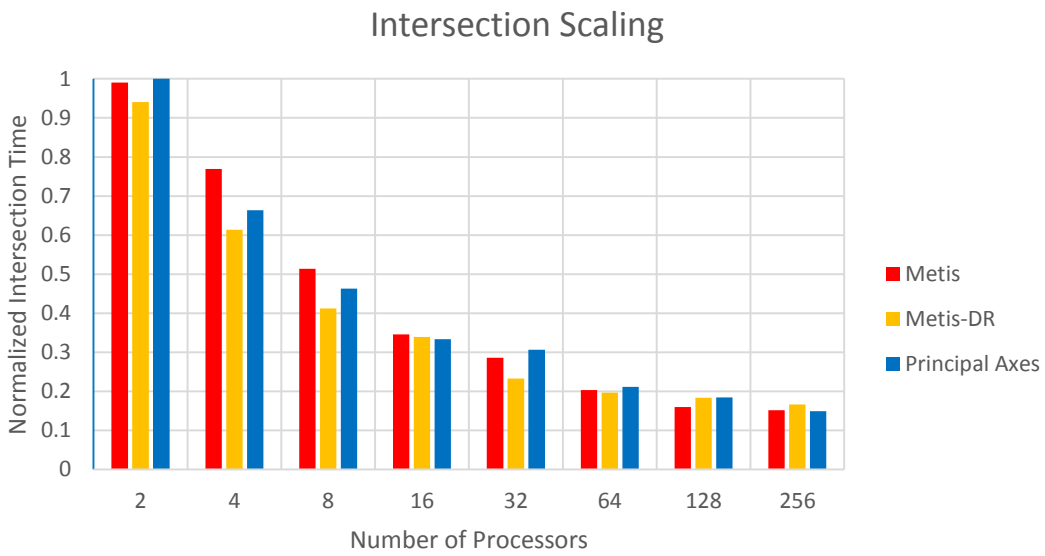
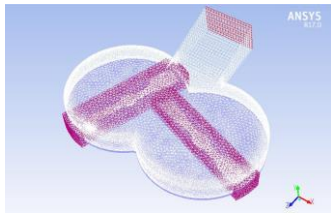
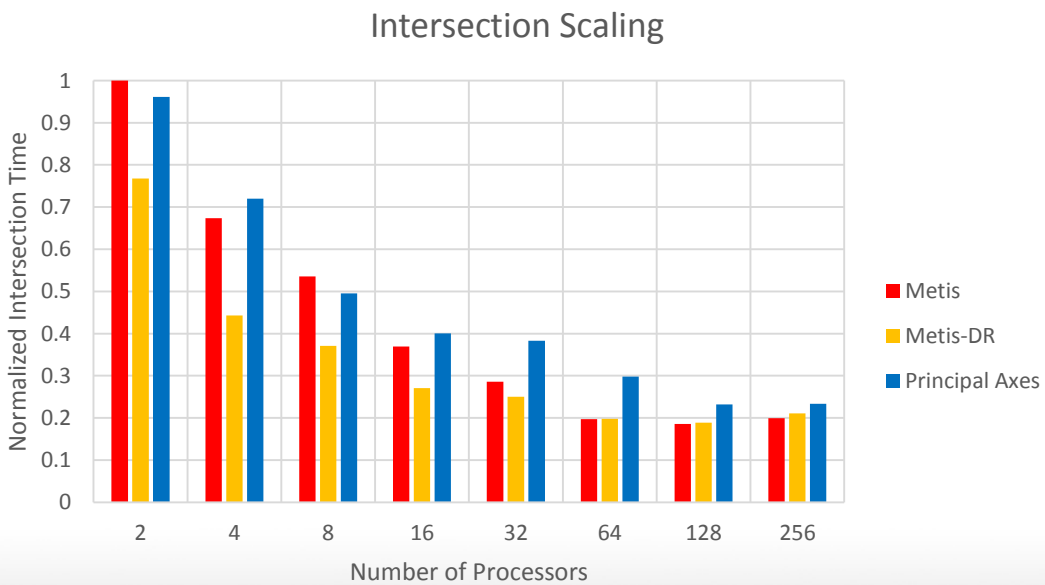
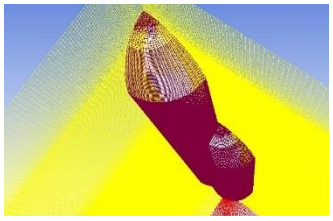
Parallel Overset Meshing





1.8M cells





1.7M cells

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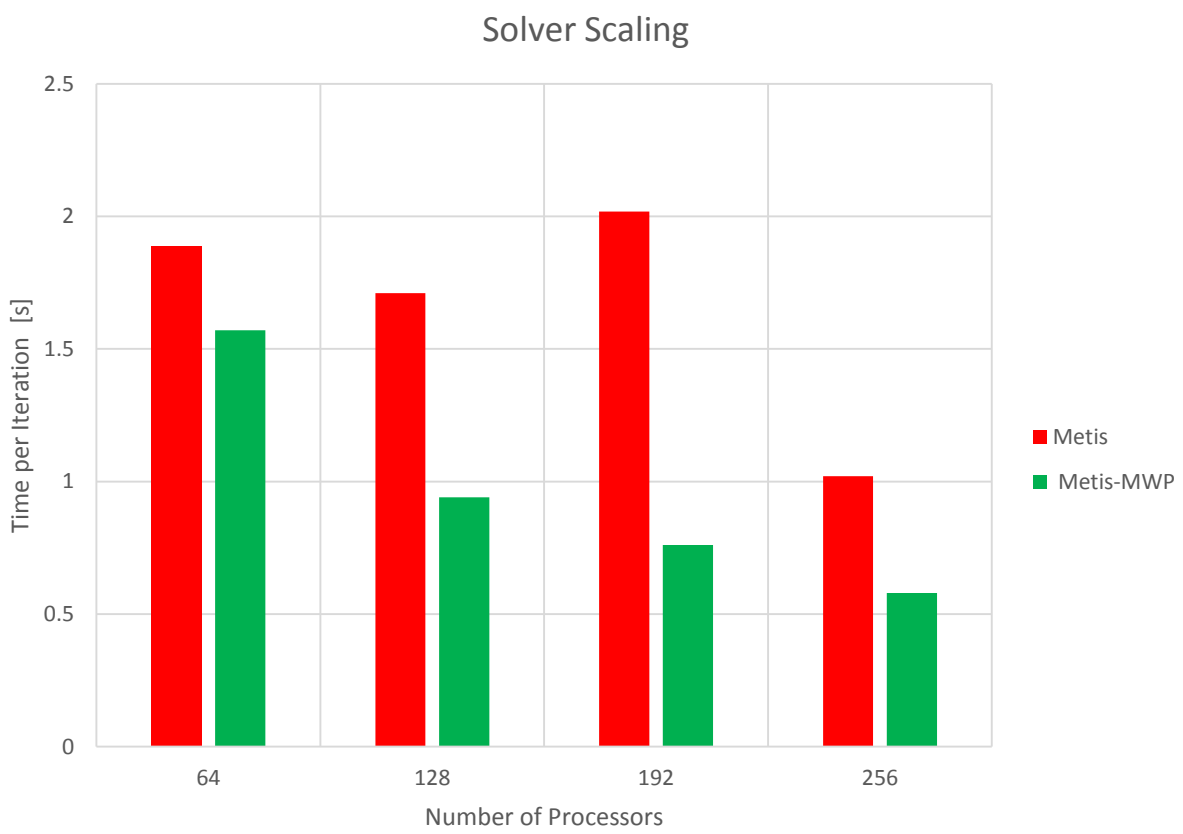
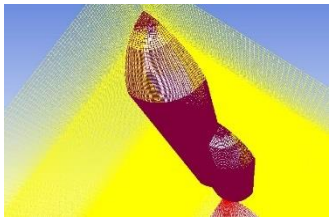
Parallel Overset Meshing





1.7M cells

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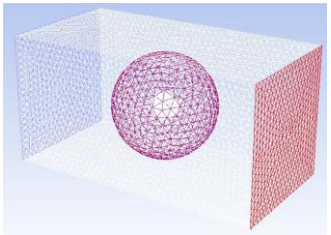
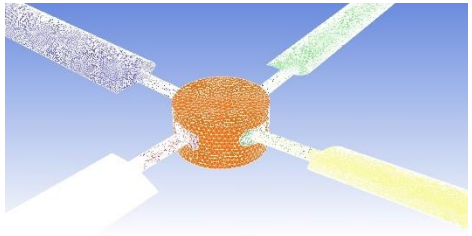
Transient Overset Meshing

- **Caching of entities to be reused in subsequent time steps**
  - **Bounding cells for overlap minimization and donor search**
  - **Extended face and cell zones for rigid body motion**
    - **Extended entities are moved/updated during mesh motion**



Moving ball

parallel, -t6, Metis	n0 [s]	n1 [s]
Intersection	26.2	17.0
filling extended zones	13.5	3.9



parallel, -t36, Metis	n0 [s]	n1 [s]
intersection	59.4	32.5
filling extended zones	33.7	8.1

Rotor model - Hub, 4 blades, 4 collar grids

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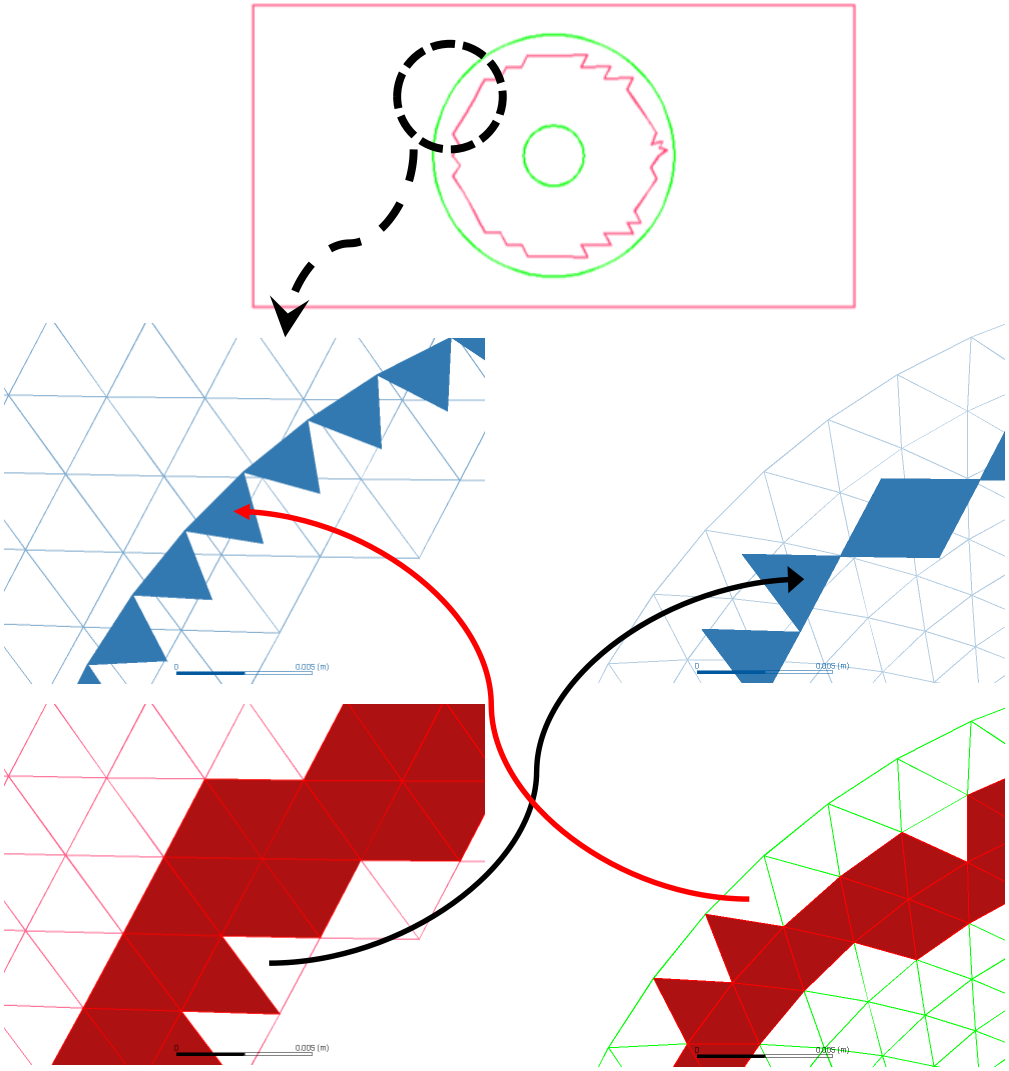
Overset Solver

Data transfer strategy

- Solution
  - Interpolate
- Gradients
  - Interpolate or compute
- Interface mass flux
  - Approximate
- Overlapped grid linear system
  - Assemble matrix with implicit coupling



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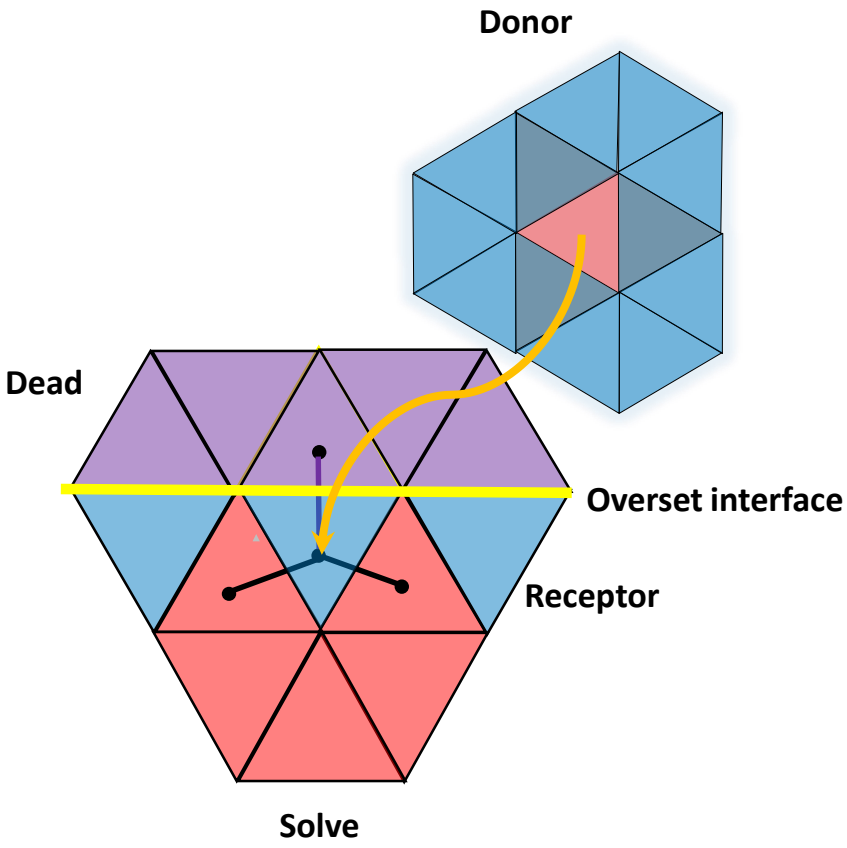
Receptor Cells

- **Interpolate solution**
  - Gradients of adjacent solve cells
  - Flux evaluations
- **Solution gradient**
  - Accurate flux evaluation
- **Supply mass flux at overset interface**
  - Linearizations, Rhie–Chow flux
- **Provide inter grid coupling information to establish matrix assembly**



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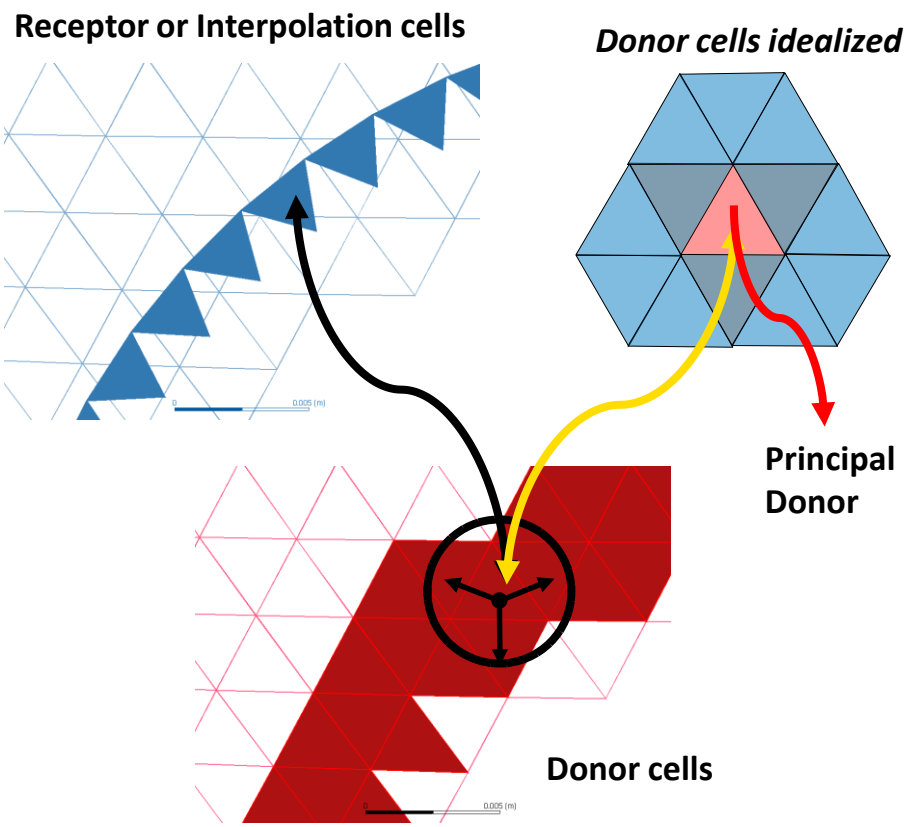
Interpolation

- One layer of receptor cells
- Face or node connected neighbors
  - Principal donor
  - Not always the centroid bounding cell
  - Variable number of donors
  - Optionally, neighbors from same grid (orphans and dead to solve cells)
- Interpolation methods
  - Inverse distance weighting
  - Least squares weighting



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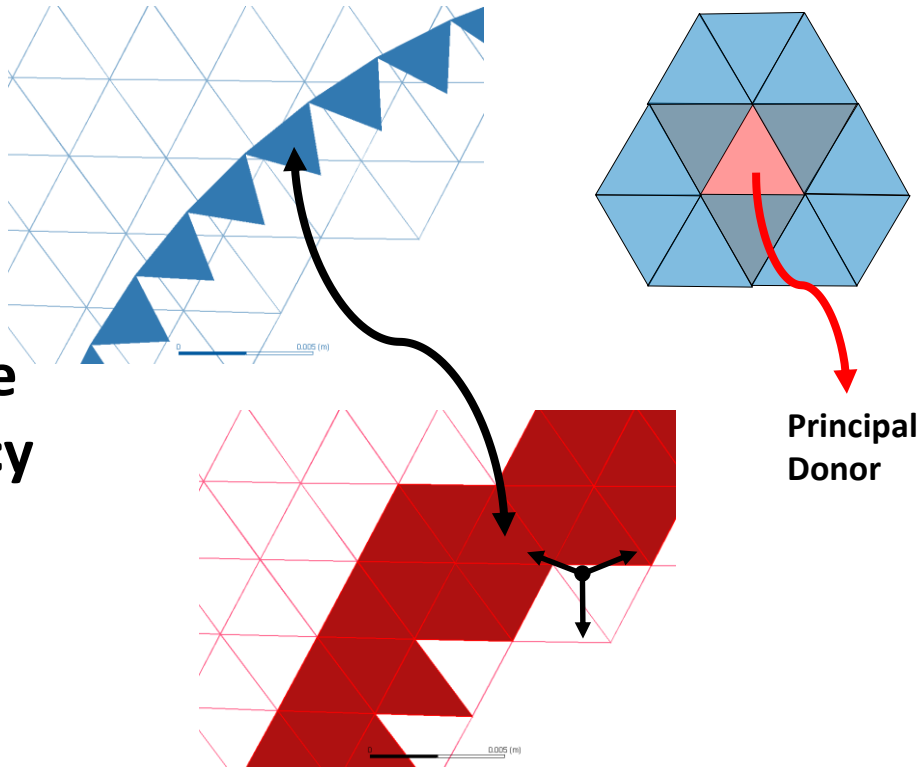
Gradients at Receptor Cells

- **Interpolate**
  - **Use principal donor gradients**
- **Compute**
  - **Use donors to evaluate gradients**
- **Resolution matching in the overlap critical for accuracy**



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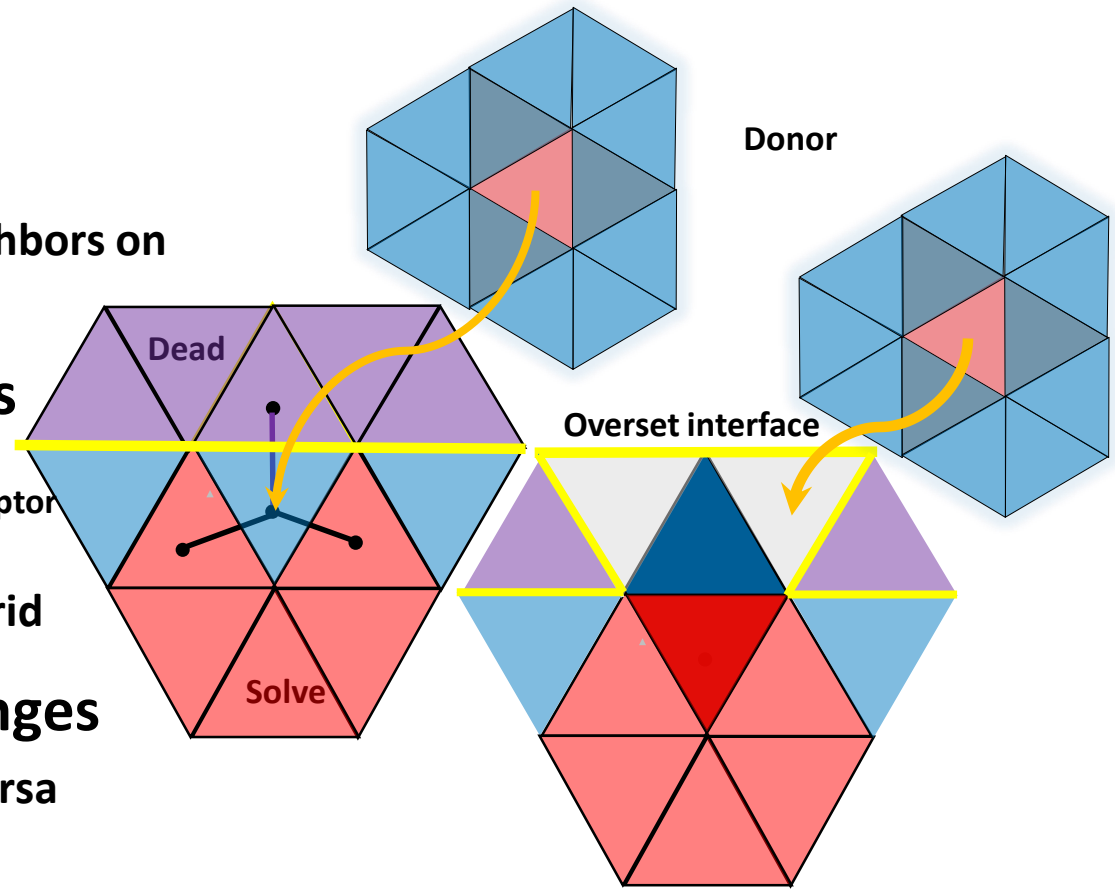
Moving Mesh

- **Dead to solve cells**
  - Interpolate from valid neighbors on the same grid
- **Dead to receptor cells**
  - Use valid donors
  - Orphans
    - Interpolate from same grid
- **Other cell status changes**
  - Receptor to solve & vice versa
  - Receptor to dead
  - Solve to dead



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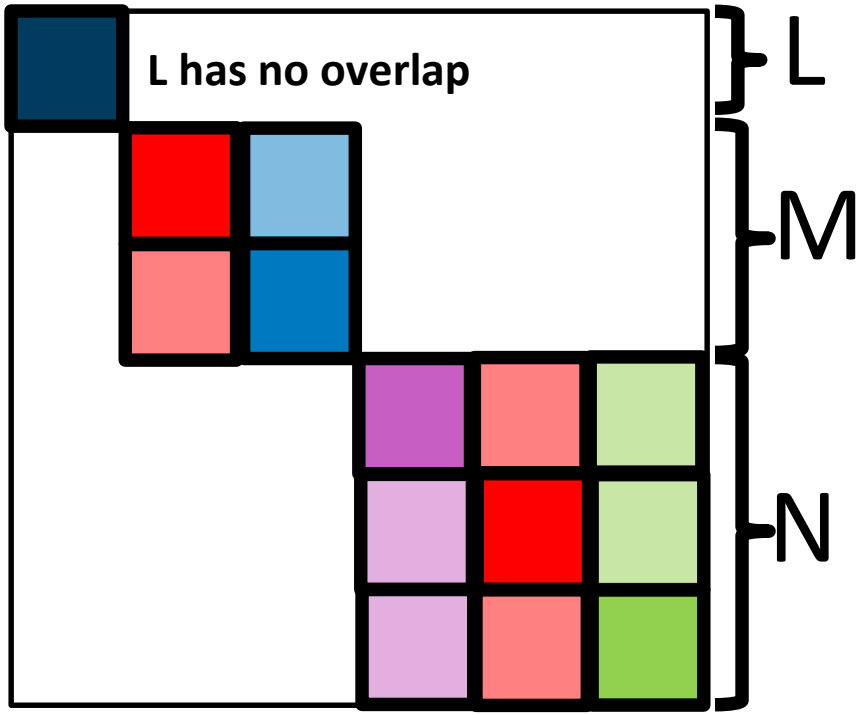
Overset Linear System

- **After discretization**
  - Augmented linear system of equations
- **Inter grid implicit coupling**
  - A_{nb} defined consistent with the interpolation at the overlap region
- **Receptors use interpolation equations**
  - Receptors are up to date after solve
- **All models are handled the same way**

$$Ax = B$$

$$A_p \phi_p = \sum_{nb} A_{nb} \phi_{nb} + S$$



M & N have overlap

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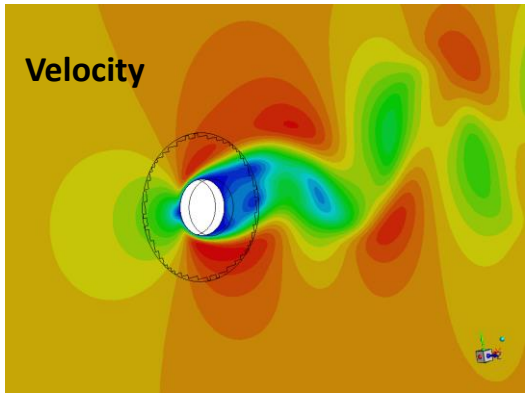
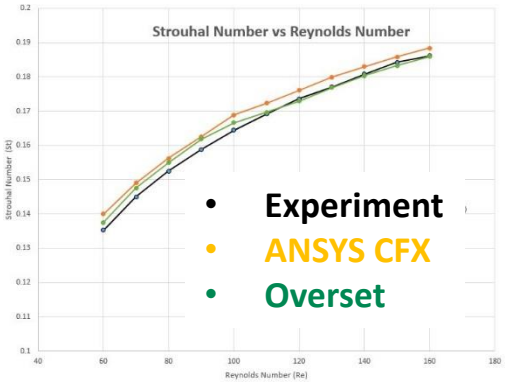
Unsteady Laminar Vortex Shedding

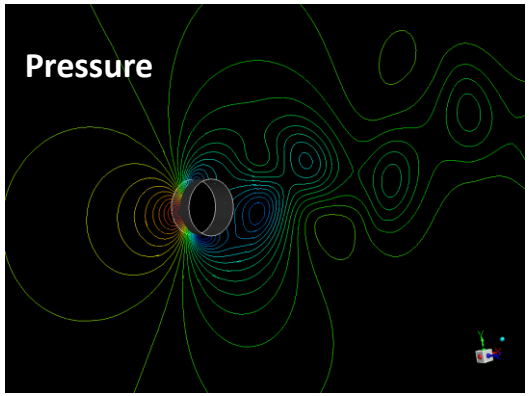


Pressure Based Coupled Solver (PBCS)

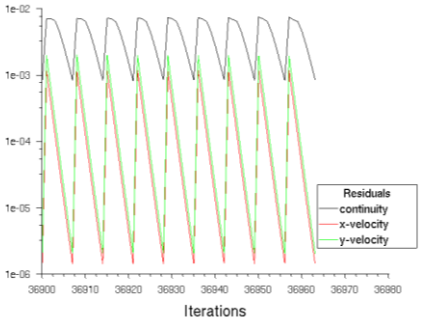
2nd order in time, dt = 0.01s

Range of Reynolds (60- 160)





Grid Size	Elements	Strouhal no. (Exp - 0.1692)	Error (%)
Coarse	11K	0.1659	1.96
Medium	25K	0.1696	-0.27
Fine	41K	0.1687	0.28



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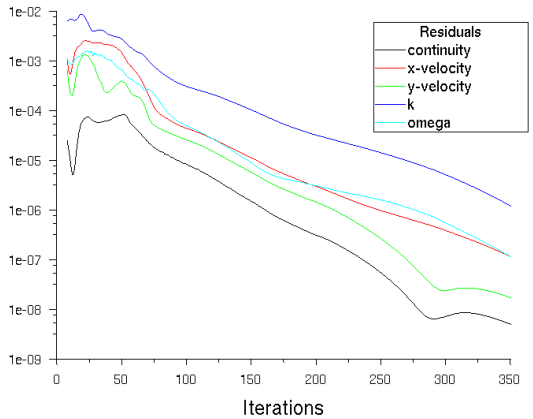
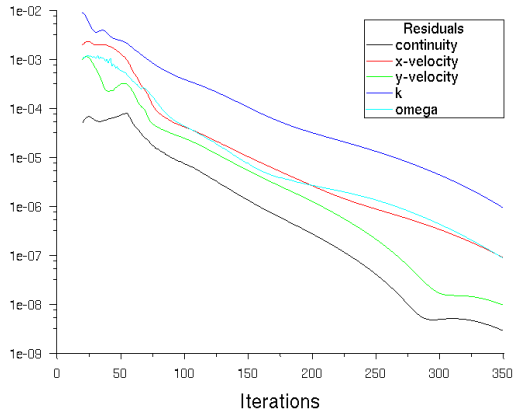
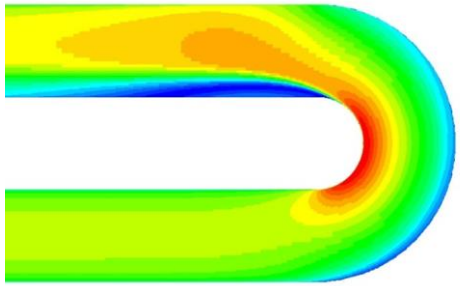
Turbulent Flow in U-Bend

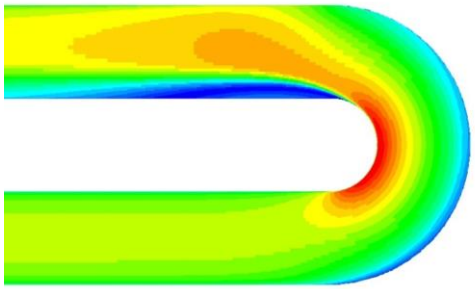




Regular

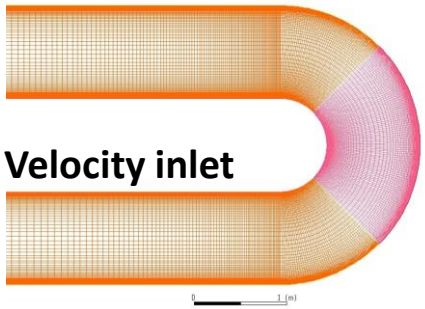


Overset

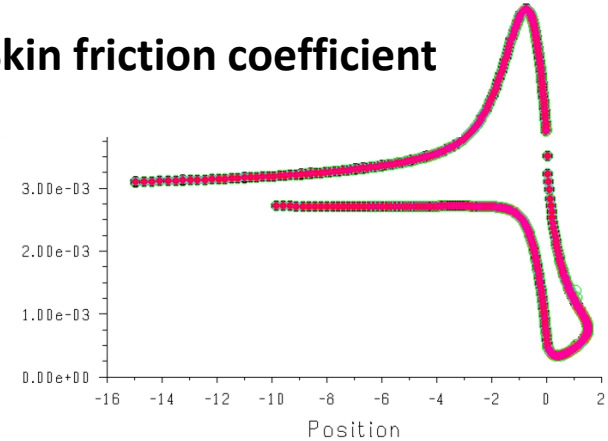


Pressure outlet

Velocity inlet



Skin friction coefficient



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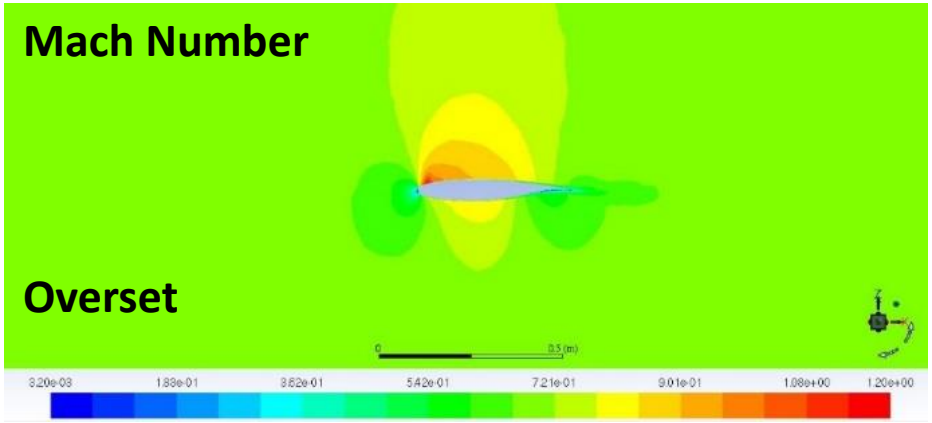
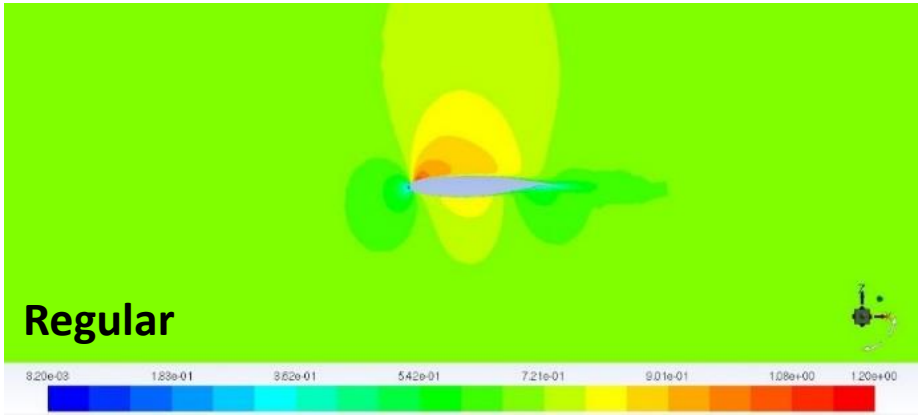
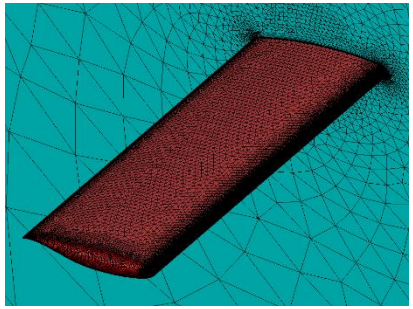
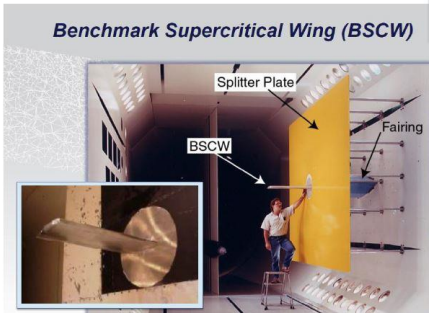
AePW-2: Turbulent Steady State External Flow

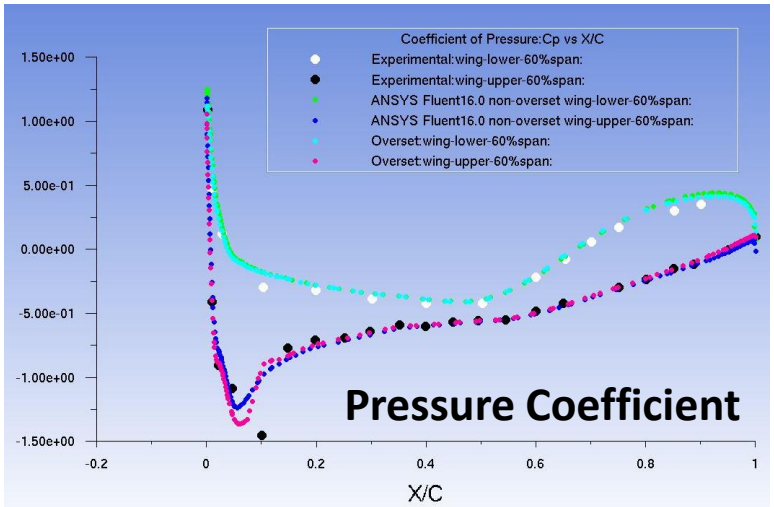








Note : More details about experimental setup is available at http://nescacademy.nasa.gov/workshops/AePW2/public/



- **4.78 M elements, AoA = 3°, Ma = 0.7**
- **PBCS, SST k-omega**

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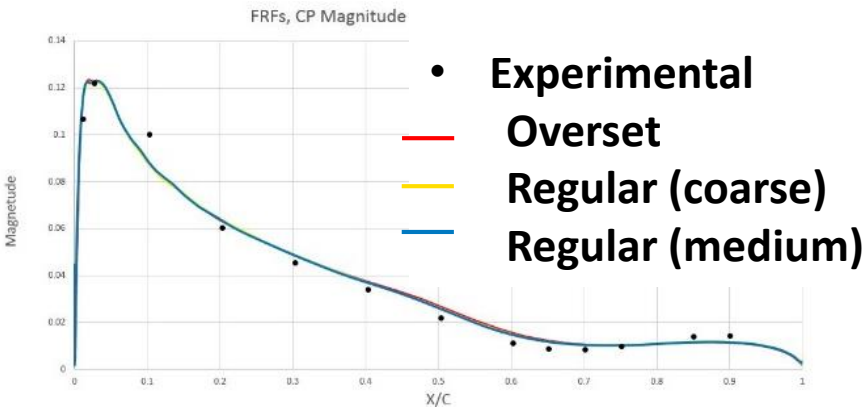
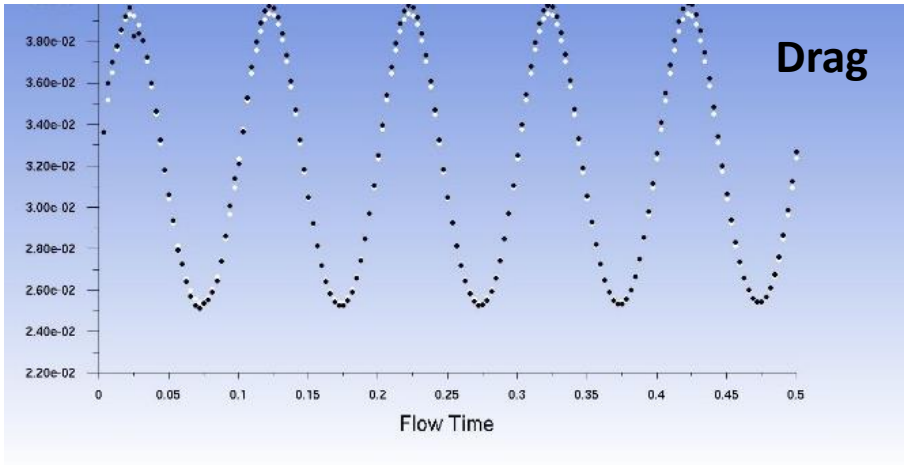
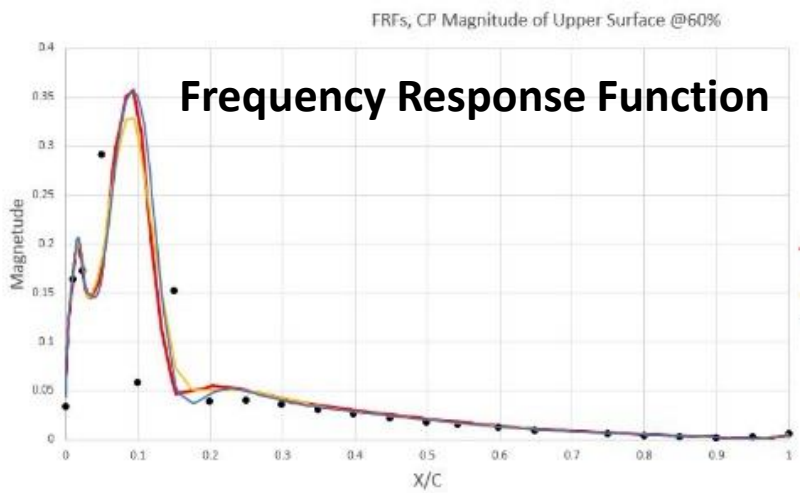
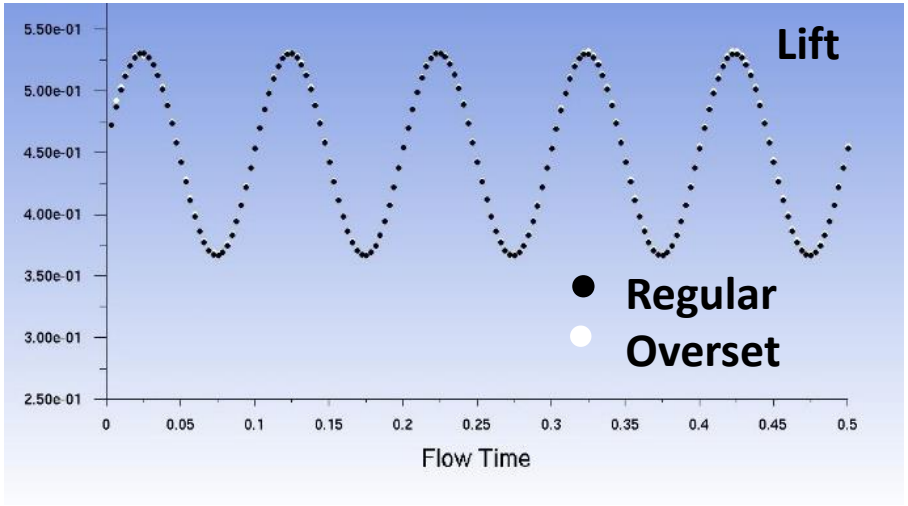
AePW-2: Transient Flow with Rigid Body Motion

PBCS, 1st order transient, SST k-omega









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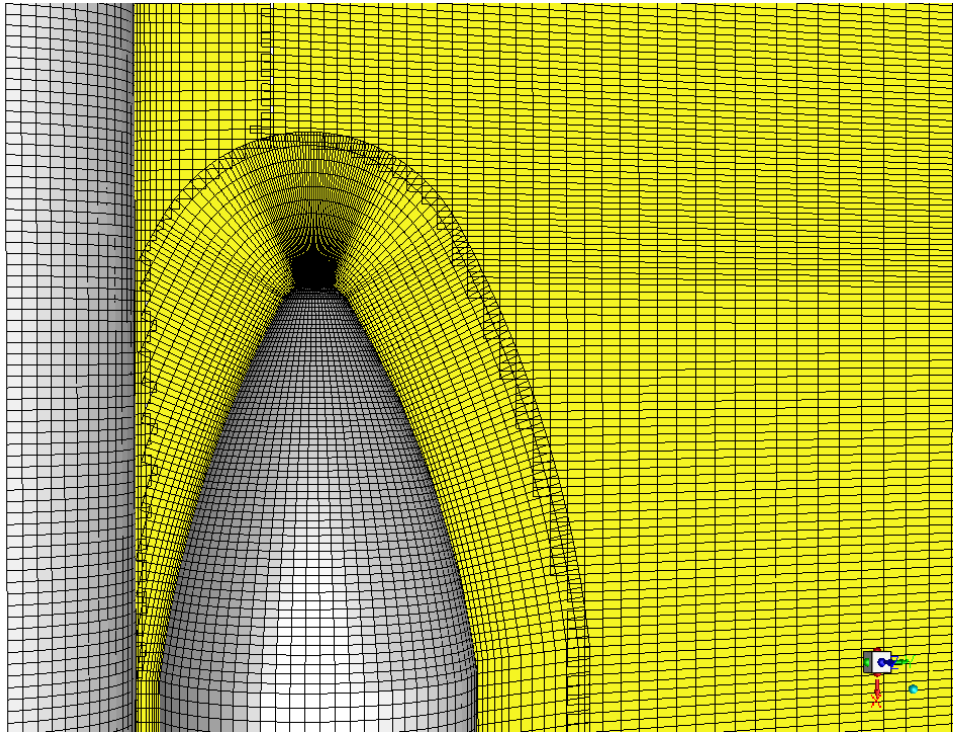
Booster Separation

Overset Mesh

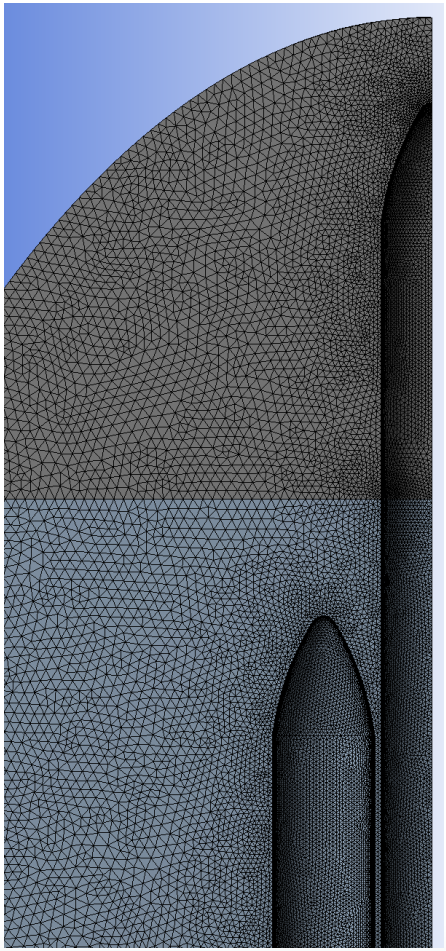
Hexahedral mesh with inflation, 1.67M cells



6DOF Rigid Body Motion

Dynamic Mesh

Hybrid mesh with inflation, 6M cells



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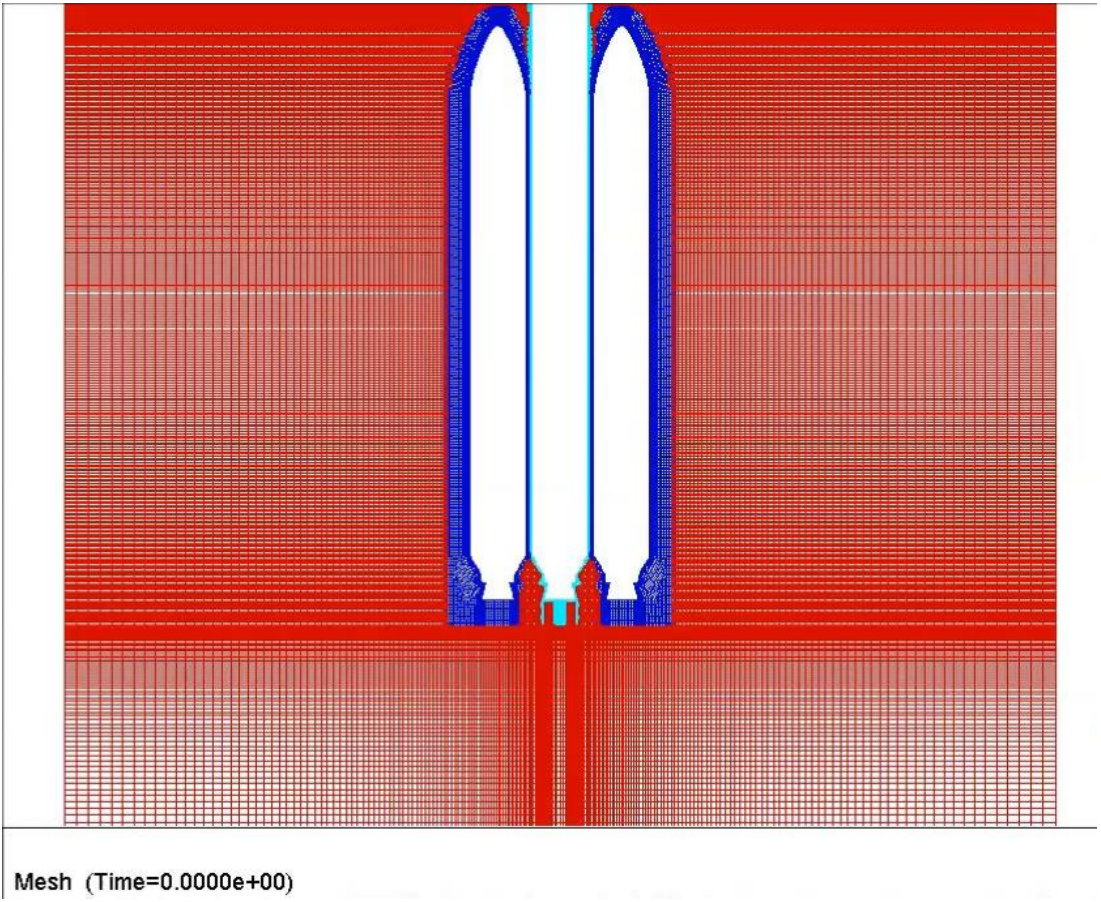
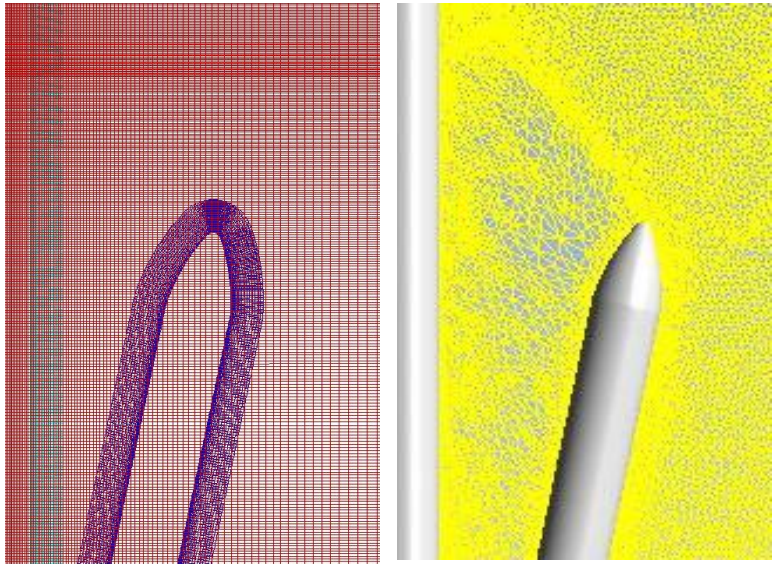
Booster Separation



Original mesh quality preserved in overset mesh



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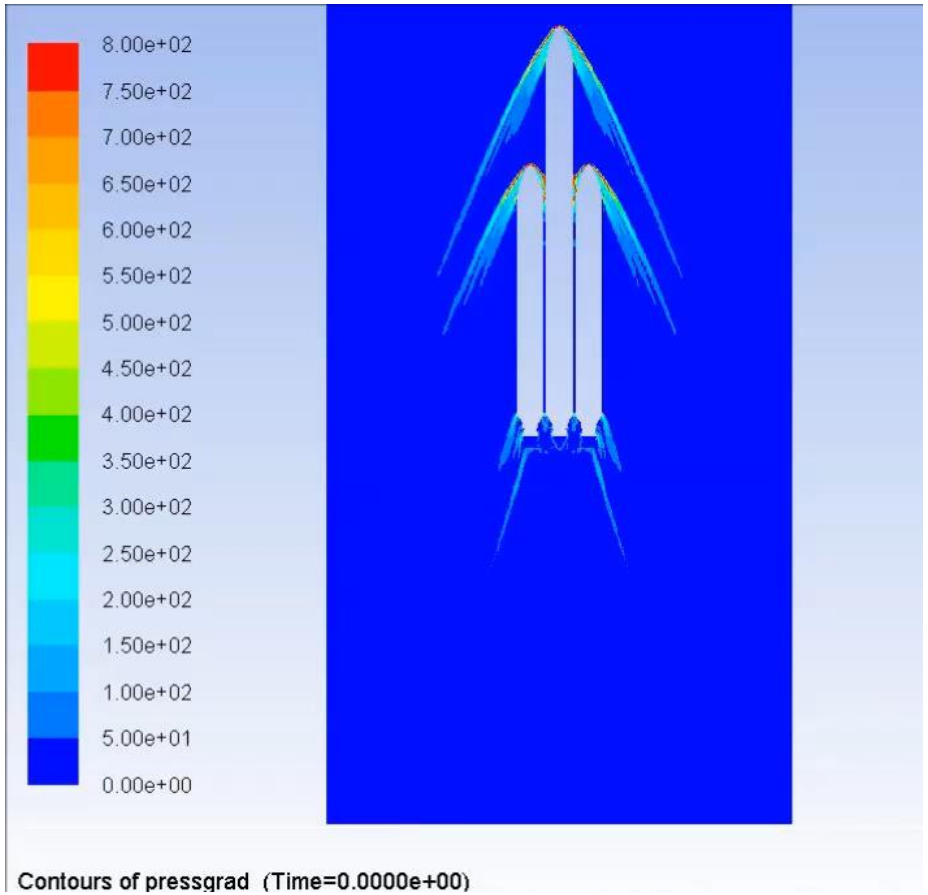
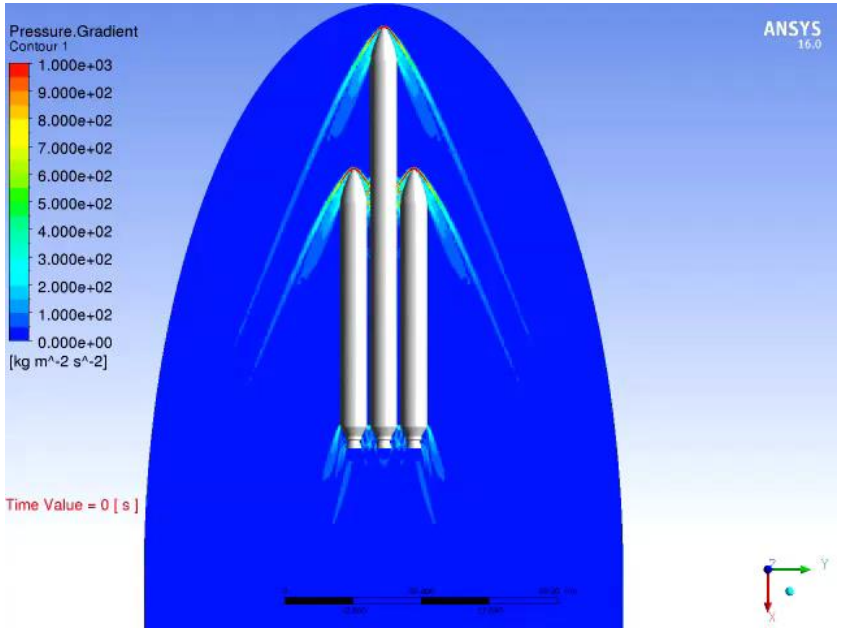
Booster Separation

Overset Mesh Solution



Dynamic Mesh Solution



Preserves quality of shocks

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