Overset Mesh and Related Technologies in CFD++ from a User Perspective

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Metacomp Technologies, Inc.

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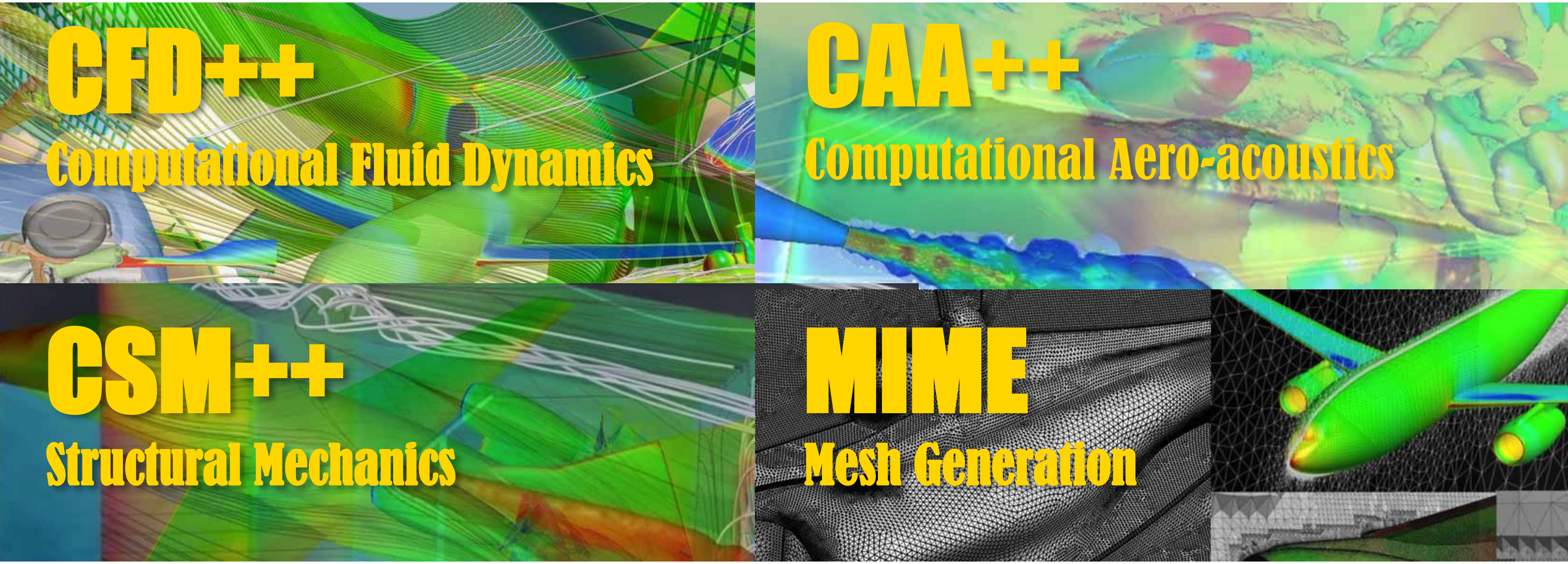
University of Maryland
College Park, MD

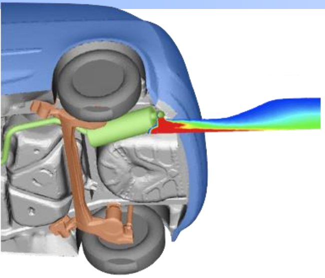
Goals

- Two example cases set up from beginning to end using ICFD++
- Introduction to general case setup in new ICMP infrastructure
  - Advanced User Interface (AUI)
- Overview of overset mesh approach in CFD++
  - Concatenation of grids
  - Cutting and Blanking (New Visualization Features)
  - Boundary conditions
- Overview of coupled Six-DOF and general mesh motion

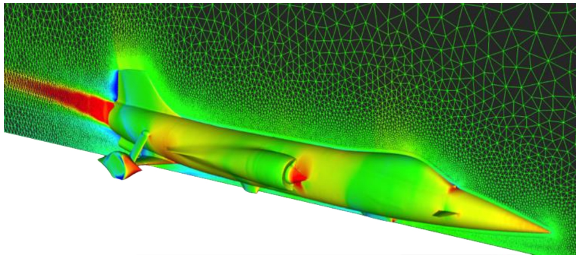
Company Background

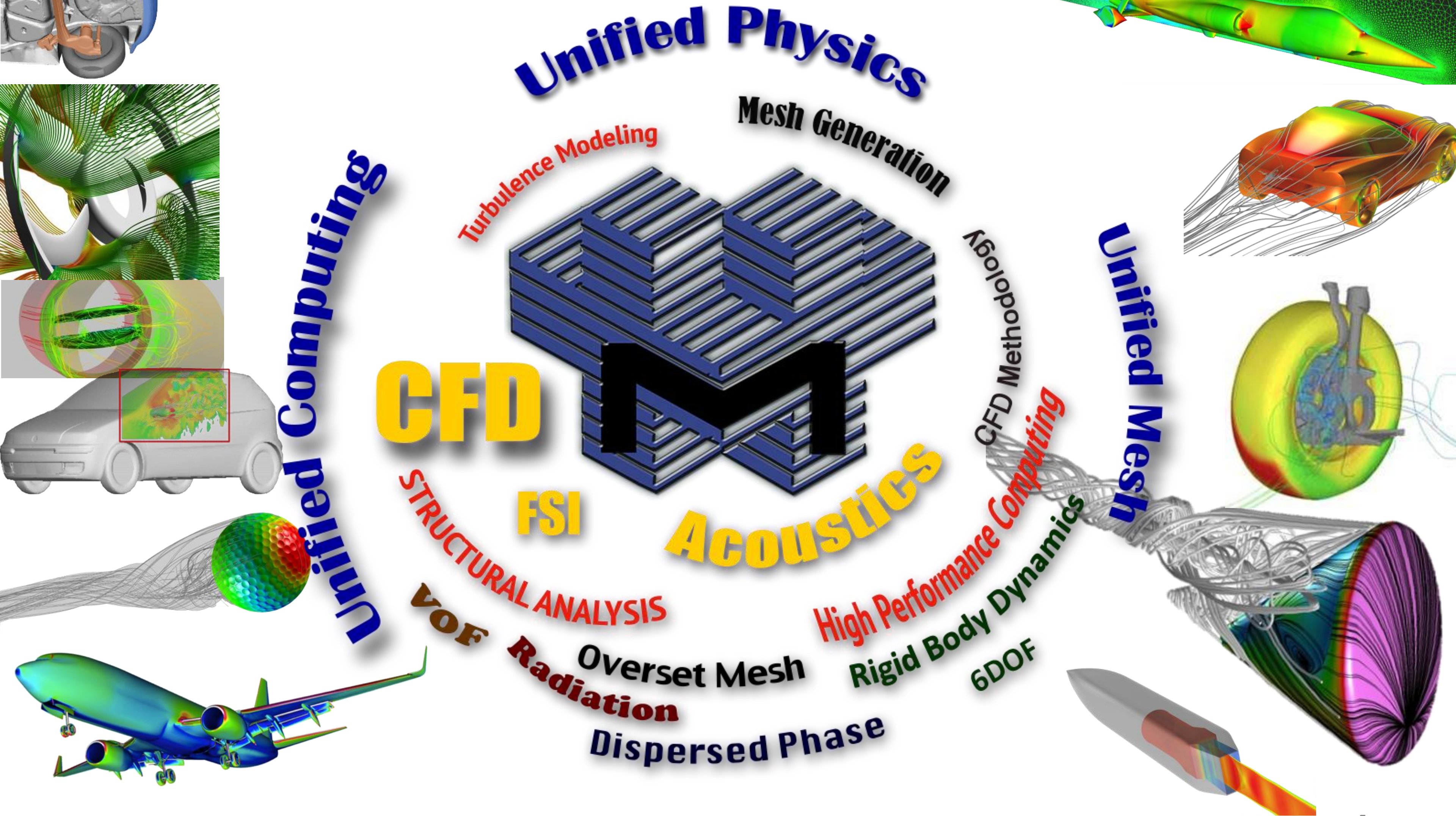
- Founded in 1994
- Key staff members are pioneers in CFD research
- CFD++ is 7th generation CFD software by founder, each one state-of-the-art when introduced
- Strong algorithm to applications experience
- Provides complete CAE solutions for its customers





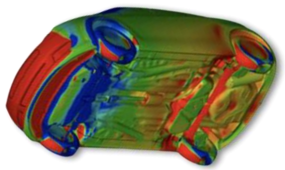
Company Focus



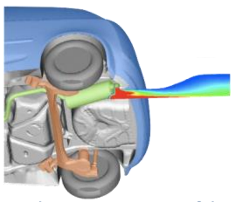


CFD++ Capabilities

External Aerodynamics

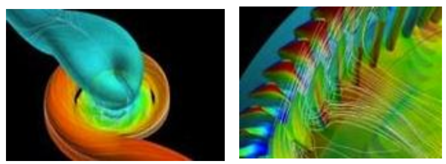


Under-hood flows

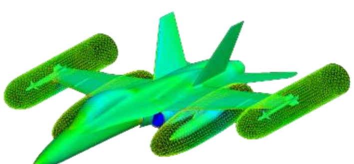


Exhaust gas infiltration

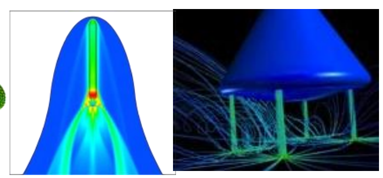
Turbomachinery



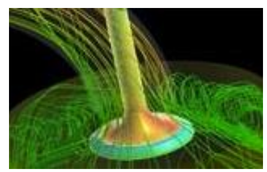
CFD++ is a comprehensive software suite that includes a rich collection of tools to help increase the end users' effectiveness.



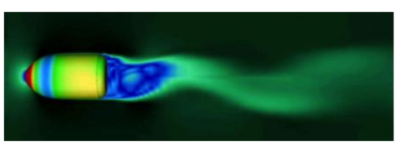
6DOF/moving bodies



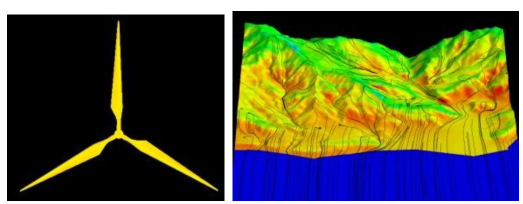
Propulsion



High- and low-Speed combustion



Unsteady flow with Hybrid RANS/LES

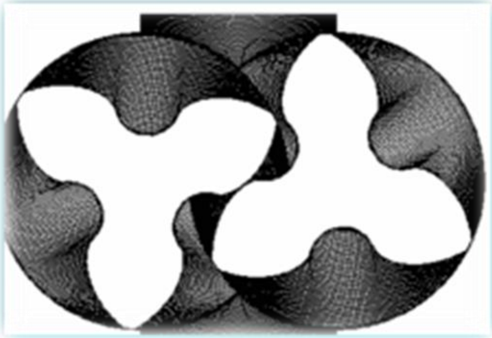


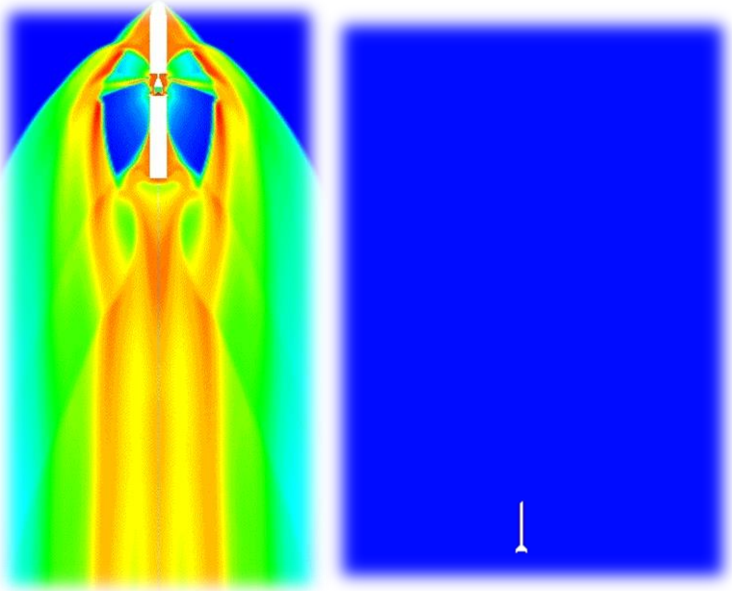
Wind energy – terrain verification

- *External and Internal flows*
- *Sliding/Moving/Overset Meshes*
- *Rotating Machinery*
- *6DOF/Moving Bodies*
- *Conjugate Heat Transfer*
- *Porous Media Modeling*
- *High-Speed and Low-Speed Reacting flows*
- *Multi-Speed Problems*
- *Supercritical Fluids*
- *Dispersed Phase Models (particles and droplets)*
- *Multiphase Mixture Models*
- *Phase Change Modeling (evaporation/condensation)*
- *Free Surfaces and Fronts (flames, shocks, etc.)*
- *Radiation Heat Transfer*
- *Unique Propeller and Helicopter Blade Model*

CFD++ Numerical Features

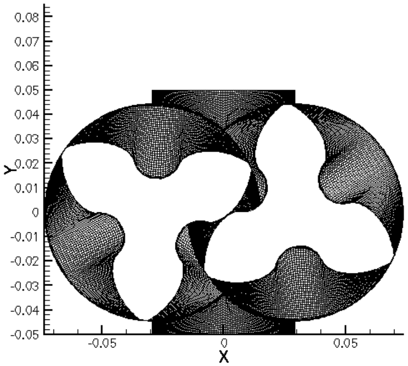
- Coupled density or pressure-based solvers
- Realizable physical, mathematical & numerical models
- Agglomeration (algebraic) multi-grid accelerated solver for fast convergence to steady state
- Multi-dimensional TVD framework for truly 2^{nd} order accuracy on all meshes
- Up to fourth order accuracy (temporal) in explicit mode
- Second order accuracy in time in implicit mode
- Specialized low-diffusion schemes for transient phenomena

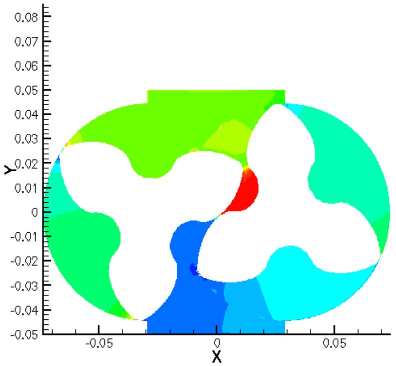


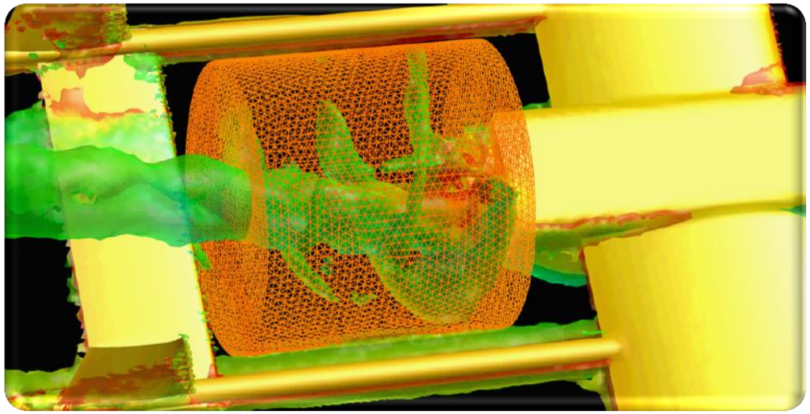


Metacomp Overset Philosophy

- ✓ *Same multidimensional least squares interpolation everywhere*
- ✓ *Very intuitive geometric approach (same for 2D and 3D)*
  - ✓ *Flexibility via sequential cutting (reduces number of overlap cells)*
- ✓ *Fully integrated*
  - ✓ *Cutting can be performed (if necessary) completely within the run*
  - ✓ *Coupled with Rigid Body Motion and 6DOF computation*
- ✓ *No re-meshing after cutting/blanking*
  - ✓ *Perfect conservation via flux-stitching*







CFD++ Key Attributes

- ✓ ***Internal unstructured book-keeping***
  - ✓ ***Allows for all cell types within same grid***
  - ✓ ***Multiple blocks OK (structured and unstructured)***

- ✓ ***Wall distance free turbulence models and fast wall distance re-computation***
  - ✓ ***Allows for transient computation with grid blanking***

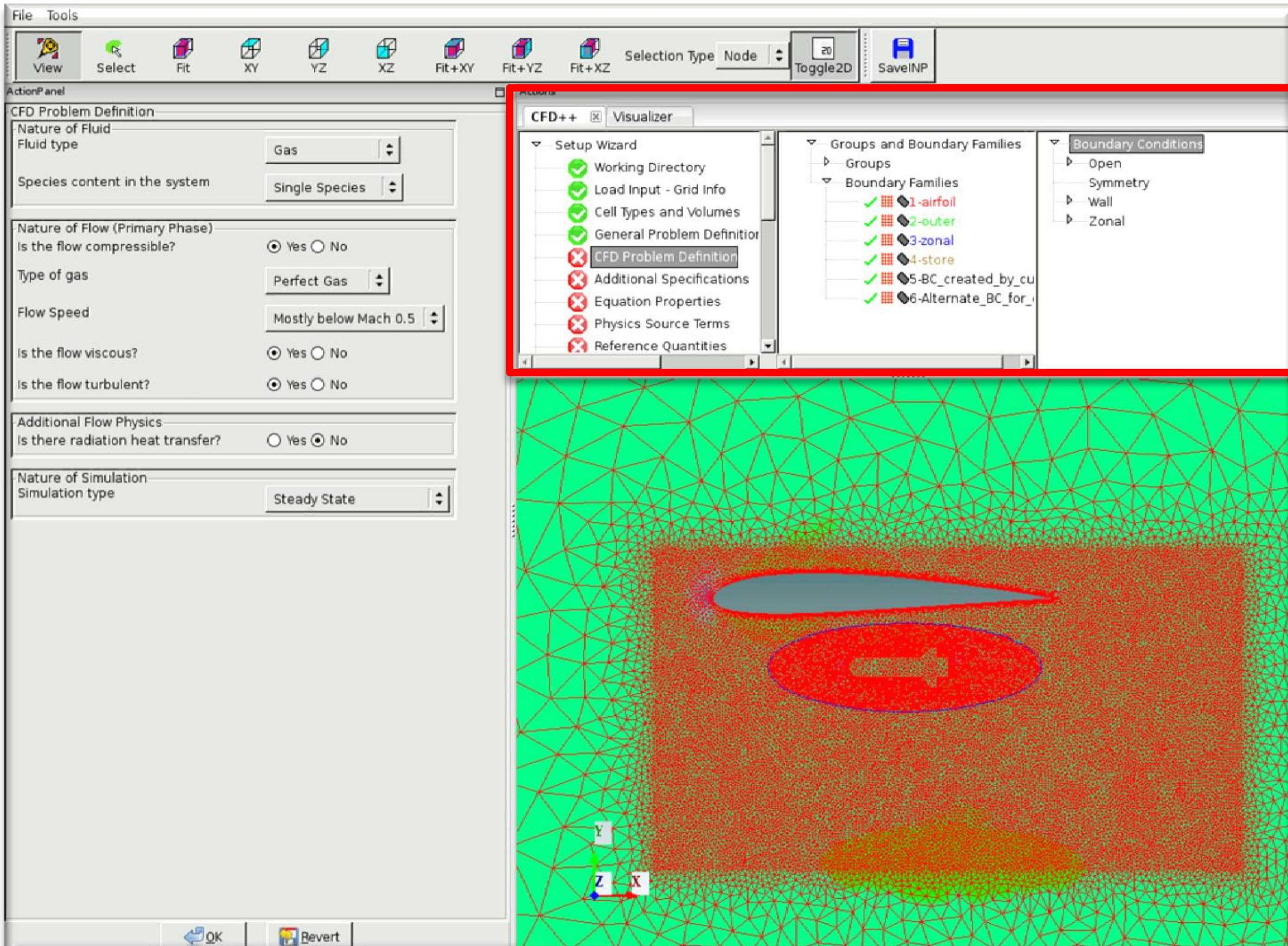
The Integral Way

ICFD++ Advanced User Interface (AUI)

- Integral Computational Multi-Physics (ICMP) concept and infrastructure
- Common interfaces across all products in series
- Intuitive and simple guided process: setting up problem definition → analyzing and understanding results
- Helps user make the best choices for the problem and decreases risk of error

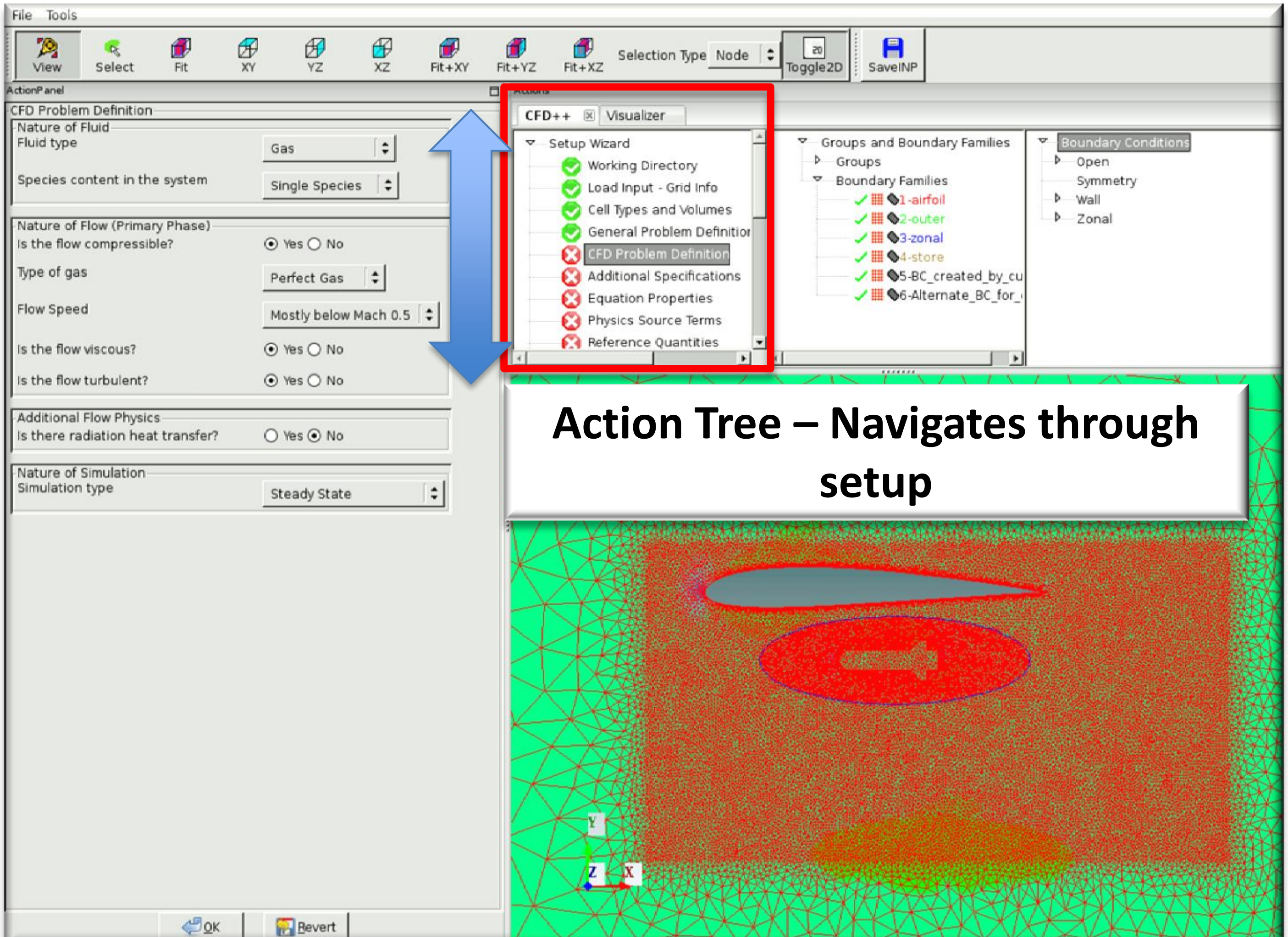
METACOMP TECHNOLOGIES

AUI

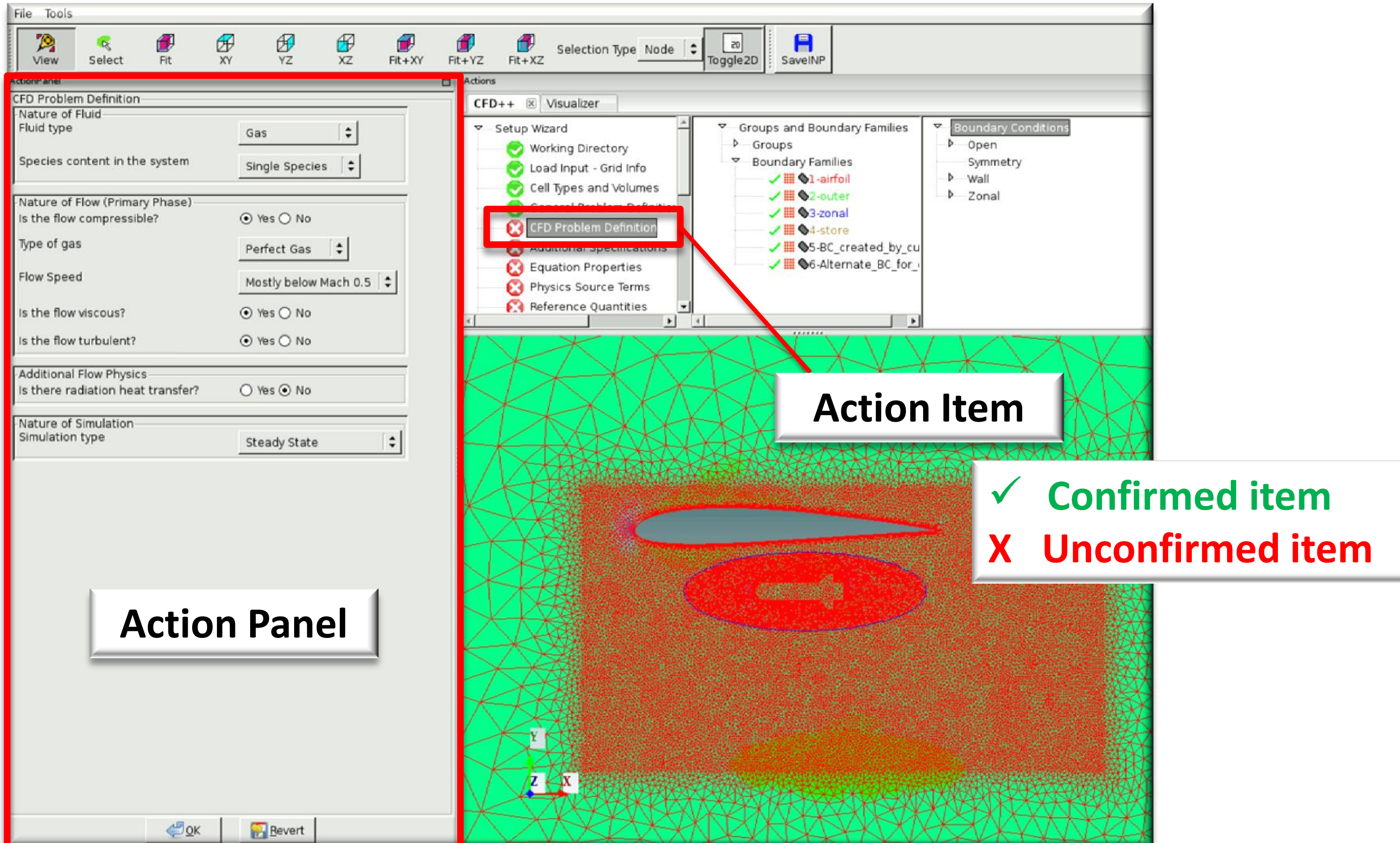


Notebook Pages

AUI


File Tools
View
Select
Fit
XY
YZ
XZ
Fit+XY
Fit+YZ
Fit+XZ
Selection Type
Node
Toggle2D
SaveINP
ActionPanel
CFD Problem Definition
Nature of Fluid
Fluid type
Gas
Species content in the system
Single Species
Nature of Flow (Primary Phase)
Is the flow compressible?
Yes No
Type of gas
Perfect Gas
Flow Speed
Mostly below Mach 0.5
Is the flow viscous?
Yes No
Is the flow turbulent?
Yes No
Additional Flow Physics
Is there radiation heat transfer?
Yes No
Nature of Simulation
Simulation type
Steady State
OK
Revert
CFD++
Visualizer
Setup Wizard
Working Directory
Load Input - Grid Info
Cell Types and Volumes
General Problem Definitior
CFD Problem Definition
Additional Specifications
Equation Properties
Physics Source Terms
Reference Quantities
Groups and Boundary Families
Groups
Boundary Families
1-airfoil
2-outer
3-zonal
4-store
5-BC_created_by_cu
6-Alternate_BC_for_
Boundary Conditions
Open
Symmetry
Wall
Zonal
Action Tree – Navigates through setup

AUI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5-BC_created_by_cu
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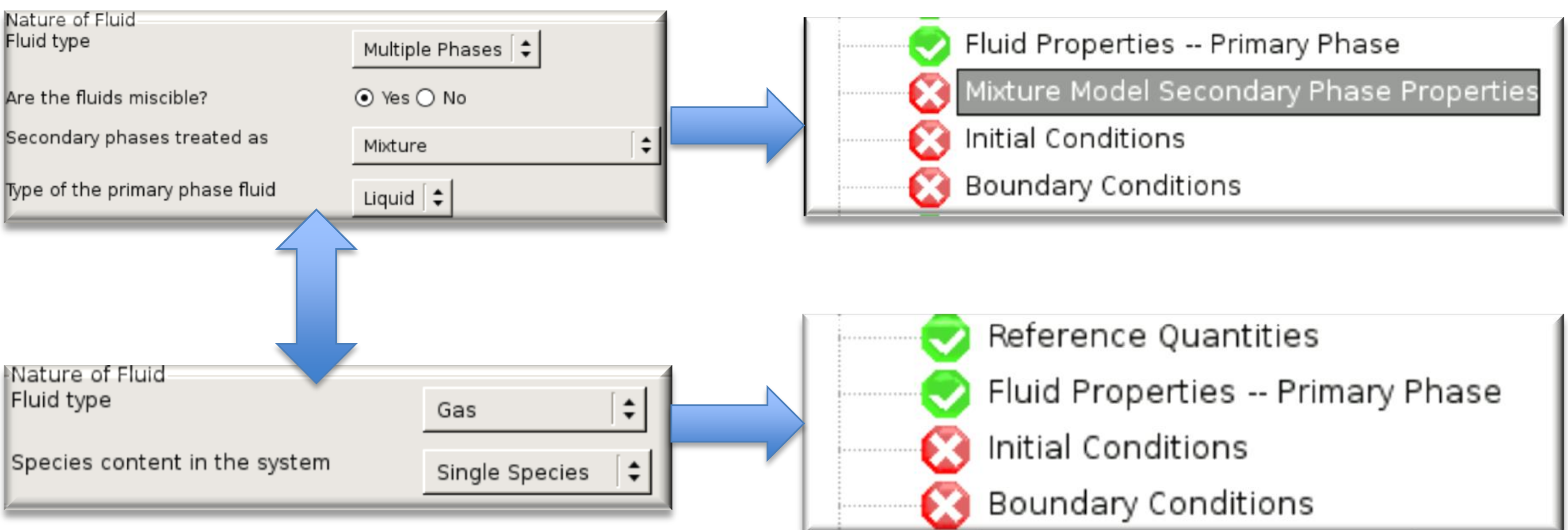
Boundary Conditions
Open
Symmetry
Wall
Zonal
Action Item
Action Panel
✓ Confirmed item
X Unconfirmed item

AUI

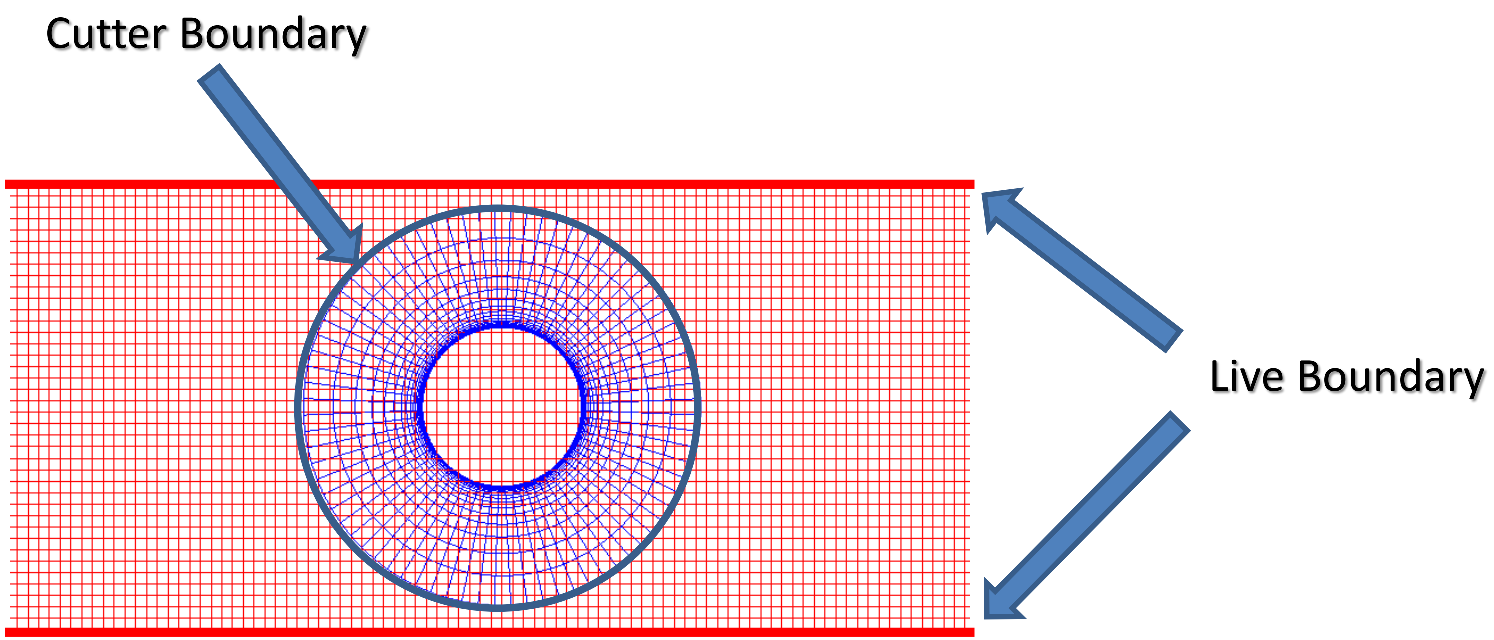
- Dependency based options in Action Panel
- “Thinking Engine” adapts Action Tree items based on selections

<u>If it’s not relevant, you don’t see it!</u>



Overset Blanking Procedure

- ✓*Marking cells intersecting the cutter surface ("cut cells")*
- ✓*Blanking cells enclosed by the layer of "cut cells" and non-live boundaries*
- ✓*Retain or not retain "cut cells"*



Overset Blanking Procedure

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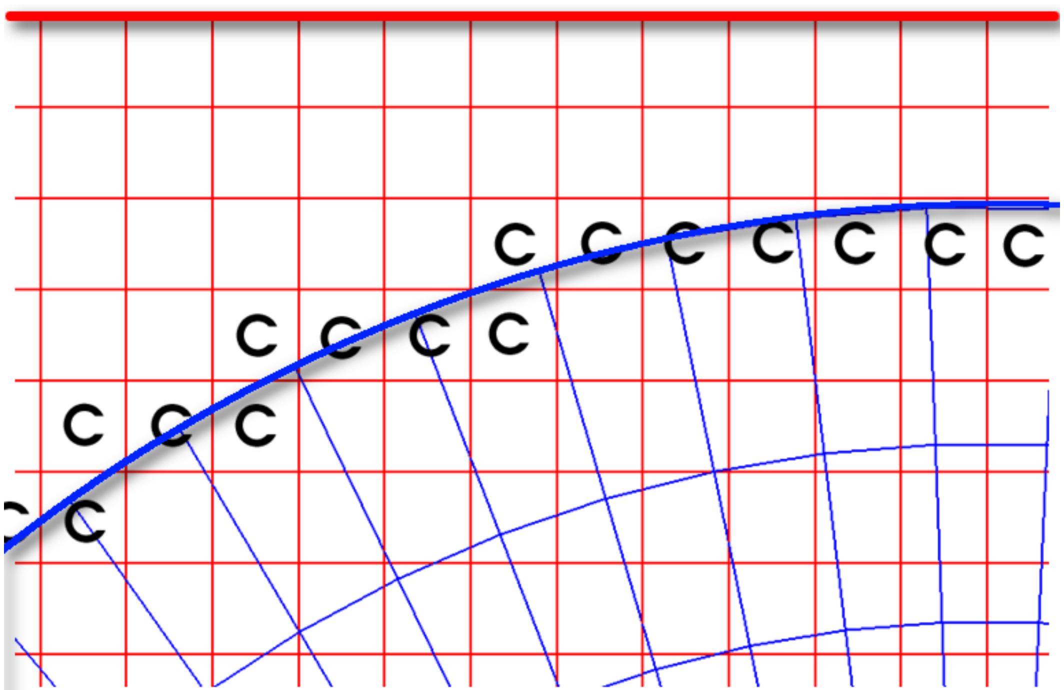
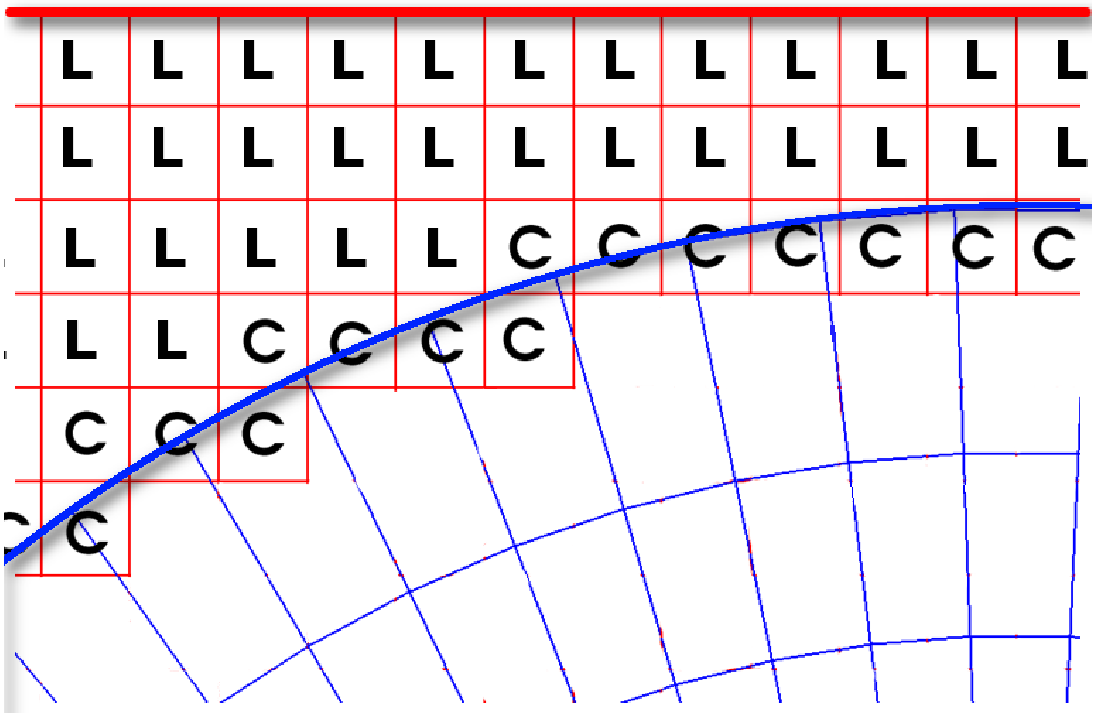


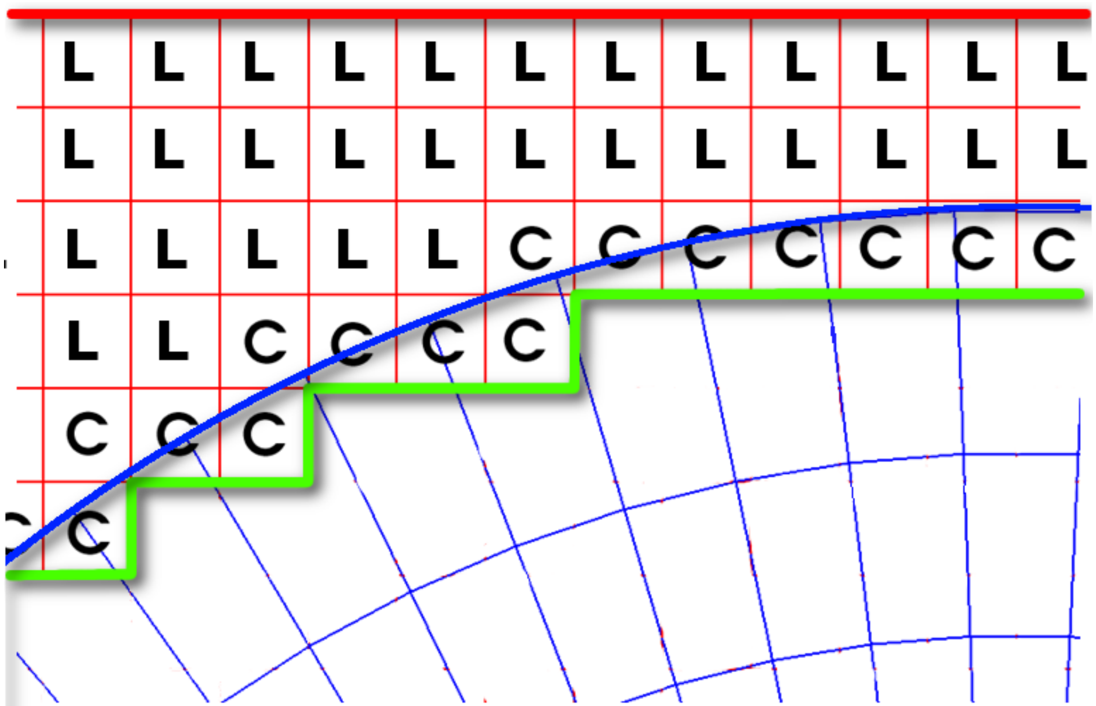
Overset Blanking Procedure

✓ *Marking "live" cells – recursively marching to adjacent cells until "cut" cell or non-live boundary is encountered*



Overset Blanking Procedure

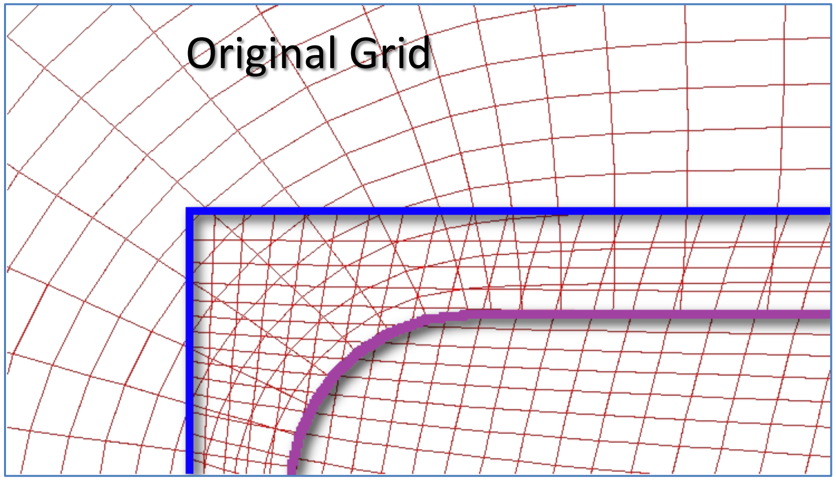
✓ ***Retain/Blank "cut" cells – additional boundary created after cutting (overset/patched)***

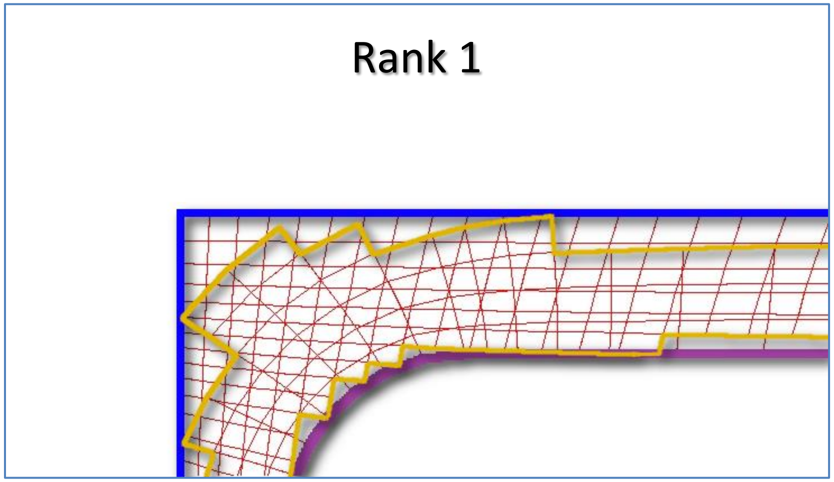


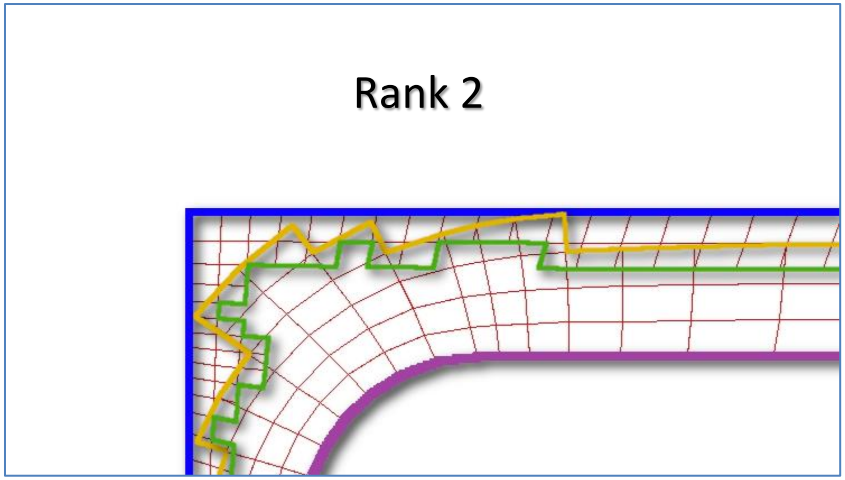
Sequential Cutting/Blanking

- ✓ *Allows multiple sequential cuts of varying types, retain options, live BC/cell designations*
  - ✓ *Multiple "Ranks"(each utilizes regular cutting procedure)*
- ✓ *Allows "BC created by cutting" to subsequently act as cutter*
- ✓ *Useful for complex overlapping geometries, robust cutting procedures for evolving transient solutions, 3+ overlapping bodies*

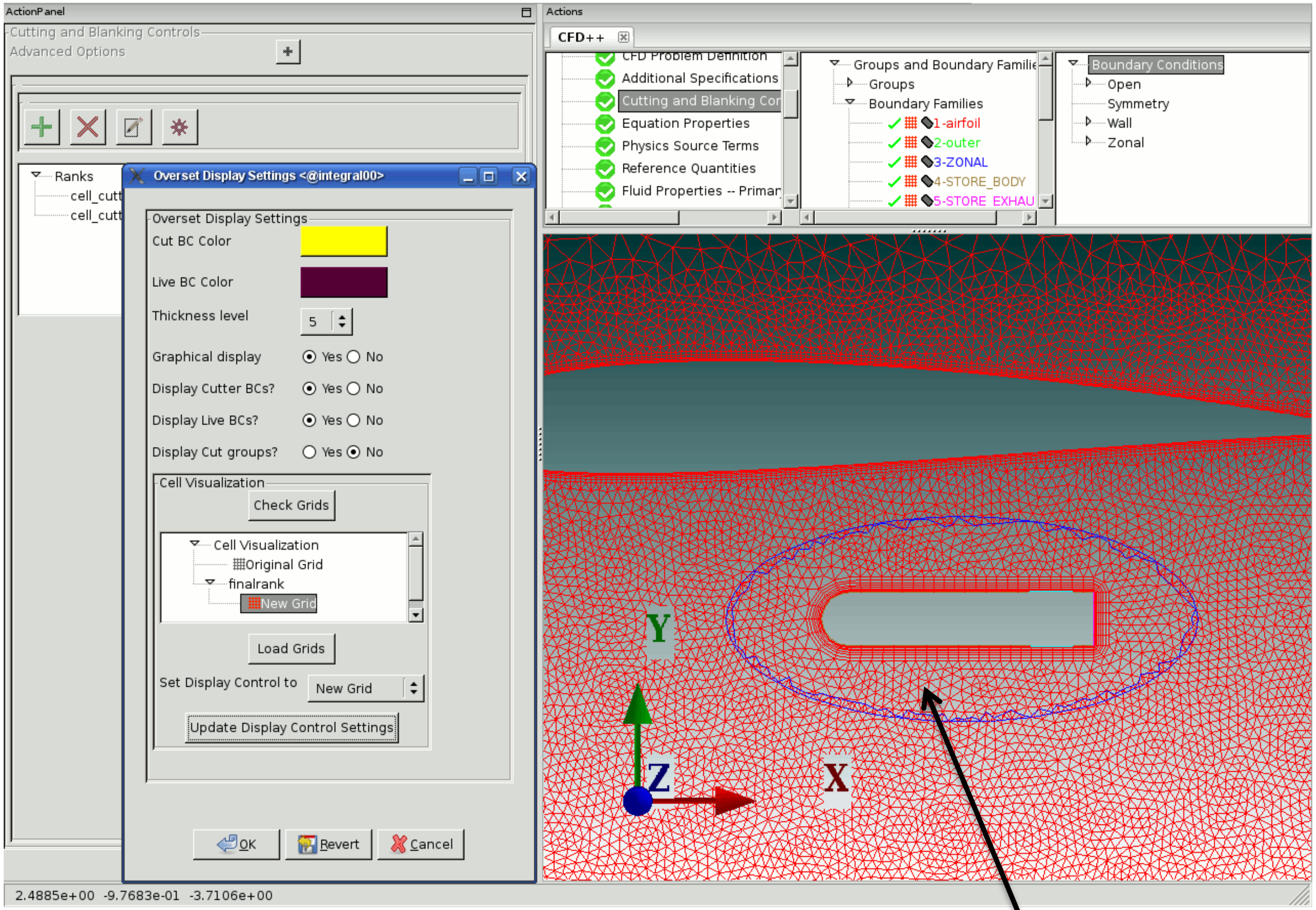
Sequential Cutting







Cutting/Blanking Visualization

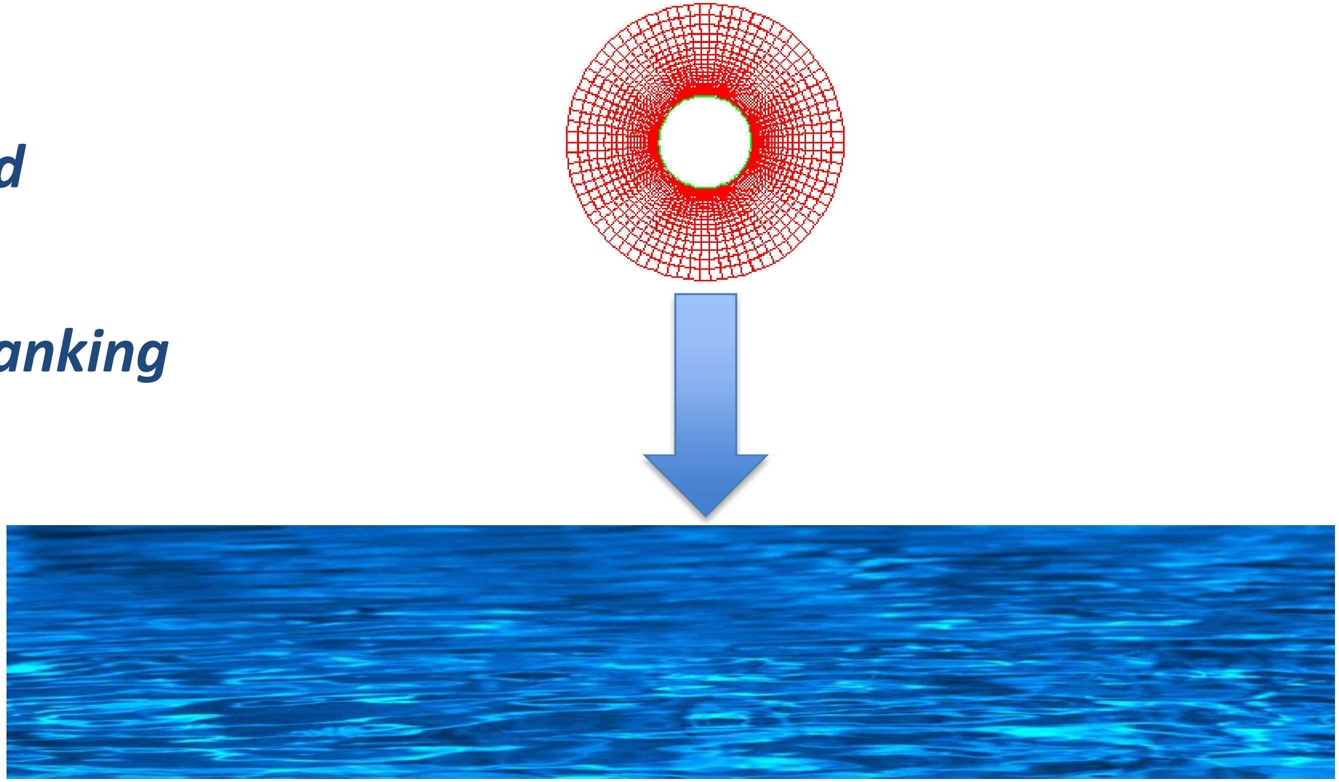


- Visualize grid blanking before launching simulation

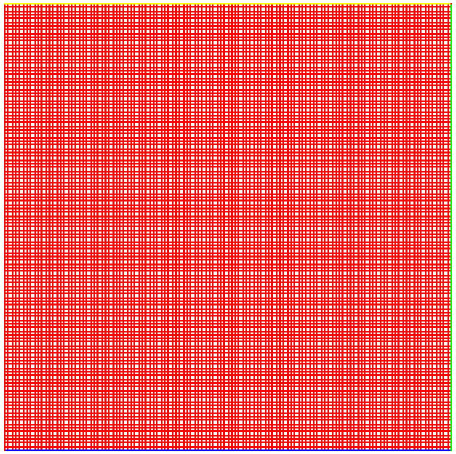
Demo Cases

1. 2D Ball Drop into Water

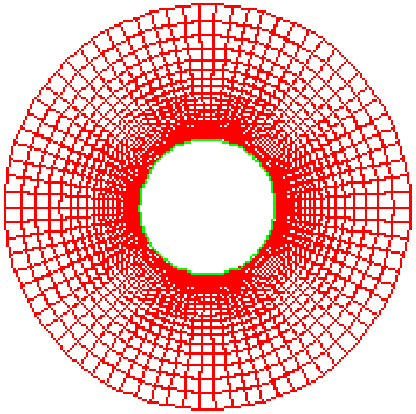
- ✓ *6DOF*
- ✓ *Volume of Fluid*
- ✓ *Buoyancy*
- ✓ *Cutting and Blanking*



Case 1: Concatenation of Grids

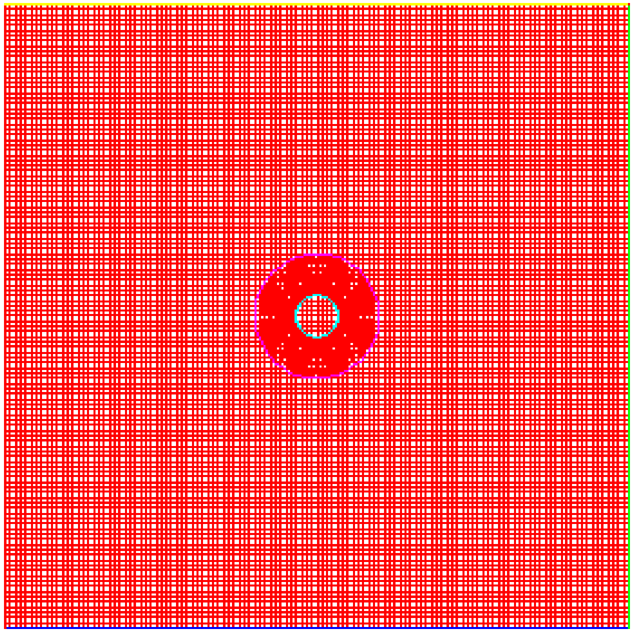


Background (Group 1)



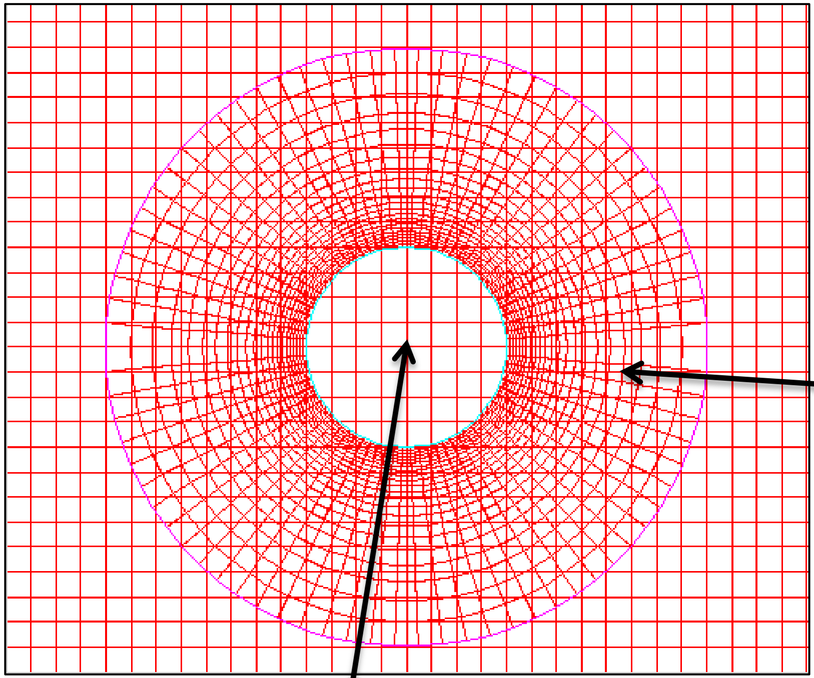
Ball (Group 2)

Case 1: Concatenation of Grids



Concatenated Grids

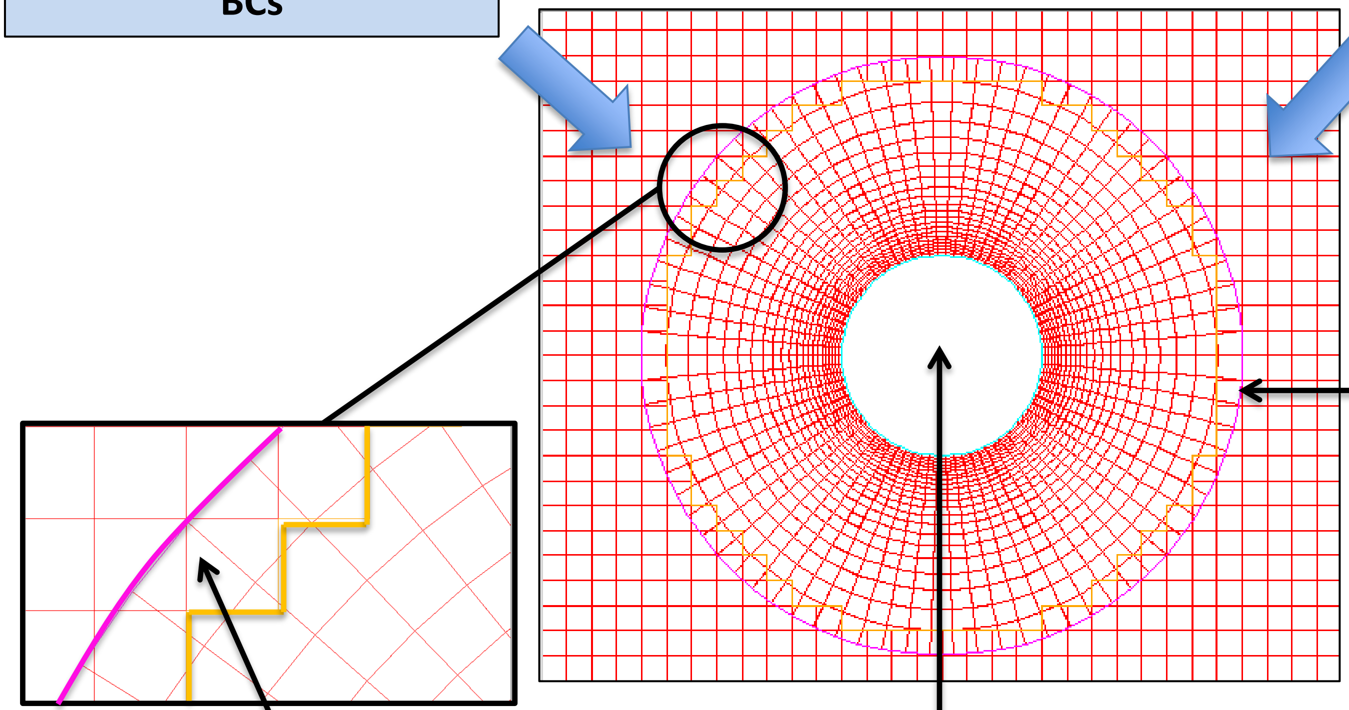
Case 1: Cutting and Blanking Goals



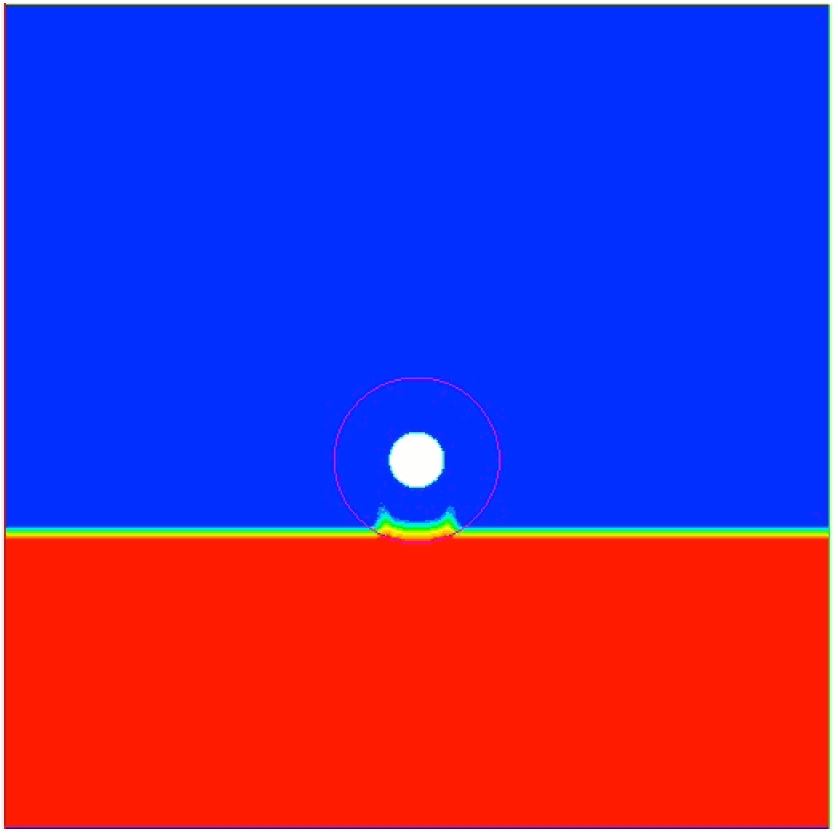
Minimize Overlap Cells

Remove Background Grid

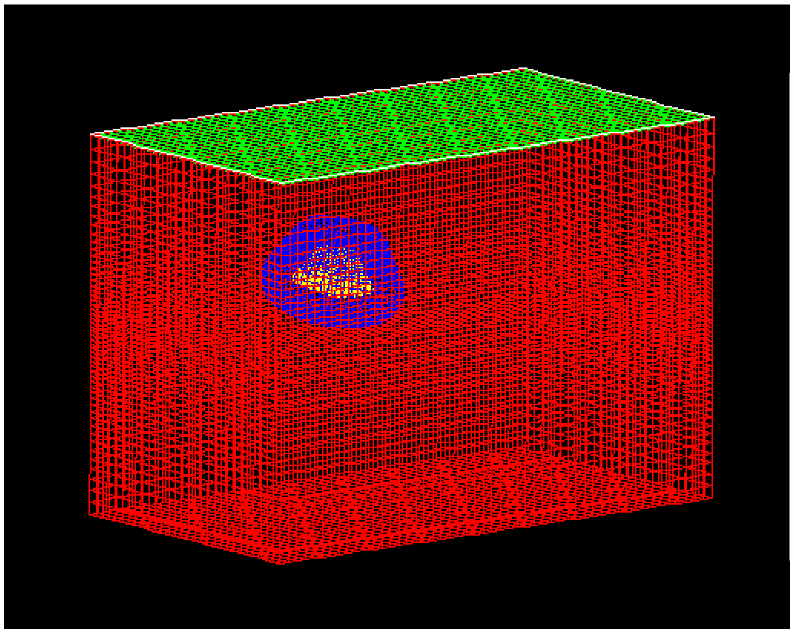
Case 1: Rank 1

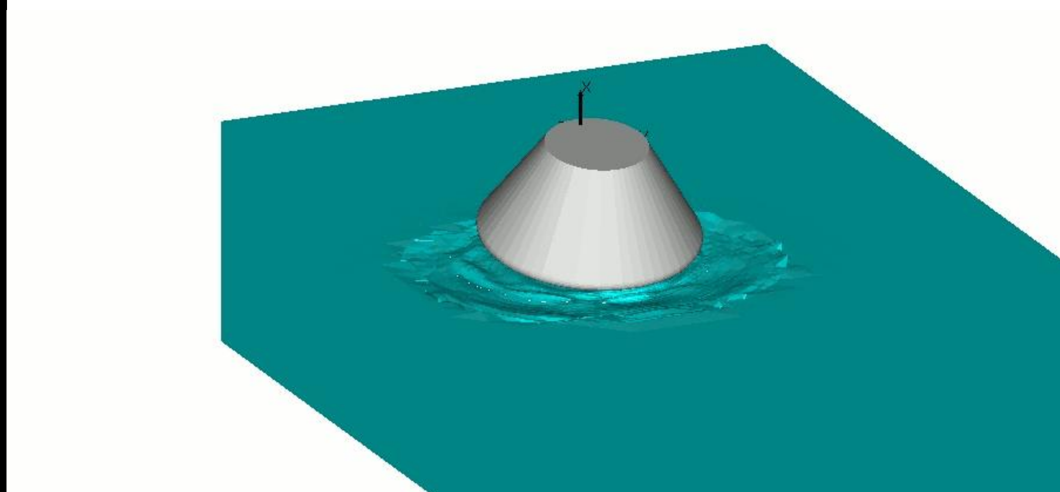

Live: Background outer BCs
Live: Background outer BCs
Cutter: Ball Zonal BC
Overlap: Retain Cut Cells
Blank: Background Group

Case 1: Ball Drop Solution



3D Capsule Drop



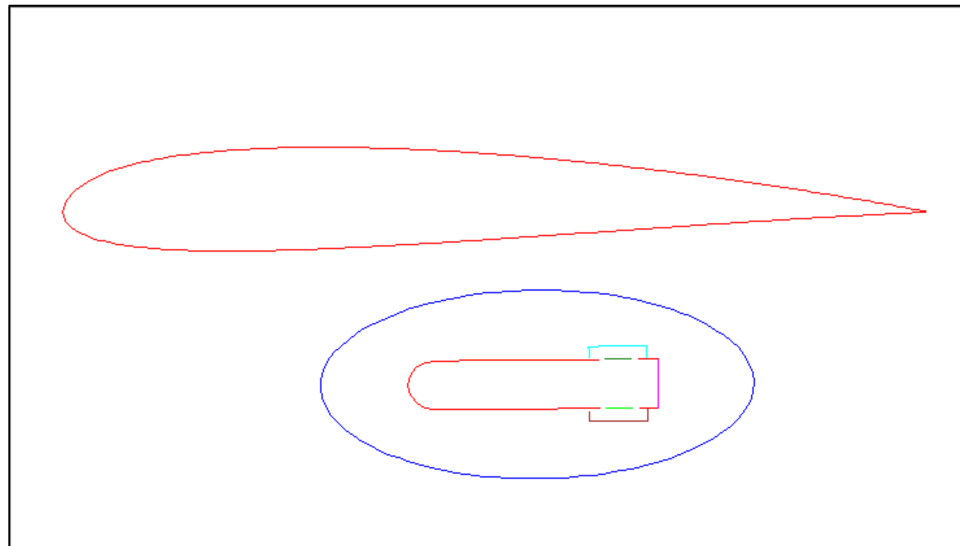


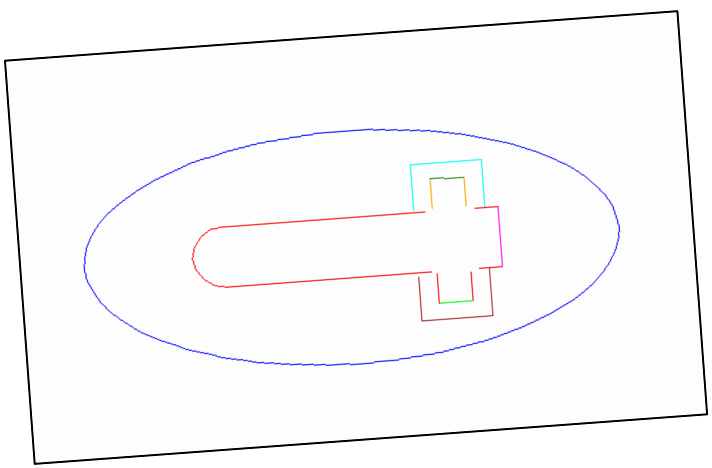
- **Same cutting/blanking settings as 2D Ball**

Demo Cases

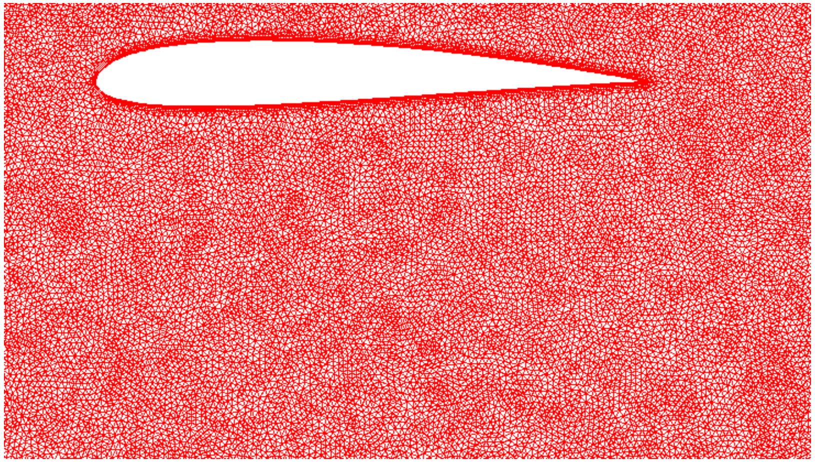
2. 2D Store Separation with Fin Deployment

- ✓ *Multiple body 6DOF*
- ✓ *Thrust from exhaust*
- ✓ *Prescribed motion RBD*
- ✓ *Multiple rank Sequential cutting*

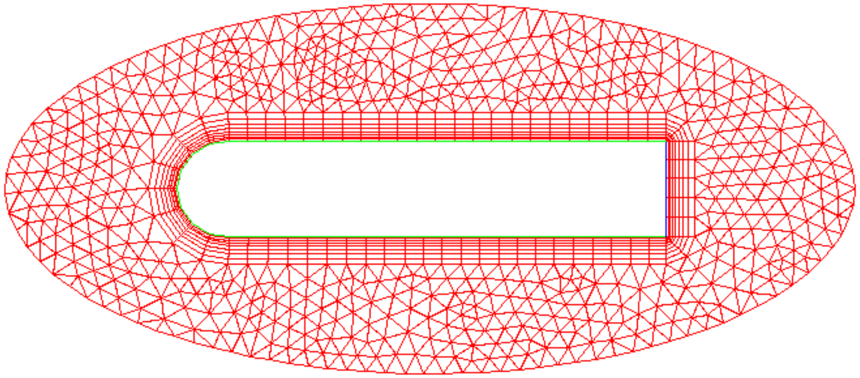




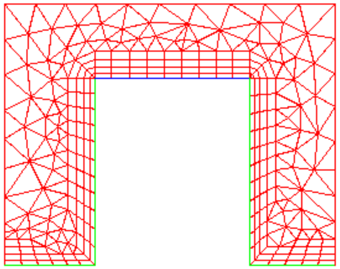
Case 2: Concatenation of Grids



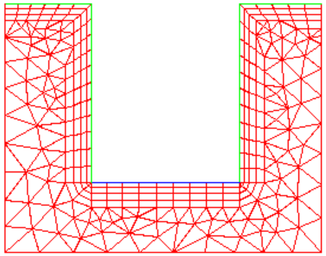
Background (Group 1)



Store (Group 2)

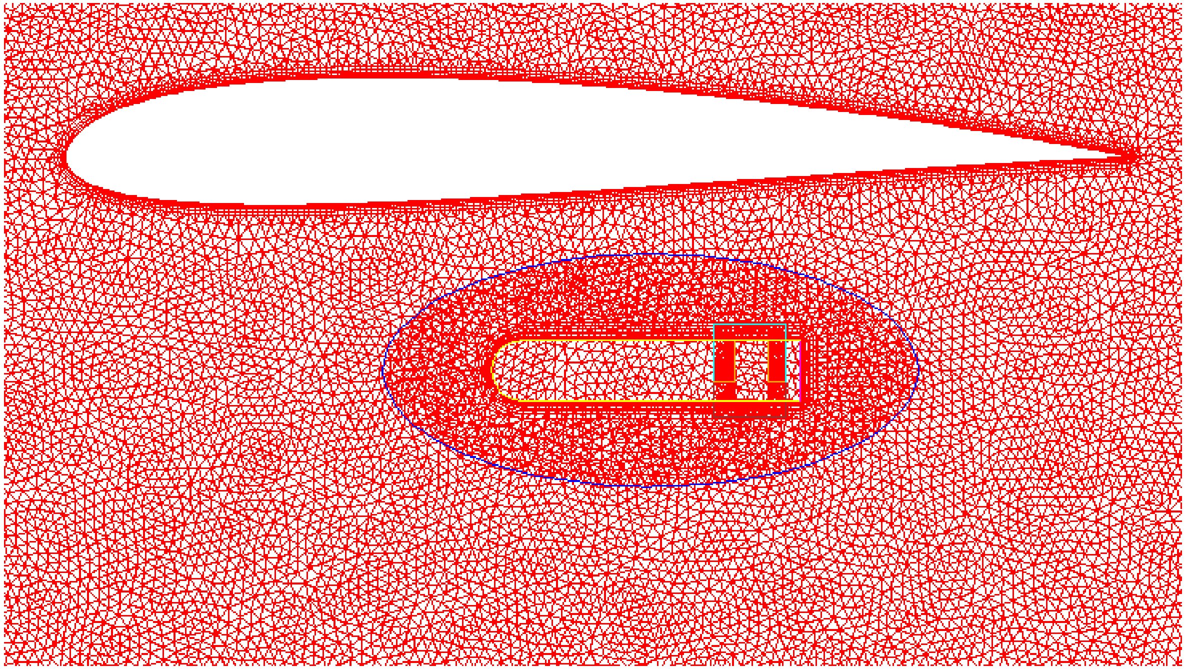


Fin 1 (Group 3)



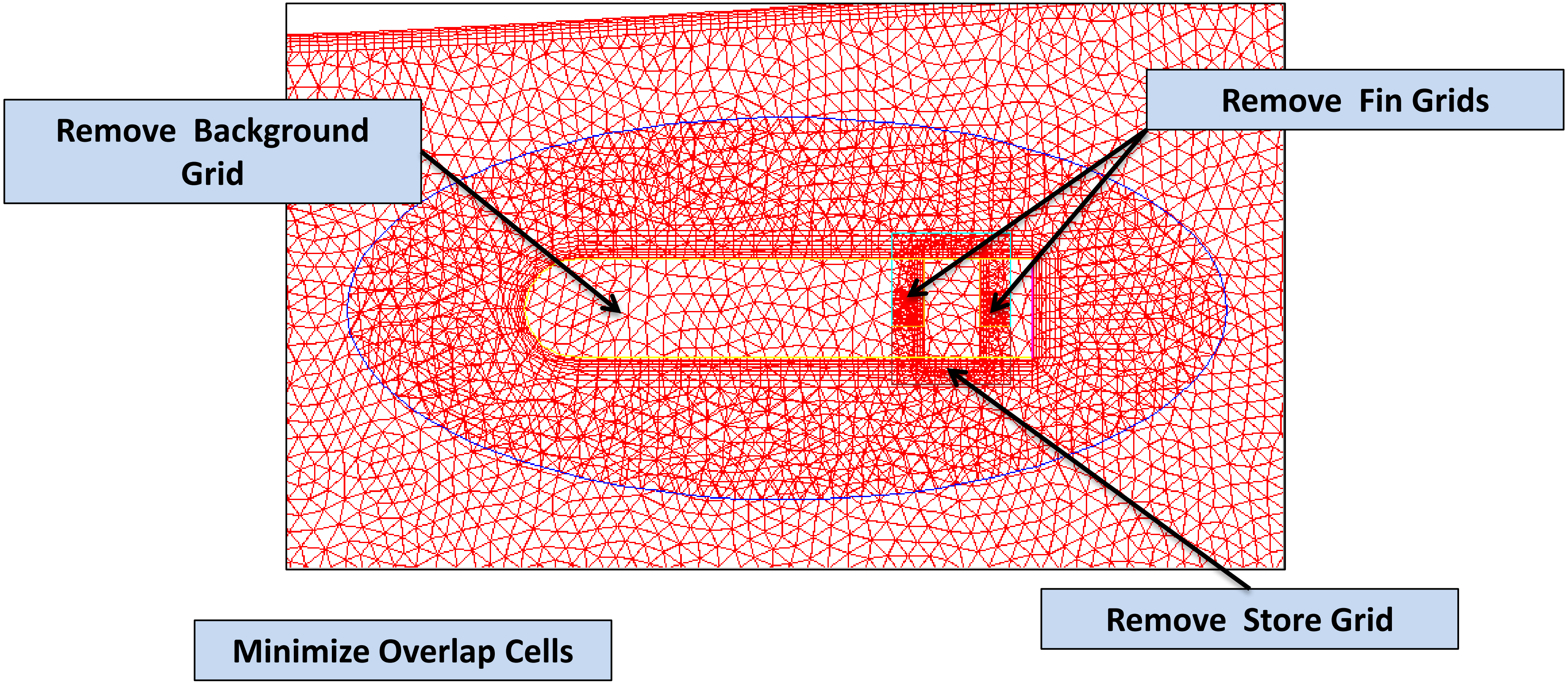
Fin 2 (Group 4)

Case 2: Concatenation of Grids

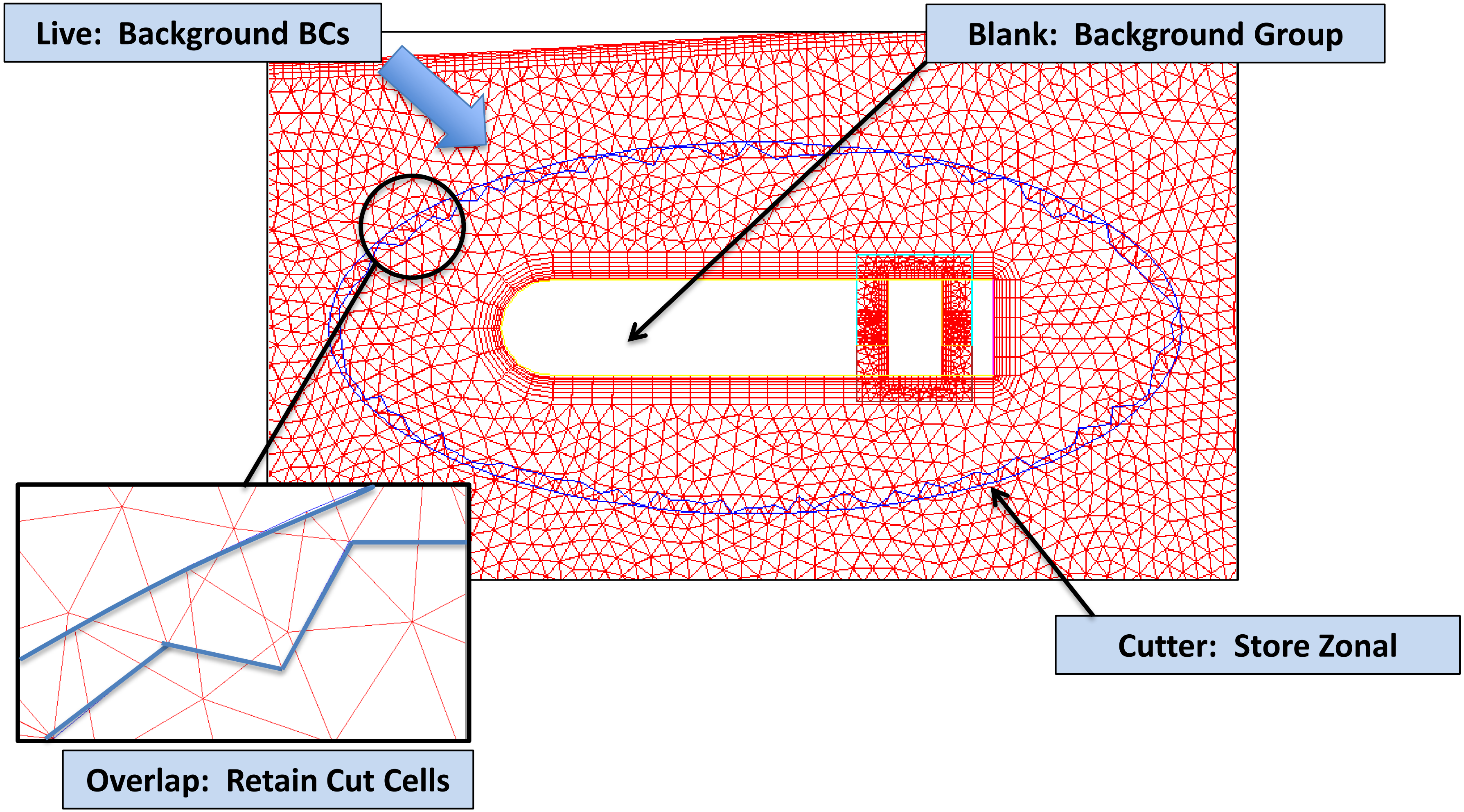


Concatenated Grids

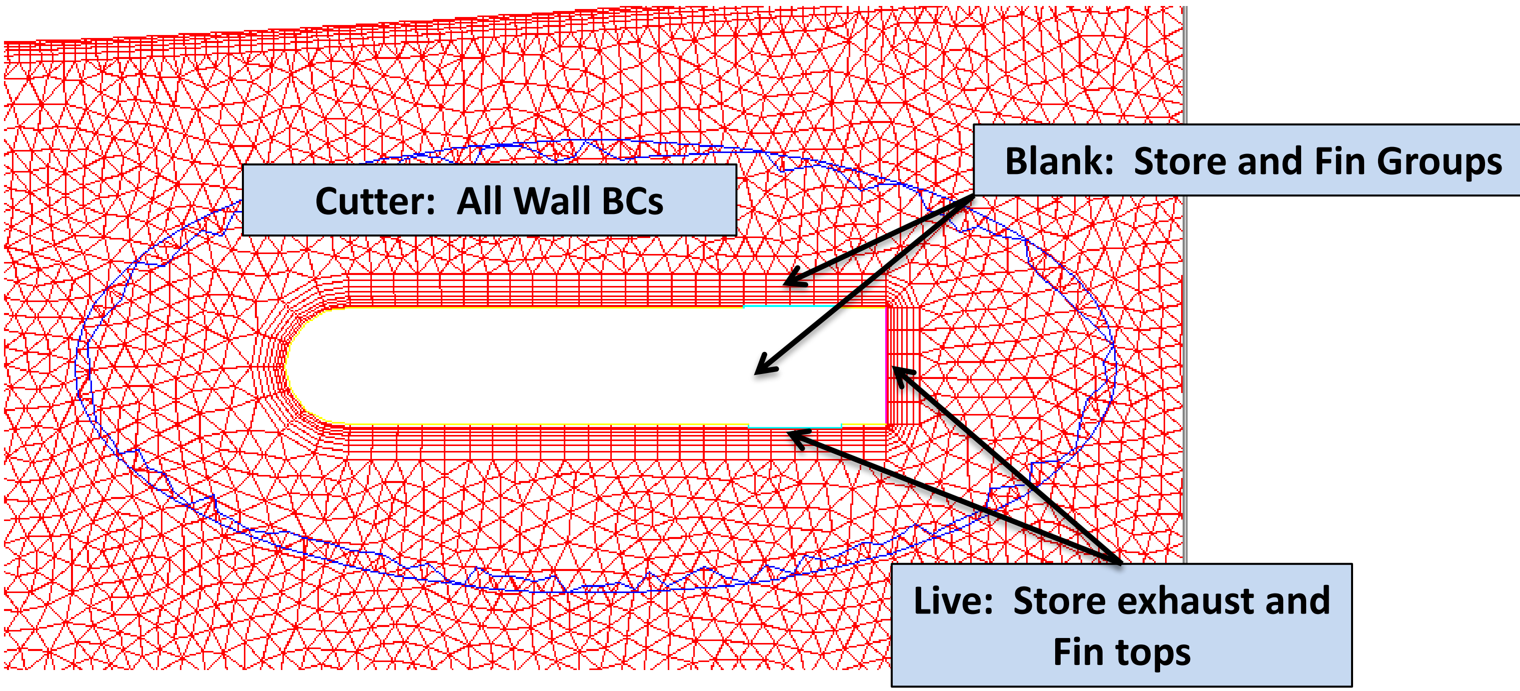
Case 2: Cutting and Blanking Goals



Case 2: Sequential Cutting Rank 1

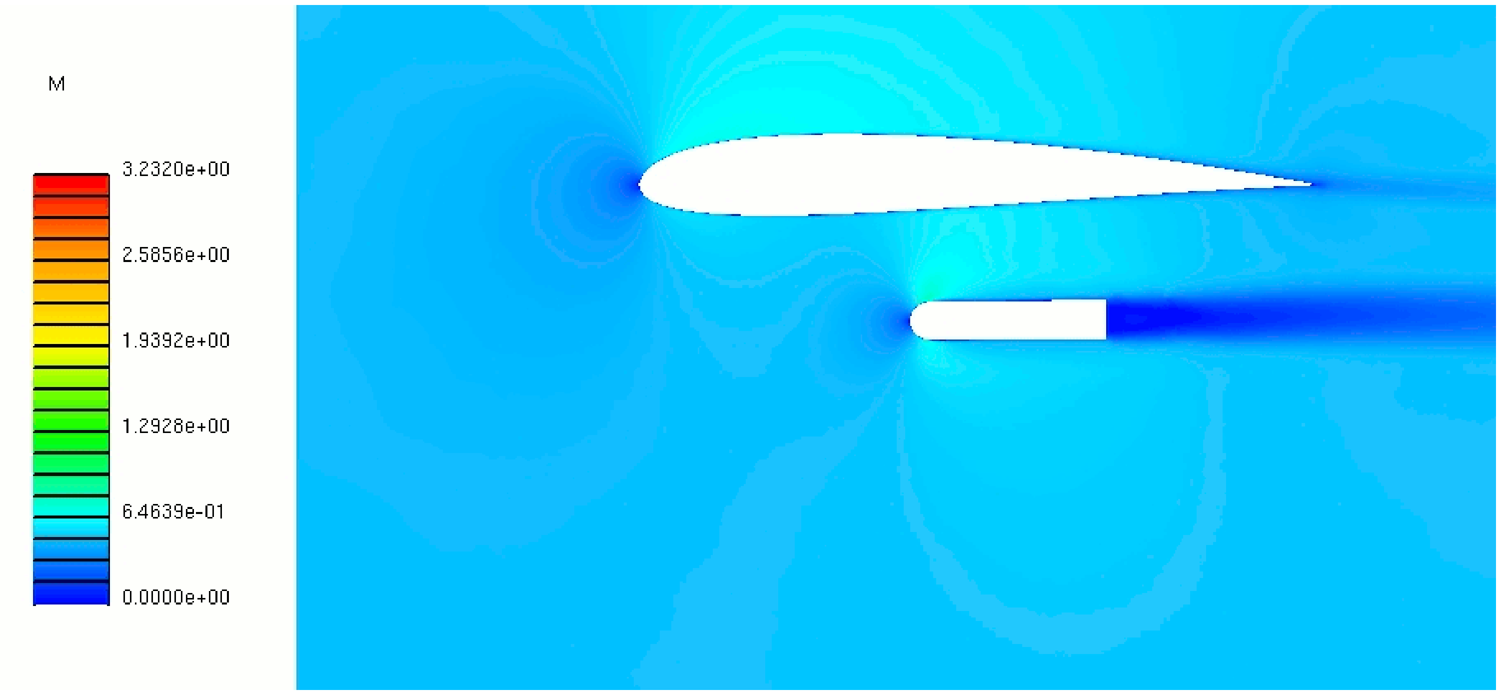


Case 2: Sequential Cutting Rank 2



No Overlap: Do Not Retain Cut Cells

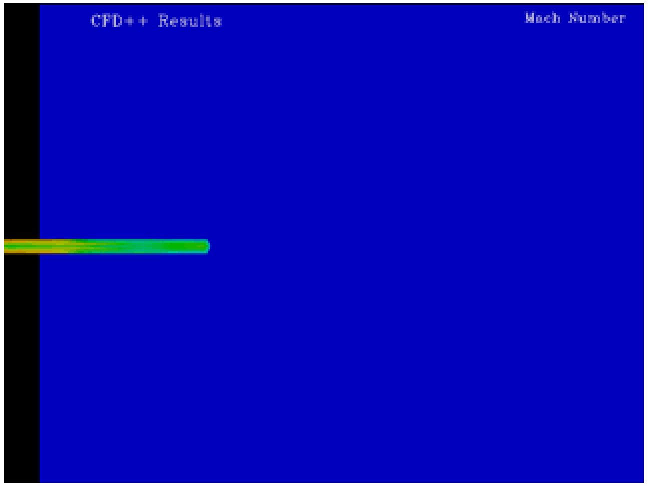
Case 2: Fin Deployment Solution

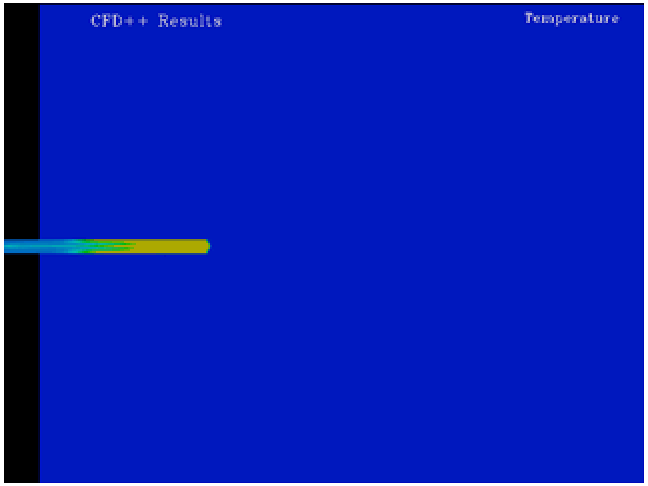


Examples

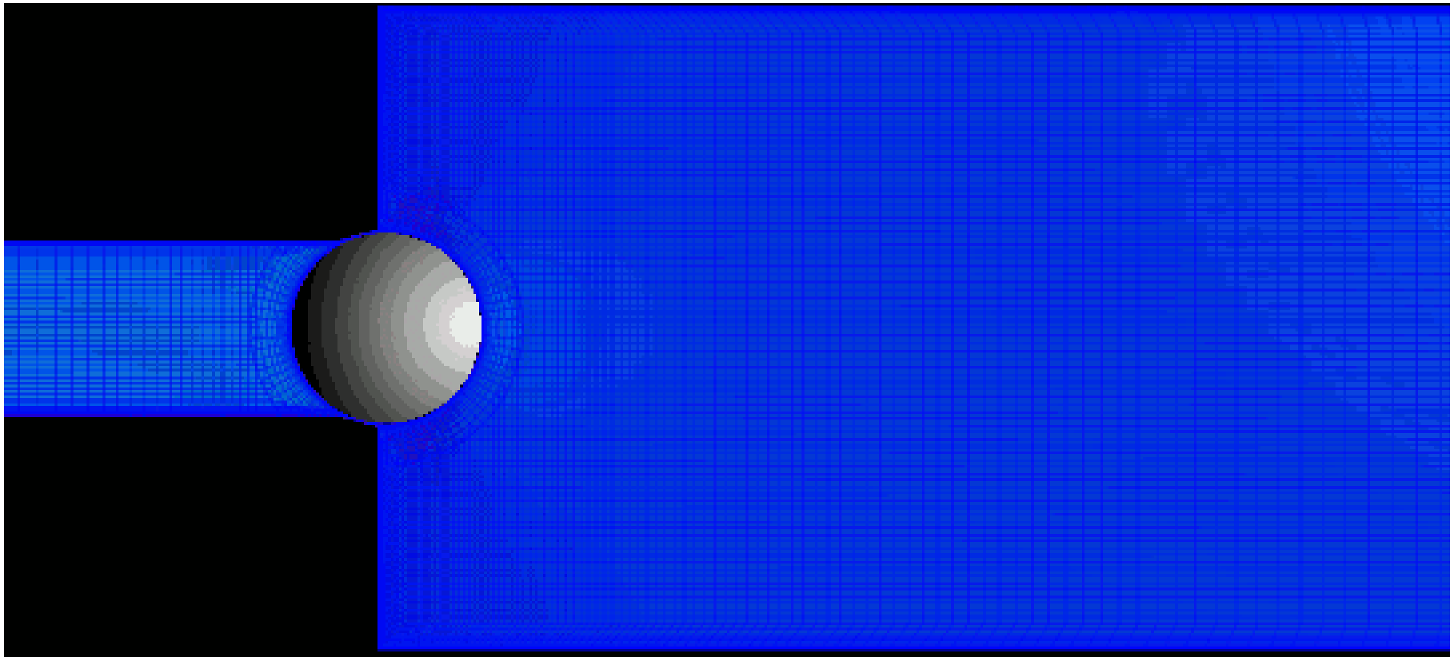
Bullet Leaving Gun Barrel

- *To simulate the detonated propellant a region of very high temperature and pressure air was imposed behind the bullet*
- *2-D axisymmetric computation simulates about 2.5e-4 s (when bullet reaches end of domain, about 0.1 m from barrel exit) - grid was 81,000 cells*
- *Propellant races ahead of bullet and exits barrel at about 6.25e-5 s*
- *1.5 hours on 2 CPUs, required 2500 global time-steps with 9900 total iterations*
- *Each animation frame is 2.5e-6 s*





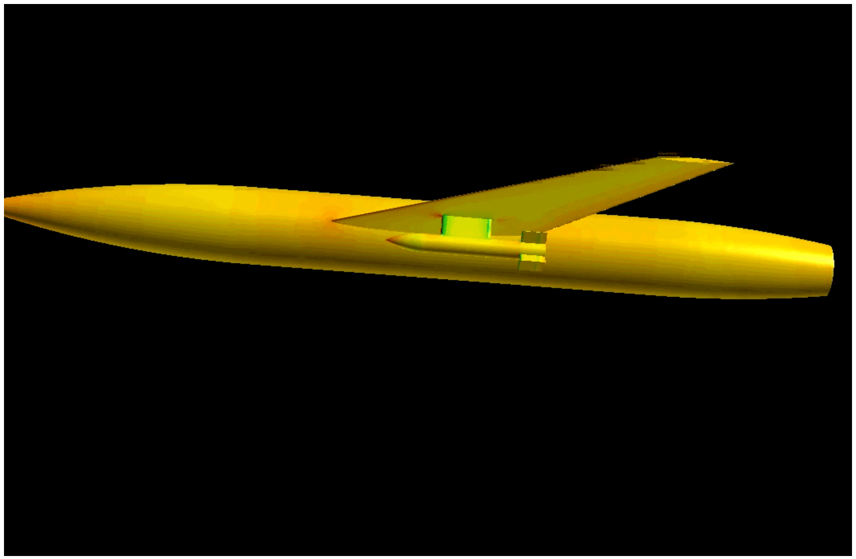
3D Ball Valve

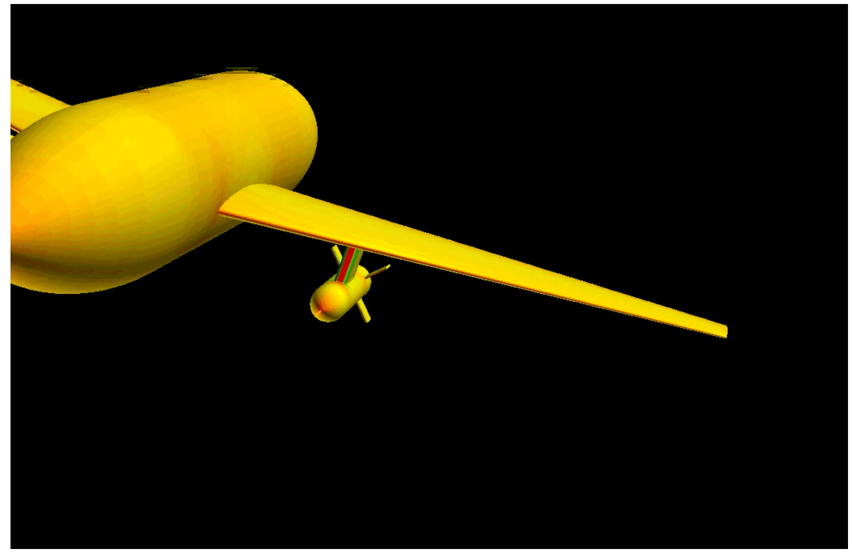


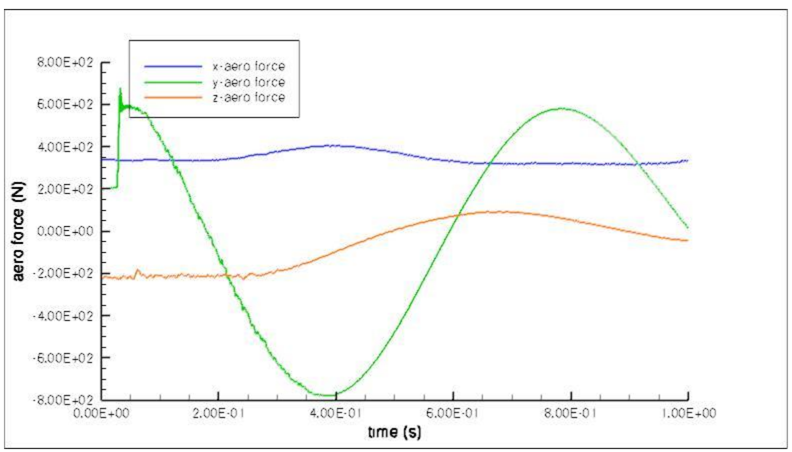
Incompressible Flow

Perfect mass balance achieved through flux stitching

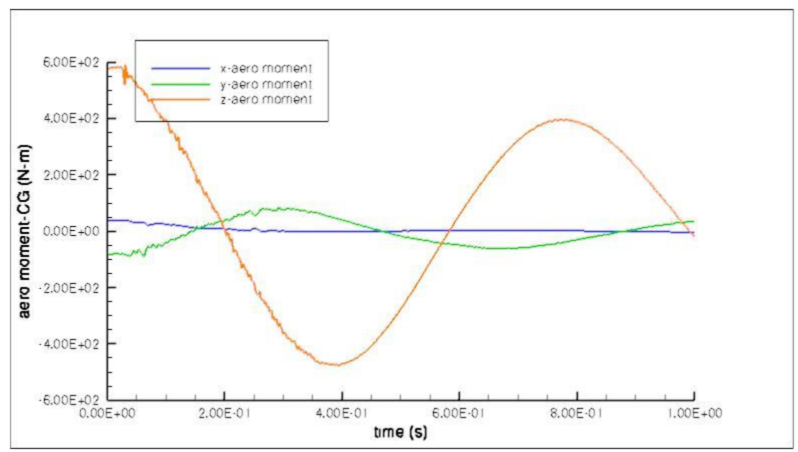
3D Store Separation





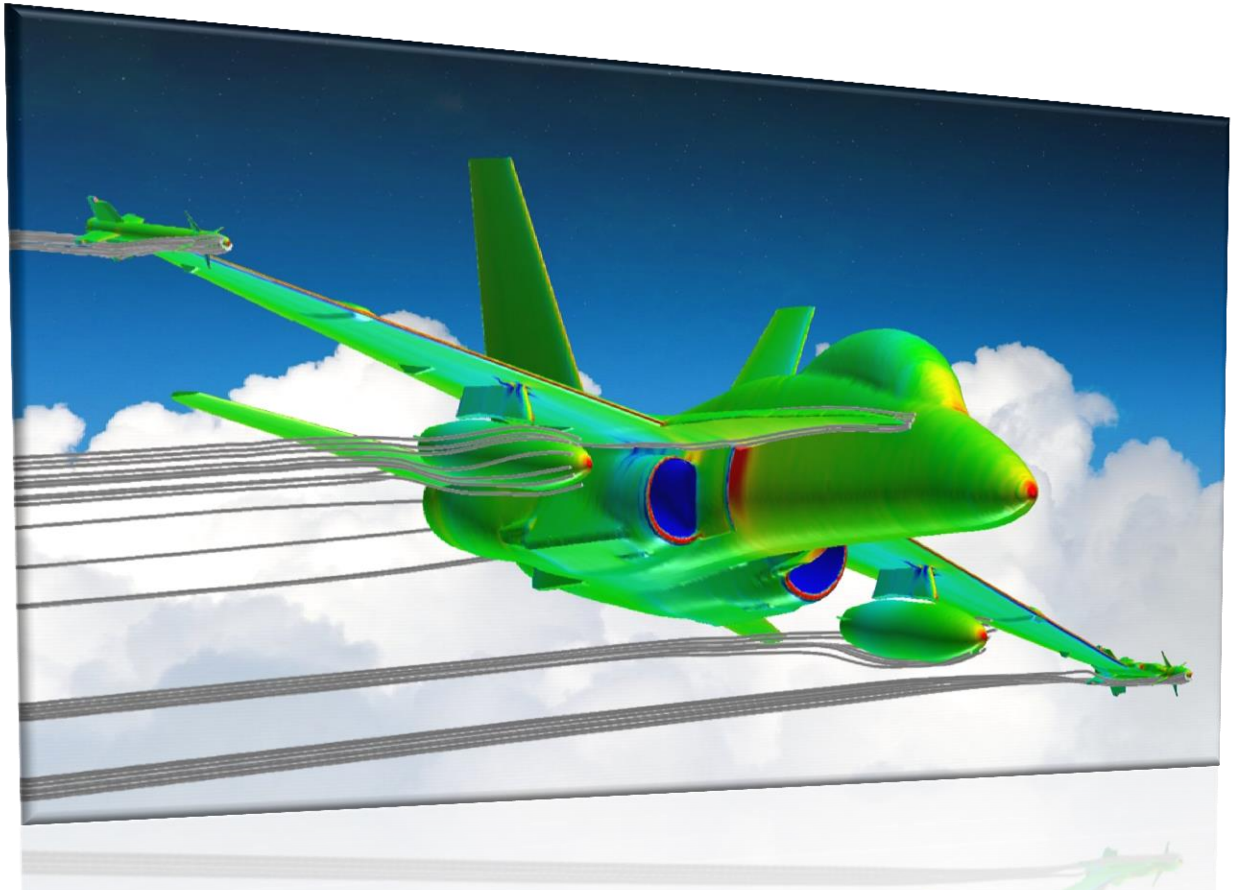


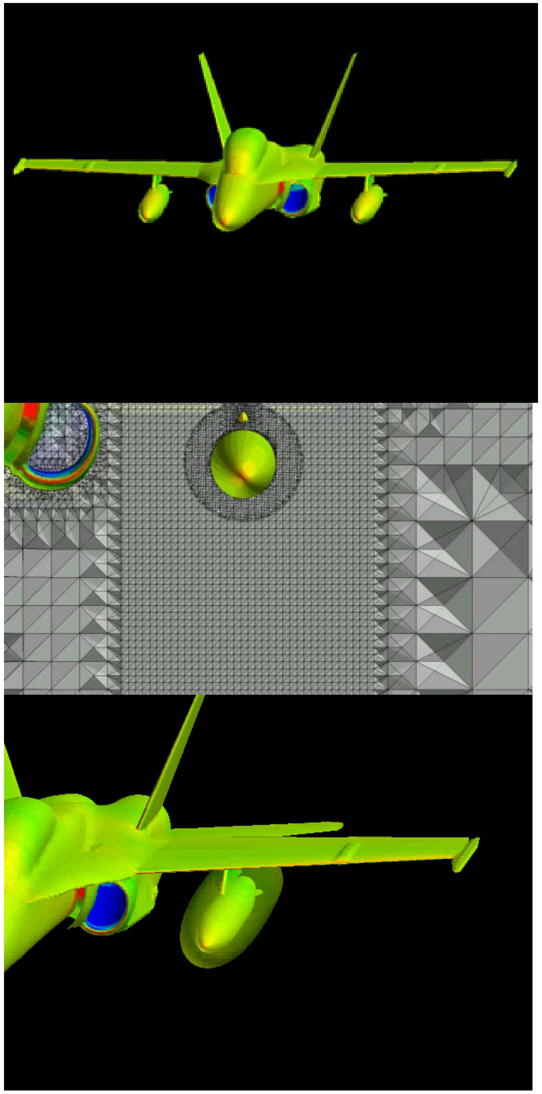
Aerodynamic forces on store



Aerodynamic moments on store

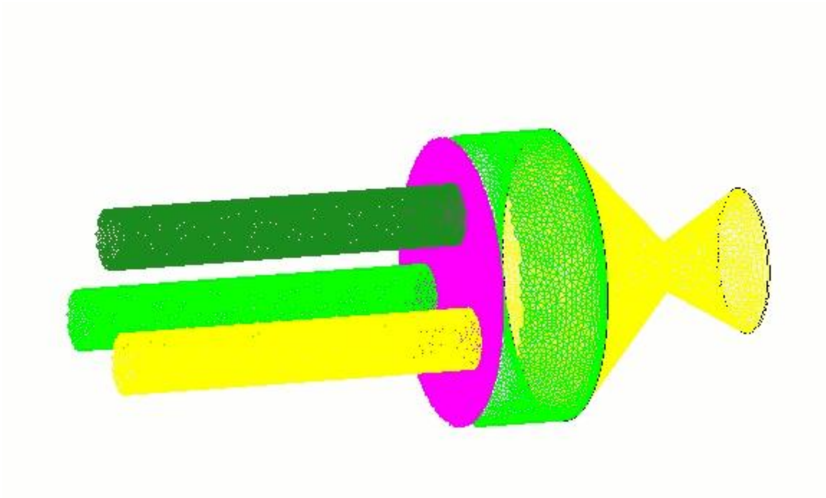
F18 Fuel Tank Separation

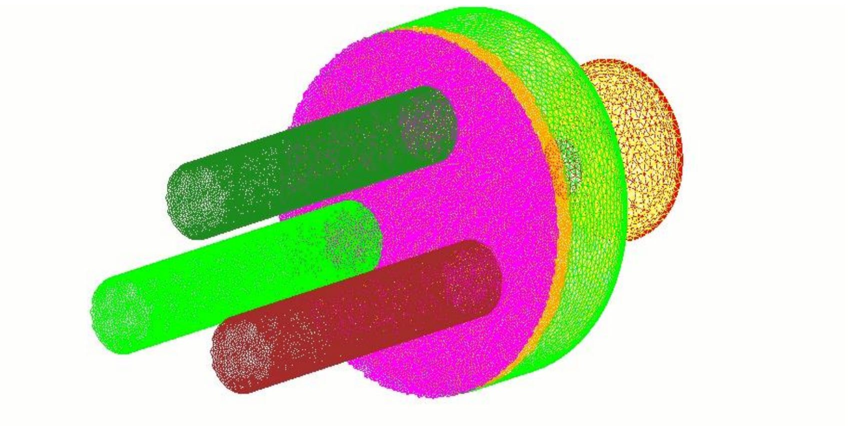


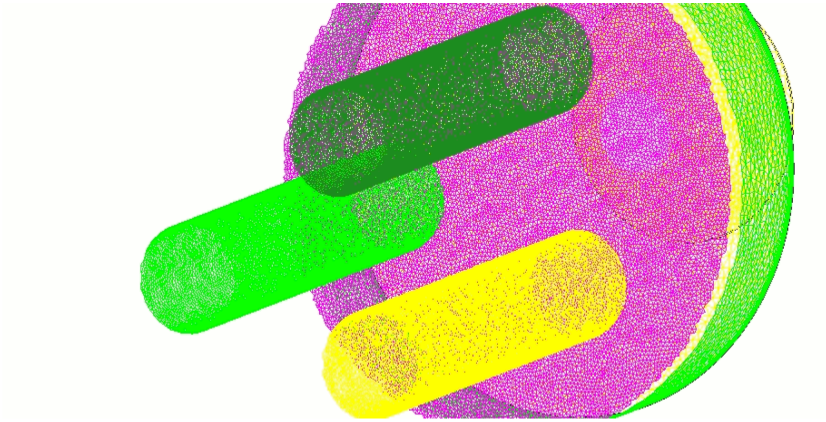


- ❑ Localized cutting, zonal connection, force integration and localized 6DOF

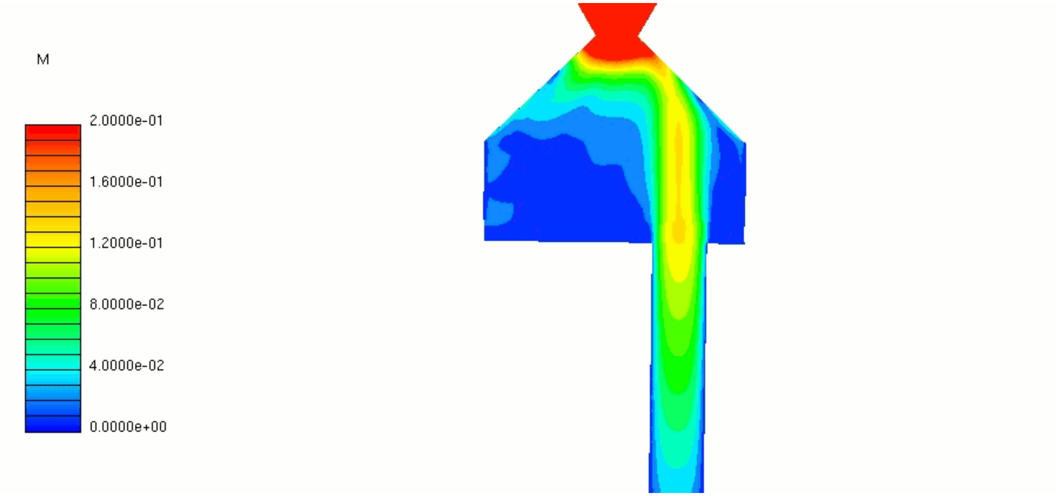
Grain Burning: Overset + Mesh Morphing

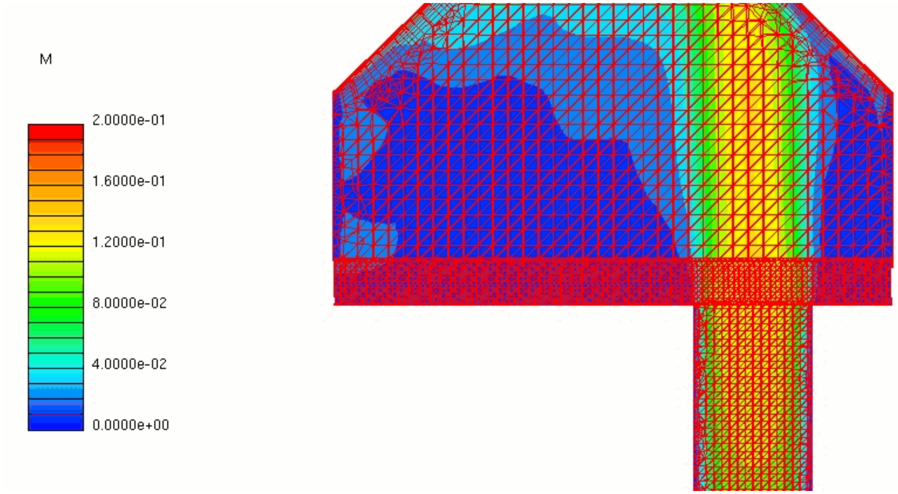




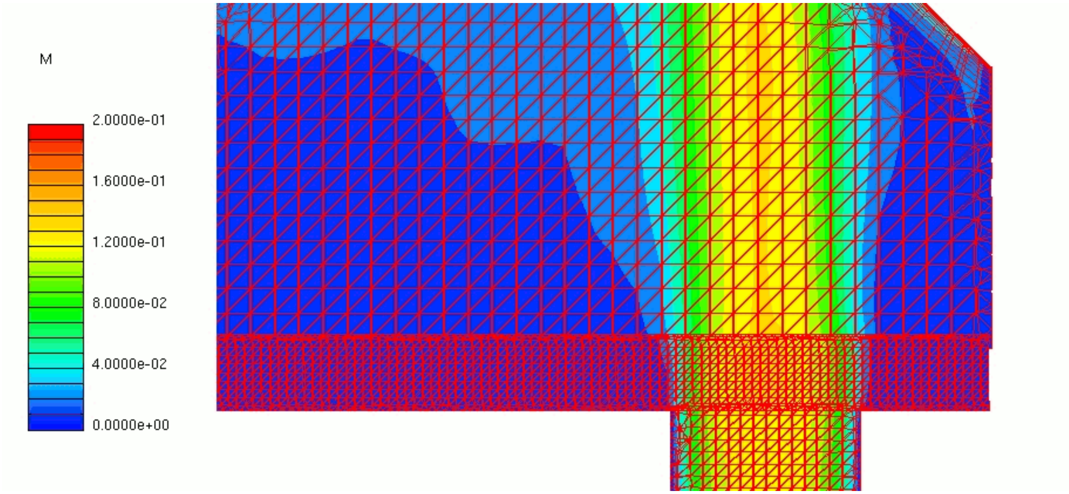


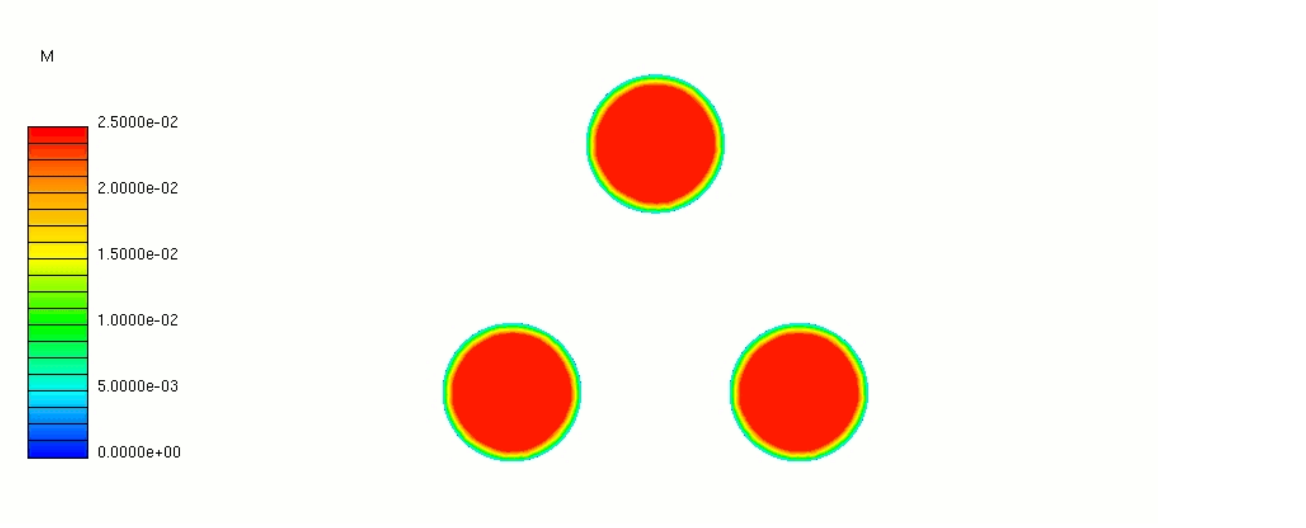
Grain Burning: Overset + Mesh Morphing





Grain Burning: Overset + Mesh Morphing





Thank you!

Questions?