What's New in STAR-CCM+ 2020.3

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Major Feature Additions in STAR-CCM+ 2020.3

- Adjoint Topology Optimization
  - Built-in constrained optimization method
- New Hybrid multiphase VOF→Lagrangian transition
  - VOF-resolves formation of droplets
  - Lagrangian tracking of the droplets
- Improved accuracy of URANS
  - Scale-resolving hybrid turbulence model
- Flexible Dynamic Fluid-Body Interaction (DFBI)
  - Account for structure deformation
- Liquid film modeling added to in-cylinder solutions
- Mixture multiphase large-scale interface model
  - Simulate free-surface flows with droplets/bubbles without resolving all scales

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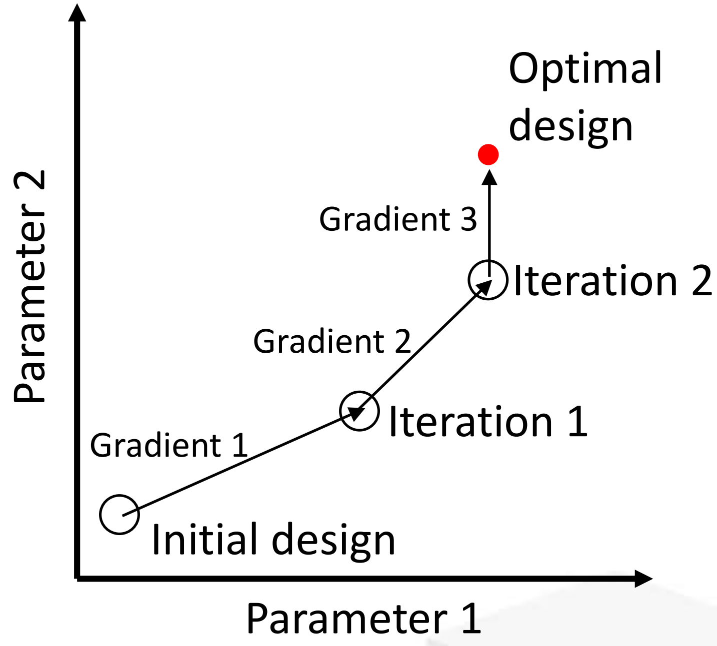
Full List: https://support.sw.siemens.com/knowledge-base/KB000020898_EN_US

Adjoint Topology Optimization

- Topology optimization method generates geometry to maximize engineering objective
- Places solid material flow domain to create flow path geometry
- Uses adjoint-based gradients to drive towards optimal solution
- Adjoint topology optimization potential benefits
  - Improve flow efficiency by removing wasteful flow features
  - Improve thermal efficiency within solid material
  - Reduce innovation cycle time
  - Does **not** need to be parametric



Adjoint Topology Optimization

Example: Rocket Engine Pintle Injector

- Pintle injector introduces rocket fuel (RP1) and liquid oxidizer (LOX) at same injection point in combustion chamber
- Combustion efficiency increases with level of mixing between RP1 and LOX
- Fuel path geometry dictates flow condition at fuel orifice
- A more turbulent fuel flow enhances mixing and can increase combustion efficiency
- Adjoint topology optimization will be used to optimize the flow path to increase fuel turbulence

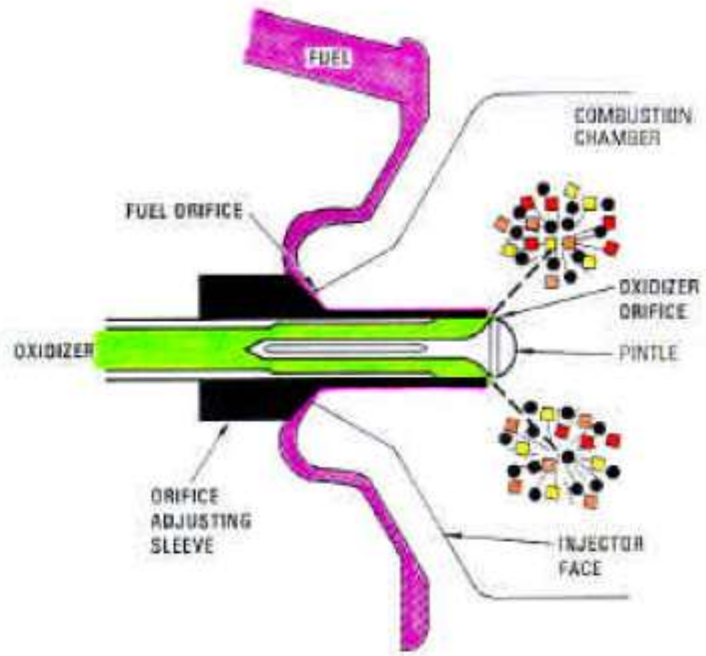


Figure 1. Pintle Injector Concept (Continuous Gap, Fixed Thrust or Thottling Designs)

Dressler & Bouer, AIAA JPC 2000

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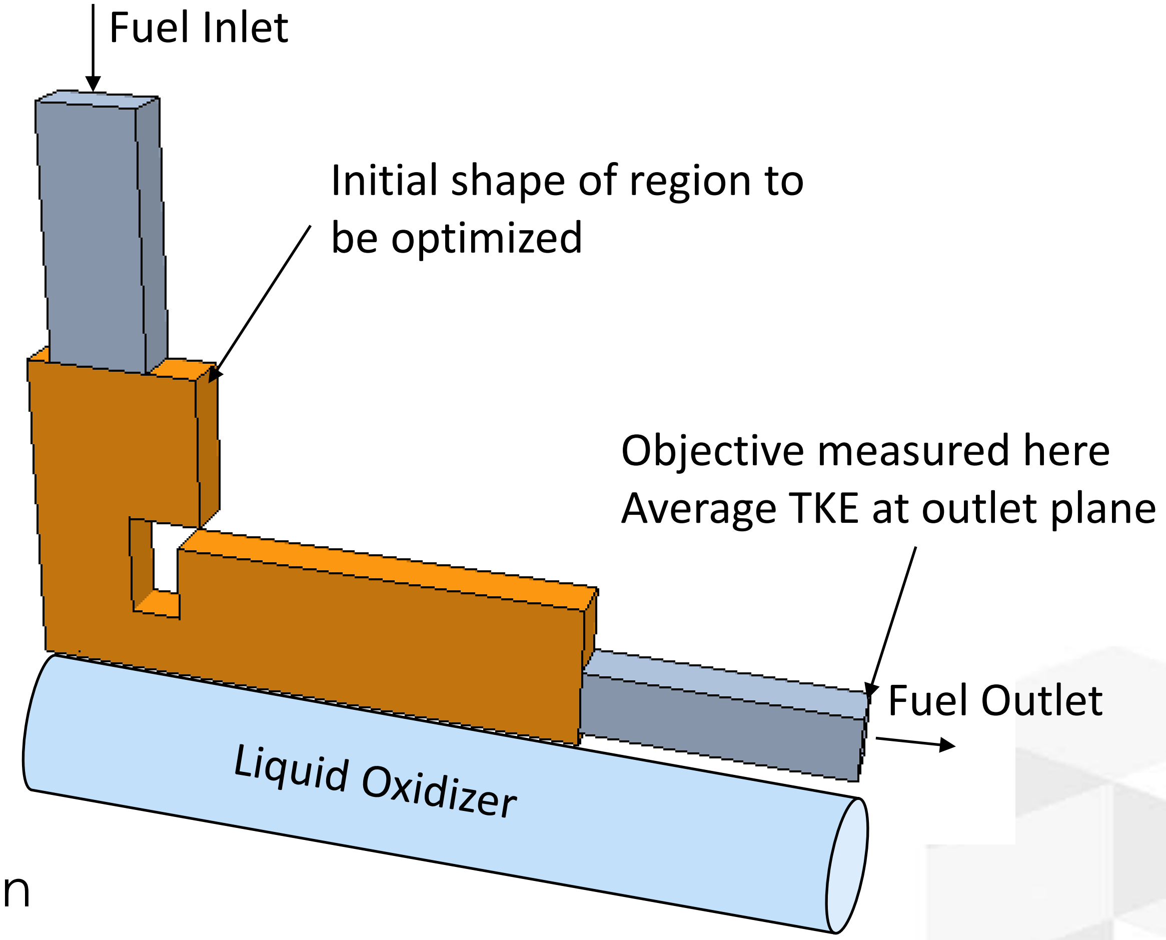
Adjoint Topology Optimization

Example: Rocket Engine Pintle Injector

- Physics Models:
  - Steady
  - Coupled Flow
  - Menter SST Turbulence Model
  - Adjoint Solver
  - Topology Optimization
  - Adaptive Mesh Refinement
    - Resolve VOF interface
- Objective:
  - Maximize TKE at outlet
- Mesh:
  - Trim cell mesher with prism layers
  - 120 thousand cells
- Simulation:
  - 2 hours on 8 cores to run 60 optimization iterations



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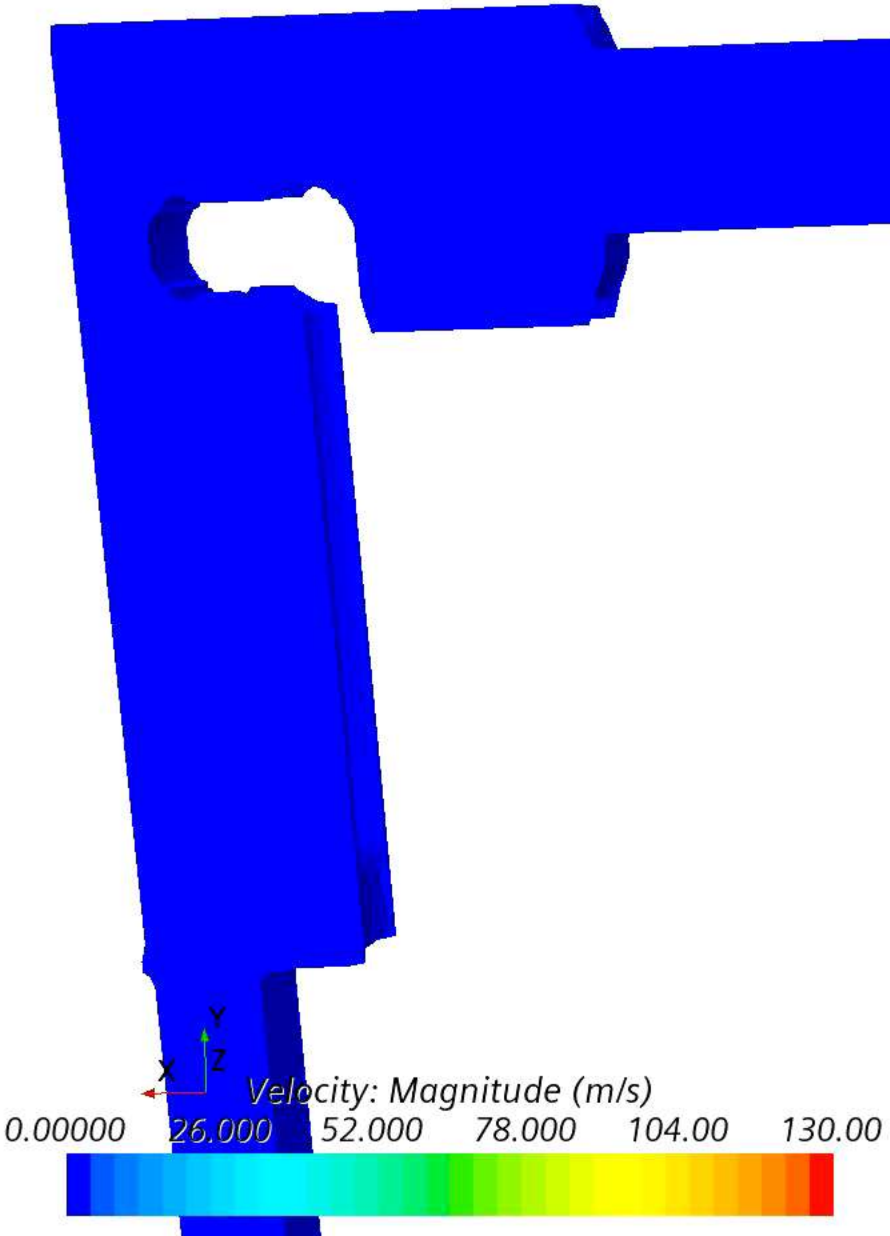
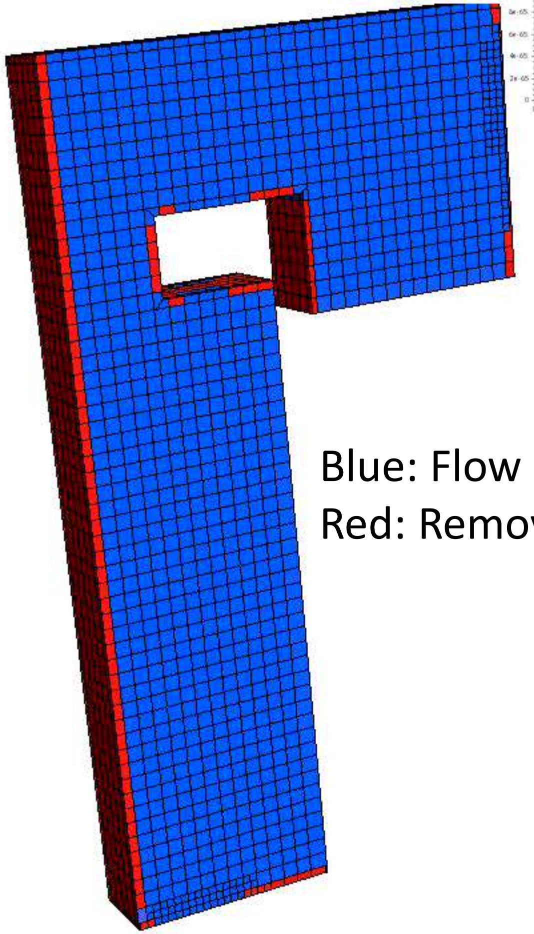
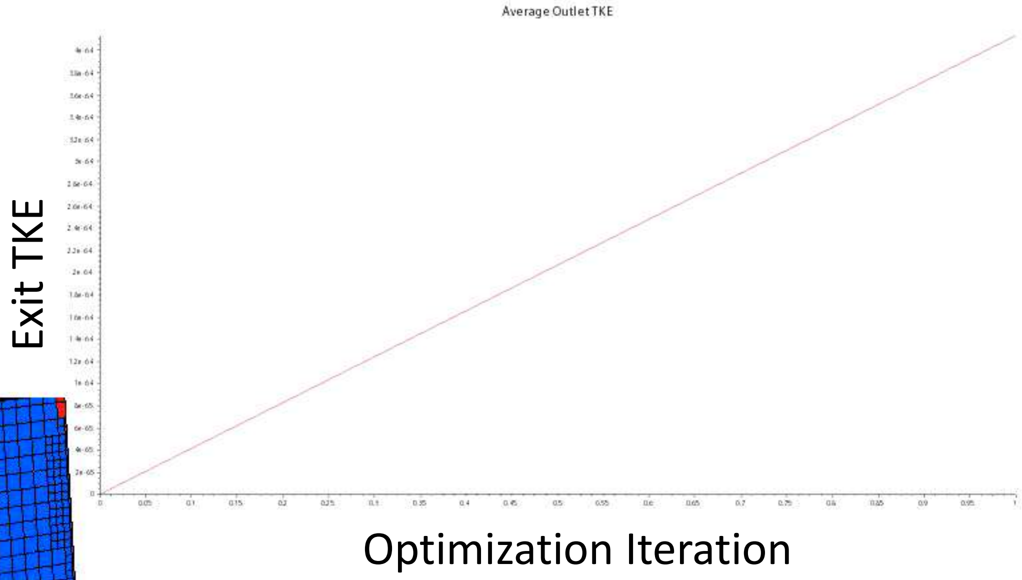
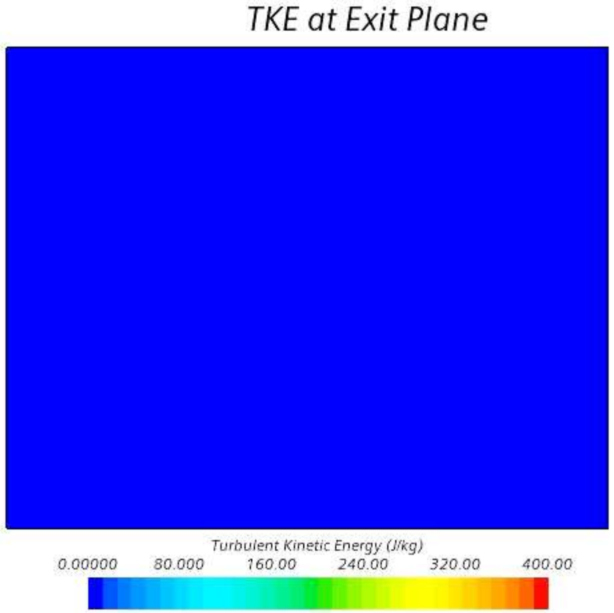




Blue: Flow
Red: Removed

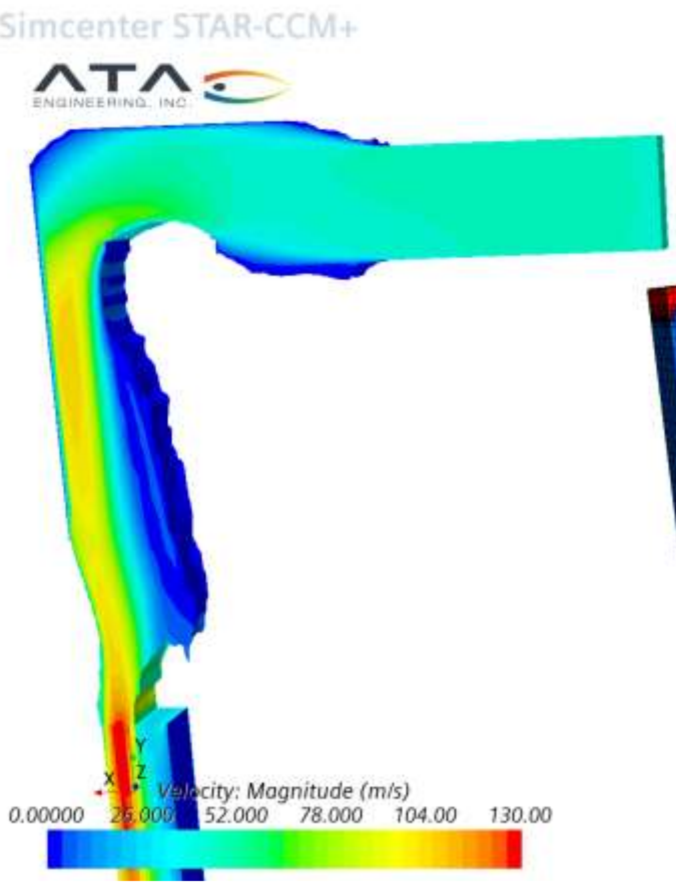


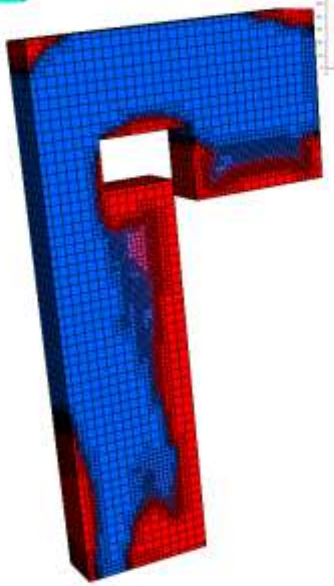


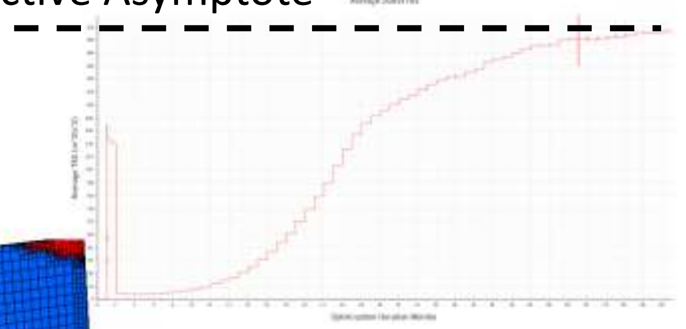
Adjoint Topology Optimization

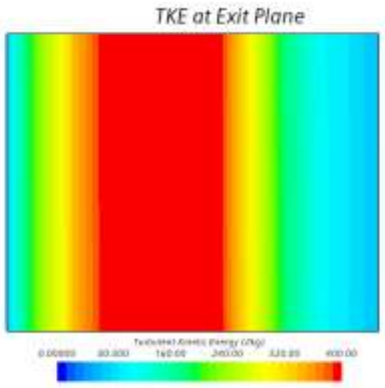
Example: Rocket Engine Pintle Injector

- Objective optimization asymptotes at 60 iterations
- Final design removed excess volume and maximized TKE at the exit
- Can be manufactured as is with additive manufacturing
  - Otherwise, can be used to suggest similar designs under conventional manufacturing constraints





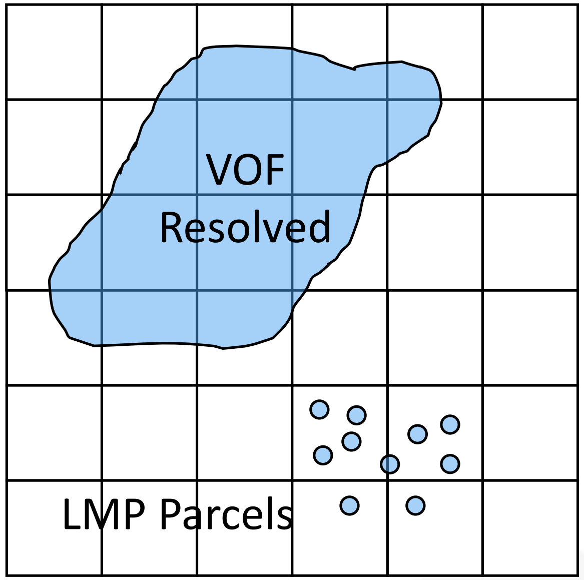




Questions?

Volume Of Fluids to Lagrangian Resolved Transition

- Volume of Fluids (VOF) and Lagrangian Multiphase (LMP) models are two approaches to multiphase modeling with distinct strengths
- VOF
  - Eulerian approach
  - Interface between phases spatially resolved
  - Good for flows of immiscible fluids, free-surfaces
  - Heavily used in marine industry
- LMP
  - Lagrangian approach modeling groups of particles as parcels
  - Parcel equations of motion subject to fluid loads from primary phase
  - Do not need to be resolved by grid
  - Good for dispersed flows, small number secondary phase particles dispersed in Eulerian primary phase

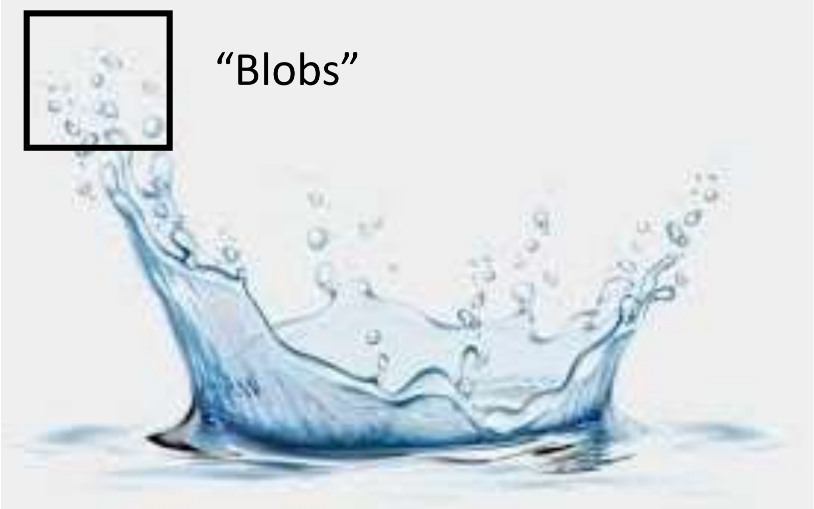


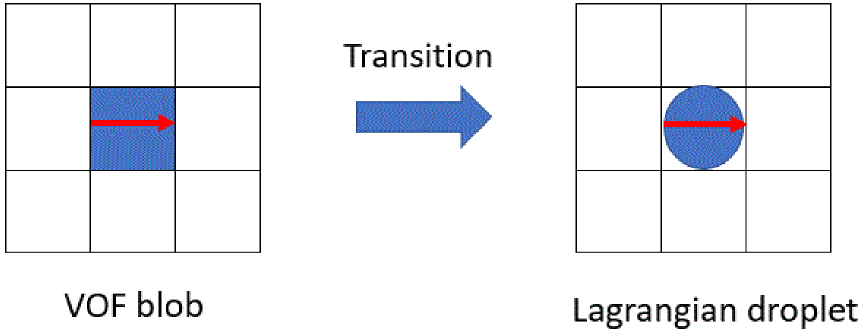
Volume Of Fluids to Lagrangian Resolved Transition

- Not uncommon for flow domain to include **both** free-surface flows **and** dispersed flows
- Example: Ocean spray off wave crest
- A hybrid model incorporating both VOF and LMP exploits the strengths of each model
- 2020.3 includes the VOF to LMP Resolved Transition model to identify when and how to properly convert between VOF and LMP

Volume Of Fluids to Lagrangian Resolved Transition

- The transition model tracks the size of fluid "blobs"
- When blob diameter drops below threshold, blob is marked for Lagrangian transition
- In the case where the blob volume ratio is close to 1, the resulting droplet has roughly the same size and velocity as the blob
- It is advised to use AMR to resolve blobs, which are coarsened after transition

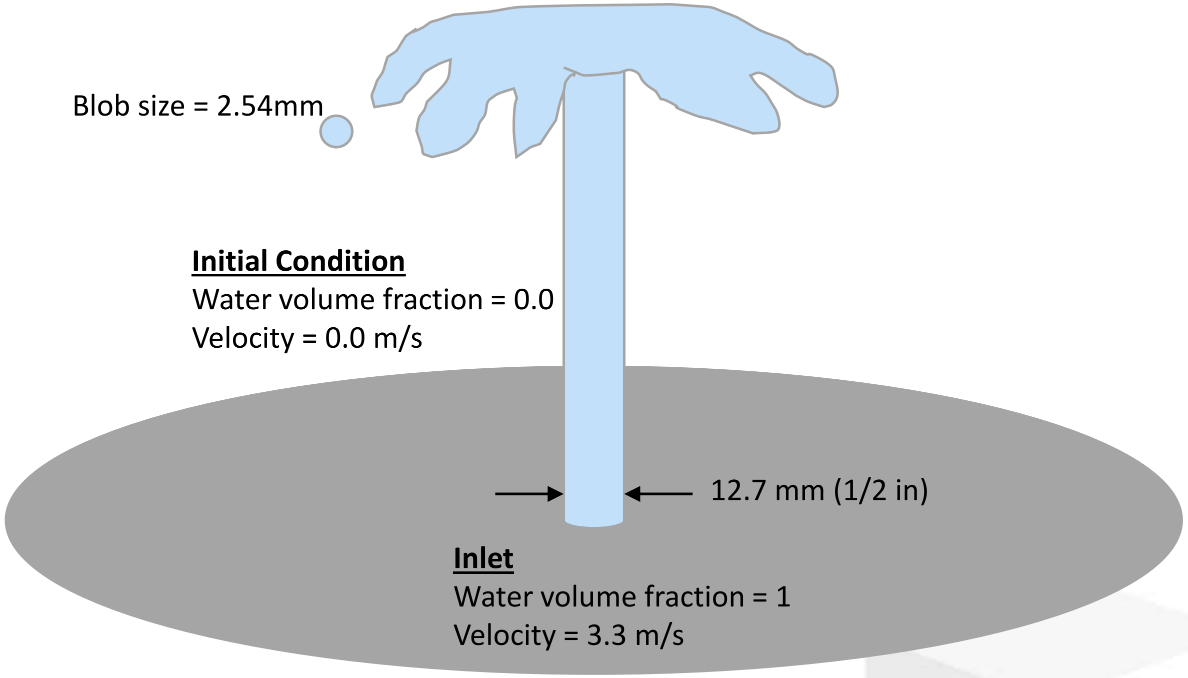


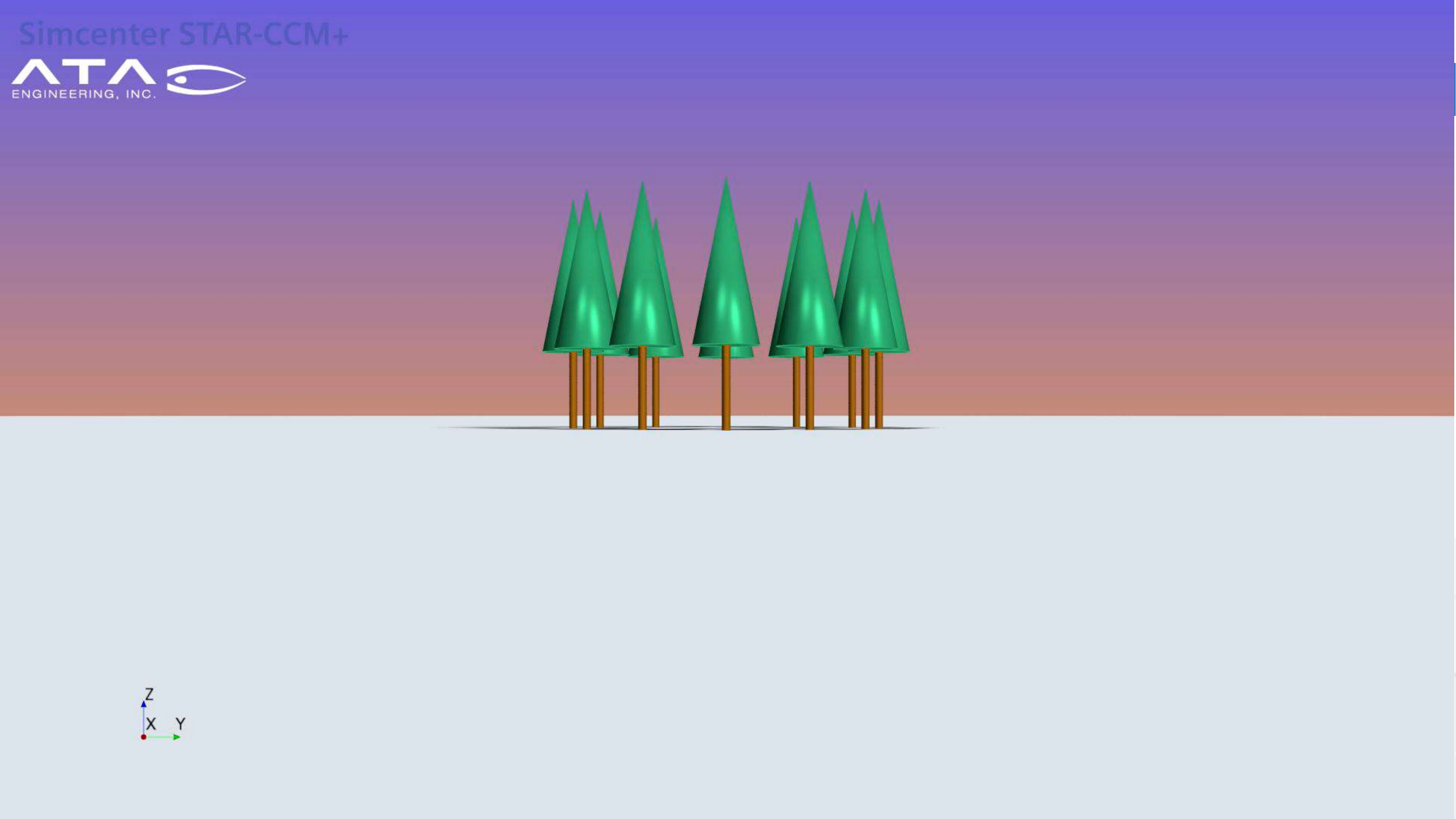


Volume Of Fluids to Lagrangian Resolved Transition

Example: Water Fountain

- Physics Models:
  - Implicit Unsteady
  - Segregated Solver
  - Menter SST Turbulence Model
  - Volume of Fluids (VOF)
    - Water and Air Phases
  - Lagragian Multiphase (LMP)
    - Water Phase
  - VOF to LMP Resolved Transition
    - Blob size = 2.45 mm (roughly 1 cell)
  - Adaptive Mesh Refinement
    - Resolve VOF interface
- Mesh:
  - Polyhedral mesher with prism layers
  - 661 thousand cells
- Post processing:
  - Screen play with advanced rendering

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