Scalable Engineering Simulation Applications

Outreach Program with NSCC

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Agenda

- **Particle Dynamics**
  - Introduction
  - Physics Validation
  - Sample Cases & Scalability Study
- **Large Area Simulations**
  - Introduction
  - Sample Cases with Scalability study
- **Other Engineering Examples**

Particle Dynamics

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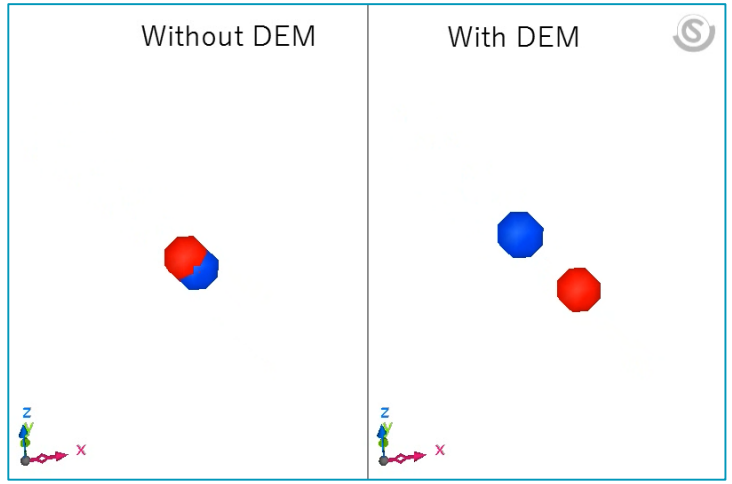
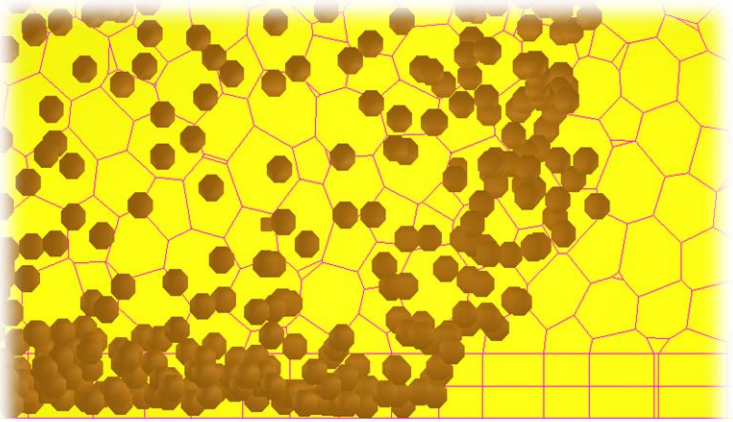
Introduction to Particle Dynamics

Complex Particle Dynamics



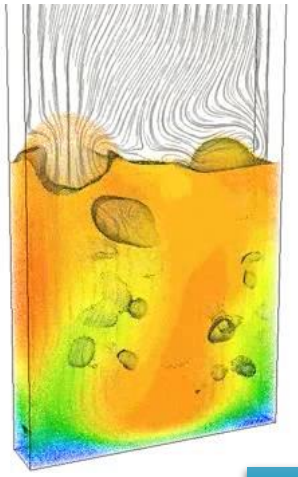
- Interaction between fluid and particles
- Contact forces between particles
- Volume of each particle also to be considered

Large Mesh Size

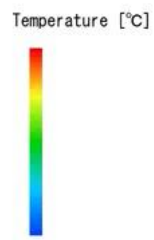


- Particle size is assumed to be relatively small compared to CFD mesh size

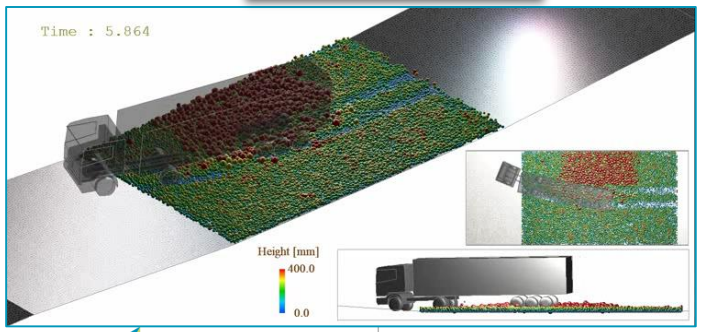
Complexity with Coupling



Fluid Coupling



MBD Coupling



Validation with Different Superficial Velocities

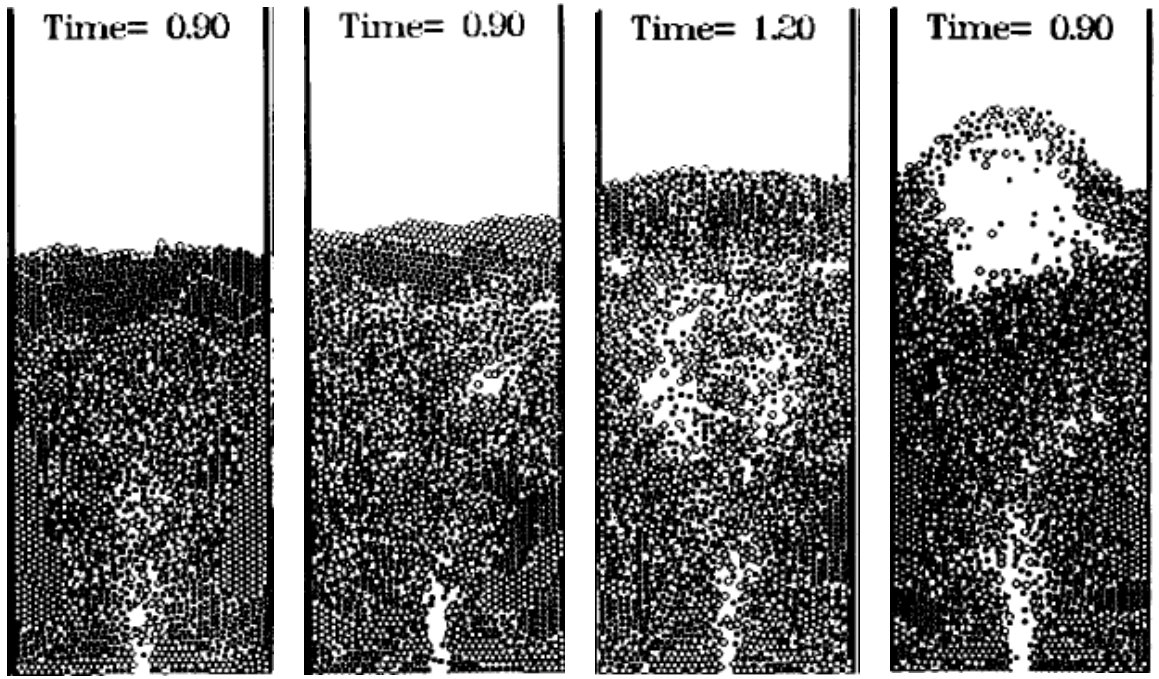
Fluidized Bed

Applications: Solid separation, Catalytic cracking, chemical reactors coating etc

* Gravel property
  - Diameter : 4 [mm] (uniform)
  - Density : 2,700 [kg/m^3]
  - Spring stiffness : 800 [N/m]

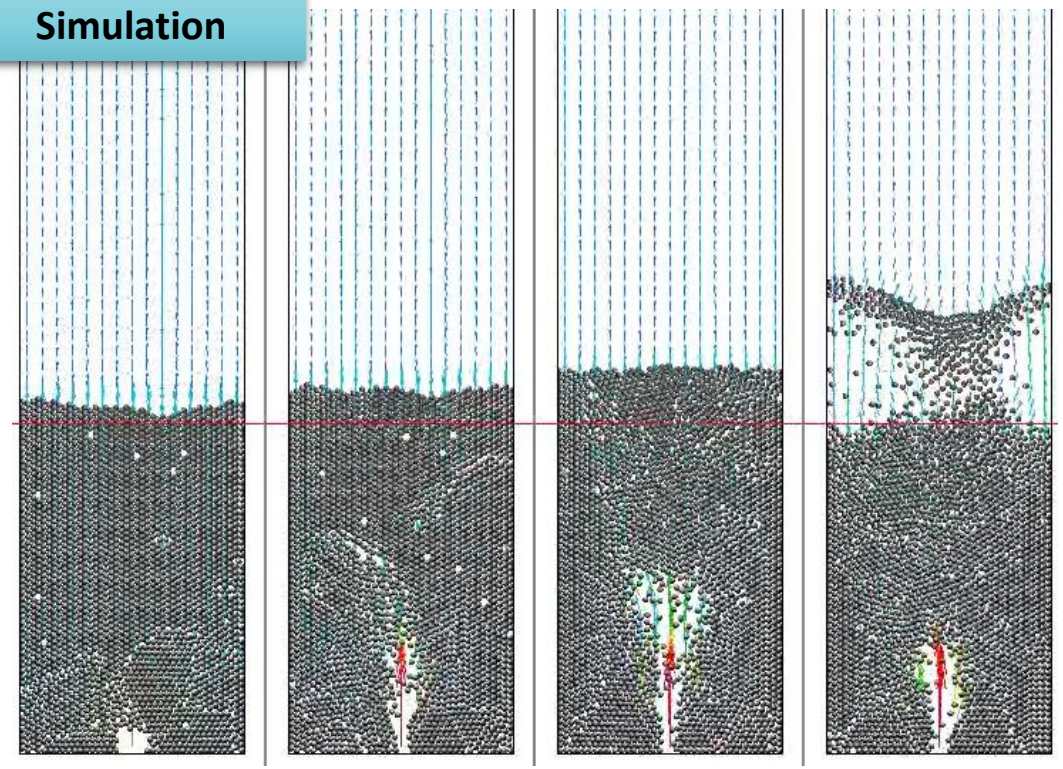
* Contact Model
  - Linear spring dashpot model

Result in paper†



$v_0 = 2.0$ $v_0 = 2.2$ $v_0 = 2.4$ $v_0 = 2.6$

Simulation



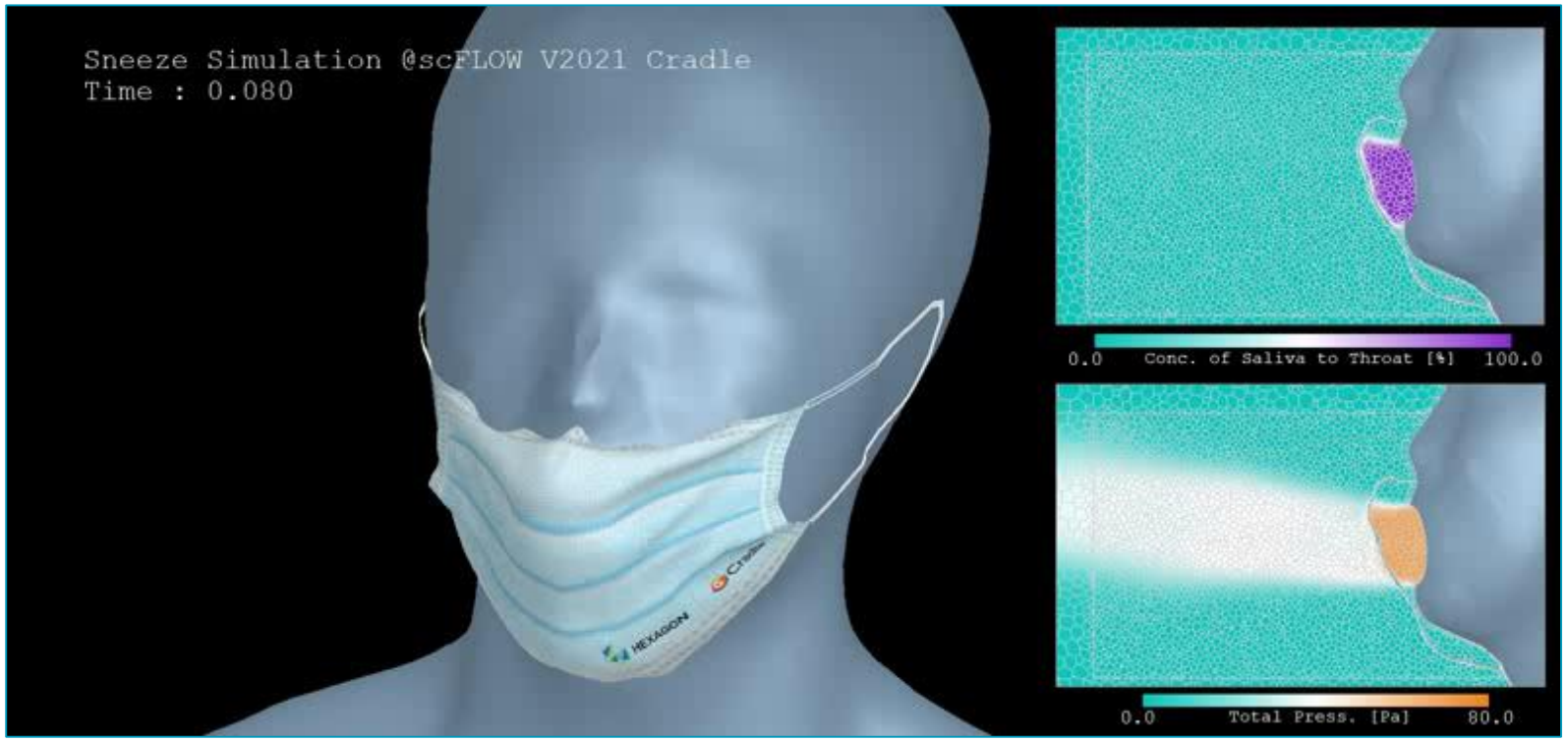
$v_0 = 2.0$ $v_0 = 2.2$ $v_0 = 2.4$ $v_0 = 2.6$

† Kawaguchi, Tanaka and Tsuji, “Numerical Simulation of Fluidized Bed using the Discrete Element Method (the Case of Spouting Bed)”, Japan Society of Mechanical Engineers Collected Articles, Series B, Vol. 58, No.551, 1992, pp. 2119-2125.

Particle Dynamics – With CFD Coupling

Cloth model emulating a Mask

Mask Trapping Sneezing Droplets



Conditions

- Sneezing Max speed : 10 m/s
- DEM particle count : 4,753
- Particle Diameter : 2 mm (Uniform)
- Particle Density : 200 kg/m^3 (4 g at the whole Mask)
- Contact model : Walton-Braun
- Young's modulus : 1 kPa
- Static friction : 0.3
- Rolling friction : 0.3
- Restitution coeff. : 0.01
- CFD coupling : Used
- Mesh Count : 728,289

Calc.Spec.

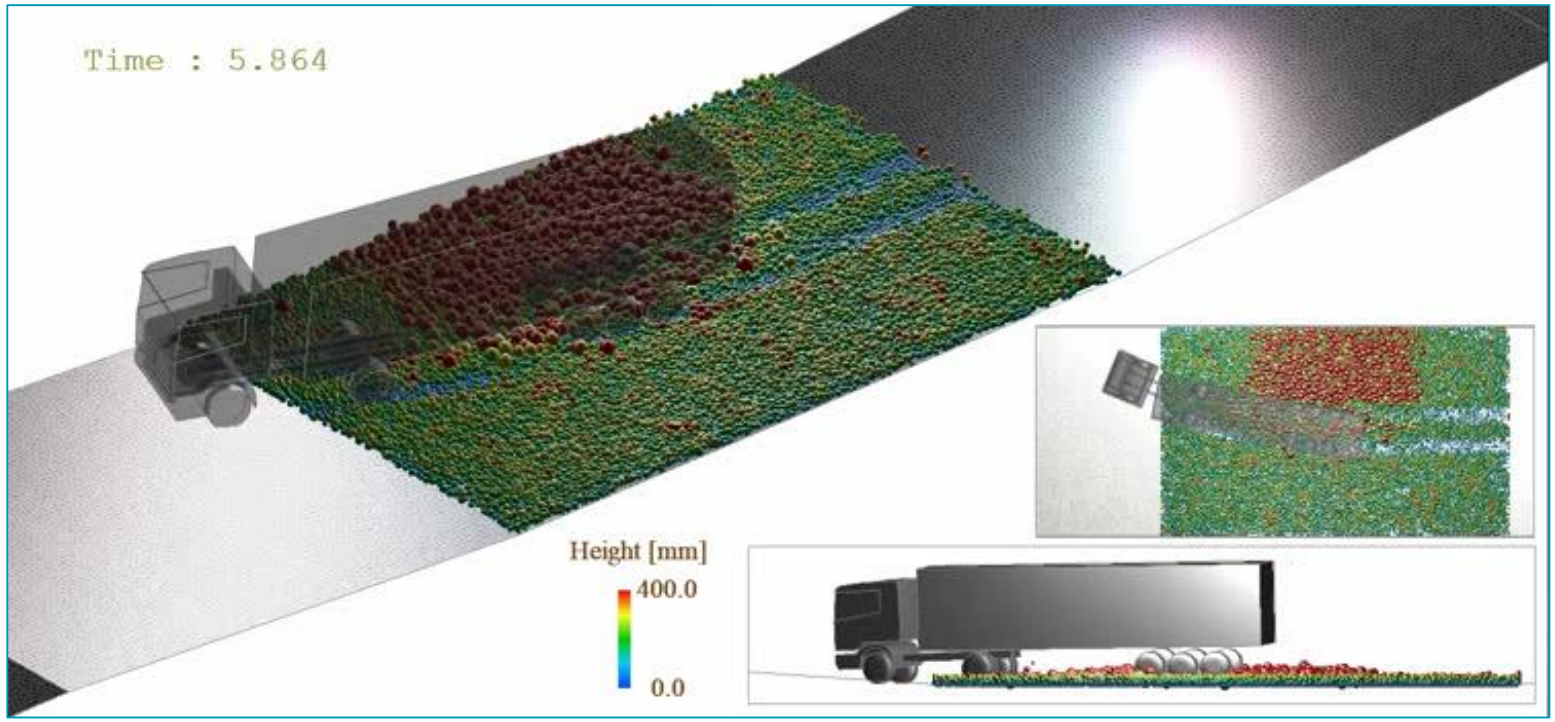
- Calc. Time : 6h : 36m : 29s @ rx2530
- MAX Memory(ALL) : approx. 38 GB
- Degree of parallelism : 144 MPI procs.
- Physical Time : 2 s
- CFD time step : 0.5 ms
- DEM time step :

the lesser of either 10 % of the critical Rayleigh time step, and 10 % of diameter divided by the velocity of particle (Avg. : approx. 0.1 ms)

Multiphysics interaction via CoSim

Coupling with Adams (MBD)

Semi-trailer Running on Soft Soil



Conditions

- Trailer mass：37 t
- Trailer speed：36 km/h (Gear position : 7)
- DEM particle count : Smaller : 18,000 / Bigger : 750
- Particle Diameter : Lognormal (100mm - 400mm)
- Particle Density : 2,650 kg/m^3 (Uniform)
- Contact model : Hertz-Mindlin JKR
- Young's modulus : Smaller : 625kPa / Bigger : 2.5MPa
- Surface energy：50 mJ/m^2 (Bigger/Smaller)
- Static friction：0.8 (Bigger/Smaller)
- Rolling friction ： 0.2 (Bigger/Smaller)
- Restitution coeff.：0.5 (Bigger/Smaller)
- CFD coupling ： Not used
- Mesh Count : 795,943

Calc.Spec.

- Calc. Time : 1d : 14h : 18m : 41s @ fjt1803
- MAX Memory(ALL) : approx. 18 GB
- Degree of parallelism : 144 MPI procs.
- Physical Time : 8 s
- DEM time step :

  the lesser of either 10 % of the critical Rayleigh time step, and 10 % of diameter divided by the velocity of particle

  (Avg. : approx. 0.8 ms)

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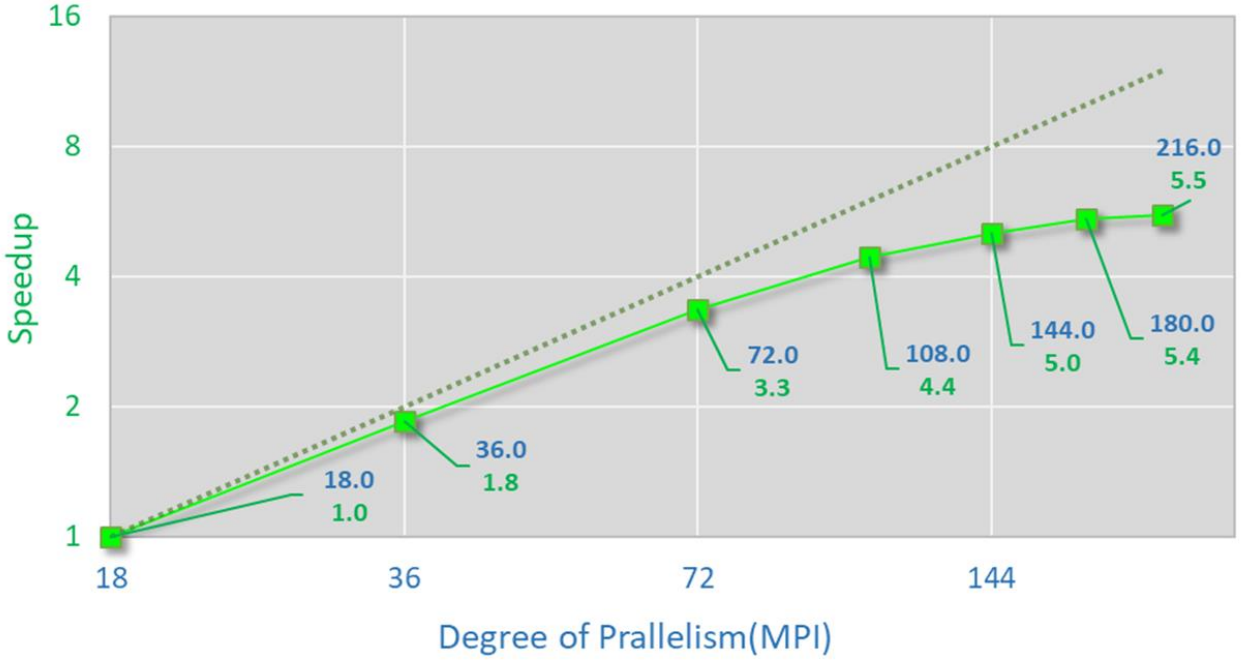
Particle Dynamics - Scalability Study

*** Conditions**

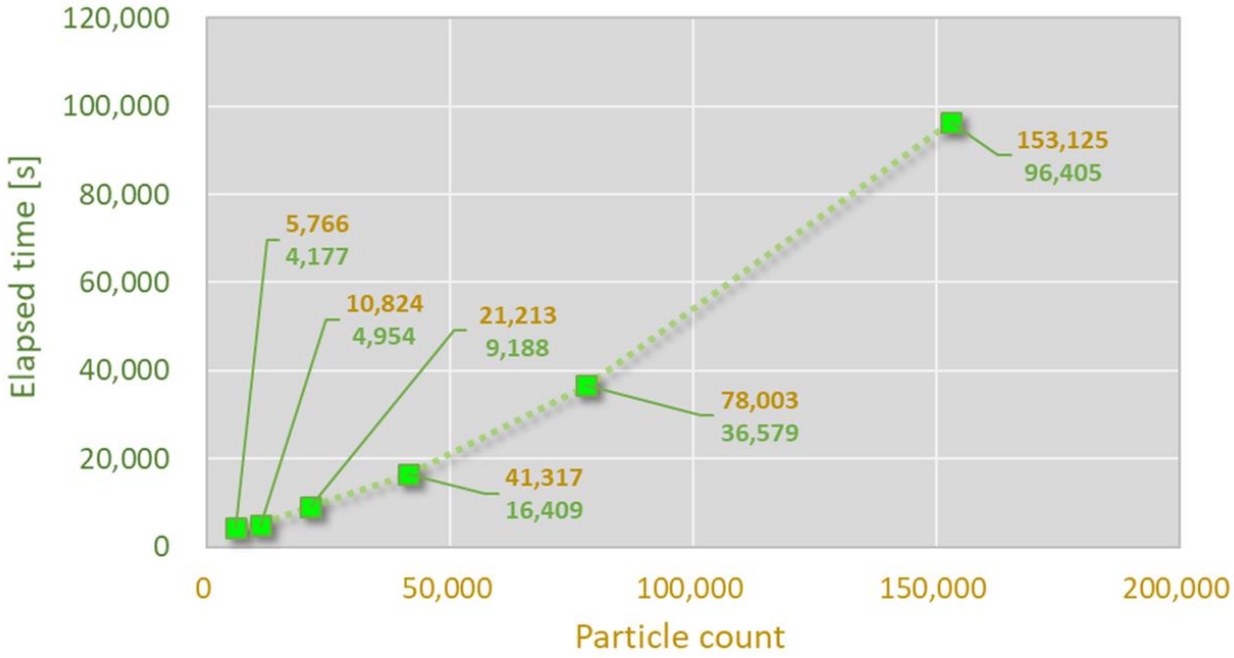
- DEM Particle count : 153,124
- Mesh Count : 28,513
- Contact Model : Walton-Braun
- Young's modulus : 1,000 Pa
- Diameter : 0.14 mm (uniform)
- Density : 2,650 kg/m^3



➡ With CFD skip mode, good efficiency achieved.

*** Conditions**

- Mesh Count : 28,513
- Contact Model : Walton-Braun
- Young's modulus : 1,000 Pa
- Diameter : 0.14 [mm] (uniform)
- Density : 2,650 [kg/m^3]



➡ The elapsed time is almost linear to the particle count.

Large-Scale Simulations

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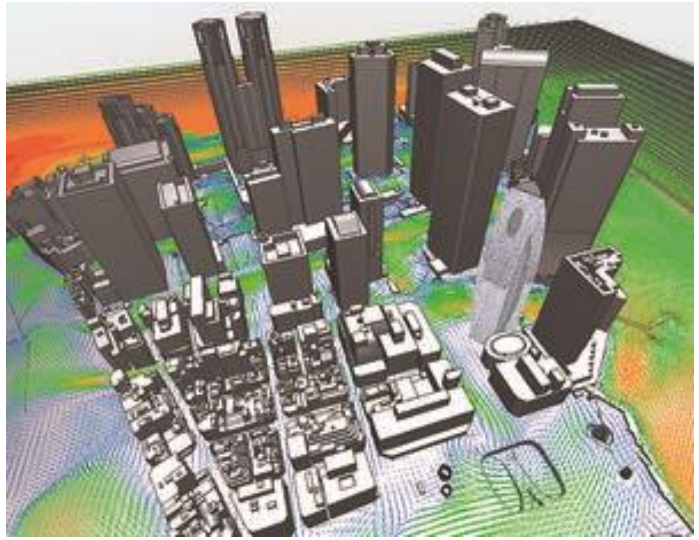
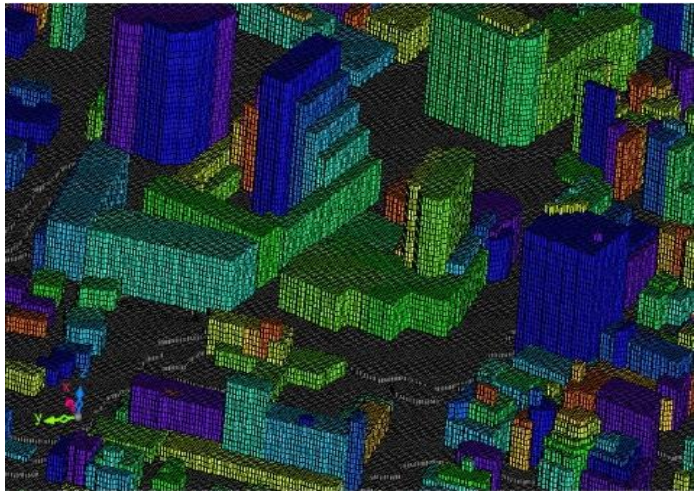
Introduction to Large Scale Simulations

Problem Size



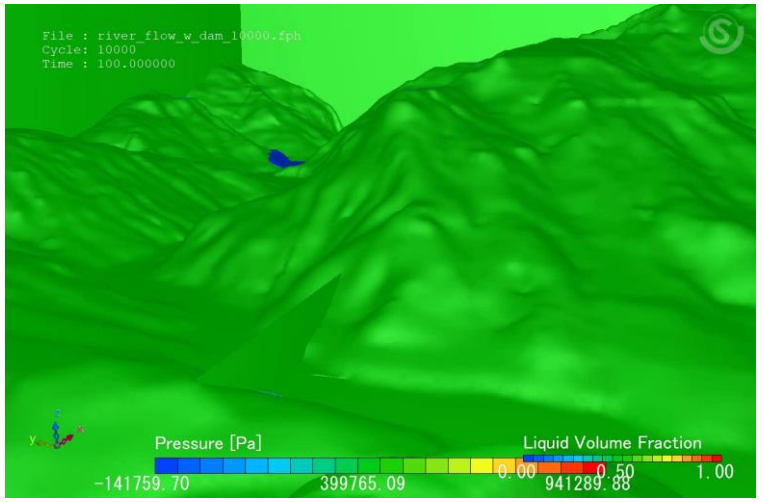
- Ranging from few sq. meter to sq. kms

Large Mesh Size



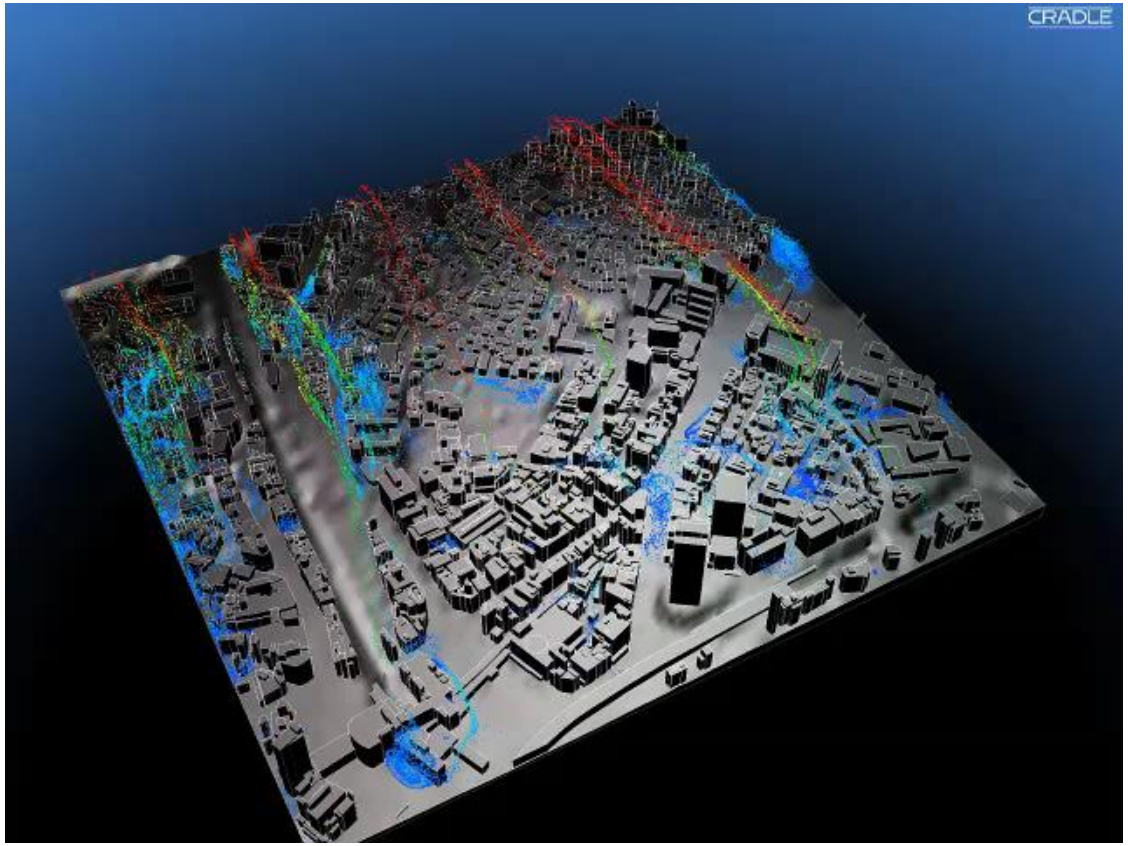
- Ranging between 50 – 500 million and above

Multiphysics



- Volume of Fluids
- Particle tracking / DEM
- Solar Tracking / Rays
- Topology Mapping

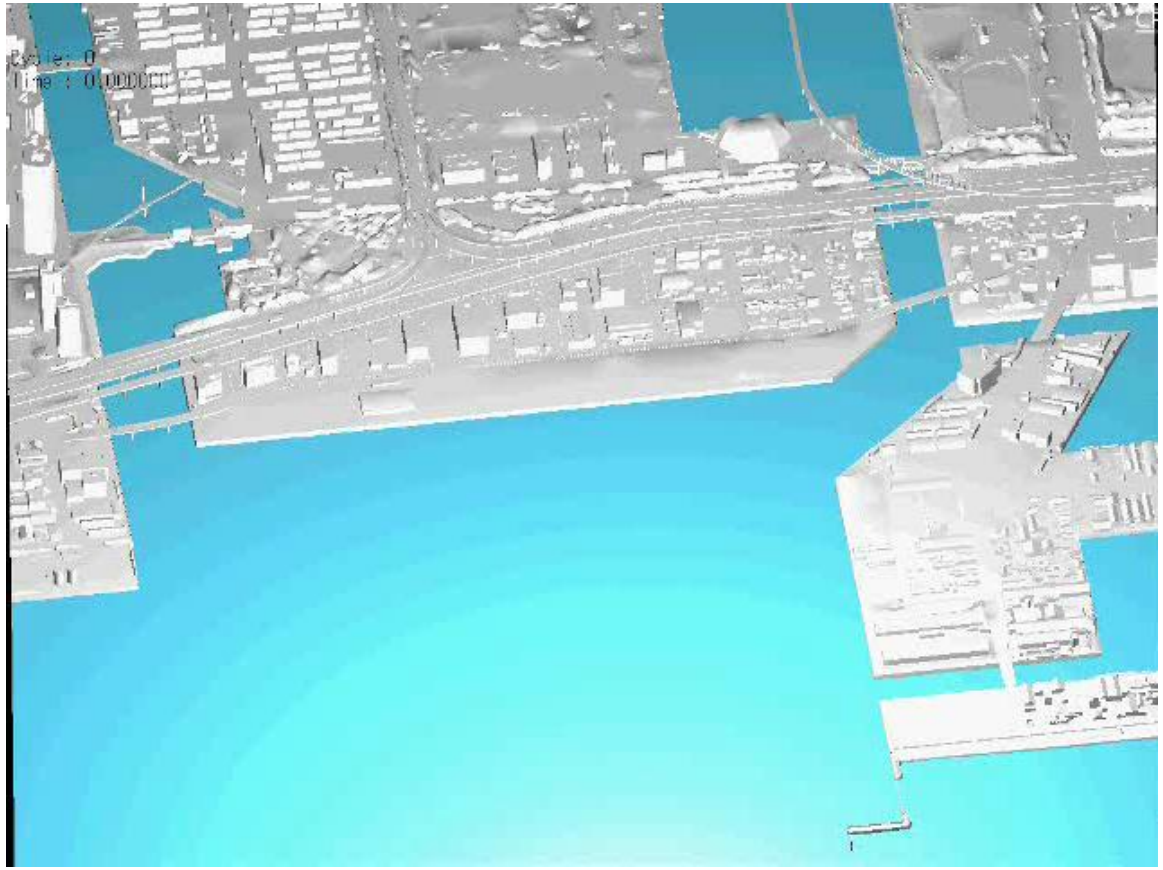
Wind flow & Pollution Dispersion



Simulation Details & benefits

- 50 Million+ mesh count
- Inclusion of Multiphase – Air and Particles
- Complex terrain conditions through topology mapping
- Effect of wind direction and ground elevation
- Pollution diffusion analysis
- Study on pollution concentrations
- Flow And structure interactions
- Inclusion of vehicular emissions, fog and moisture

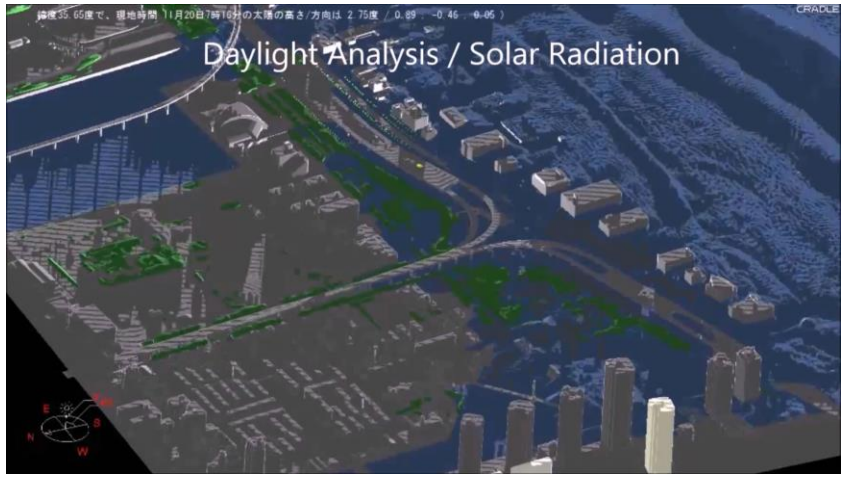
Tsunami Run-up Analysis

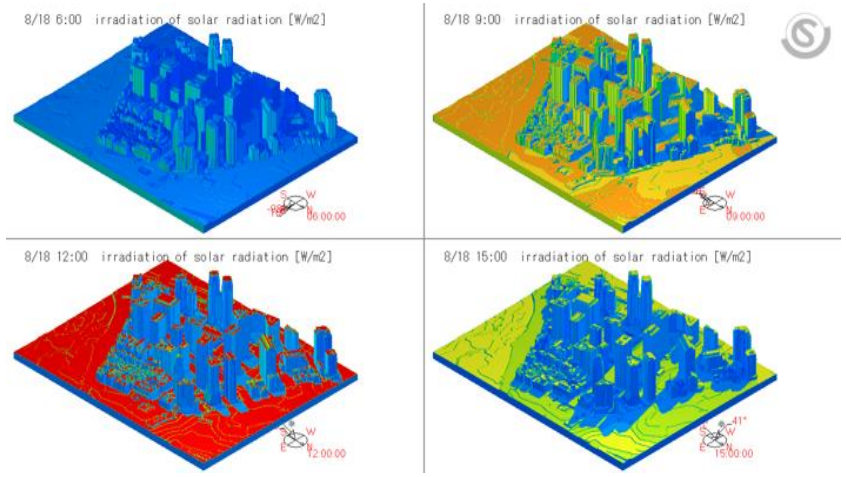


Analysis details and benefits

- Mesh Count – 100 million
- Simulation involves wave generation and VOF
- Catastrophe Assessment
- Effective Disaster response
- Water Ingress and flow path analysis
- Infrastructure damage

Daylight & Sun Tracking Simulation

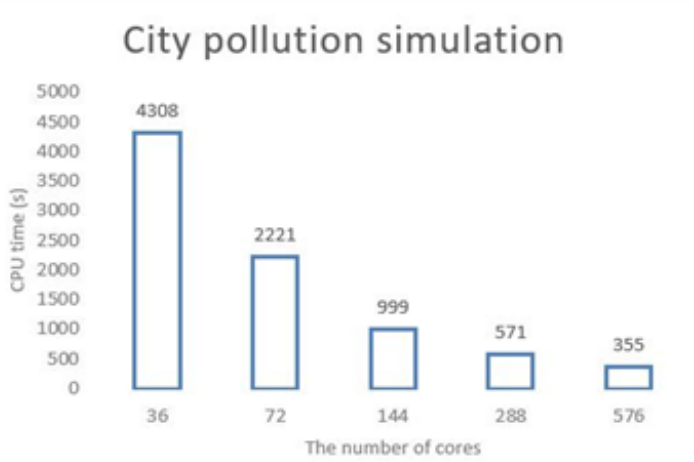


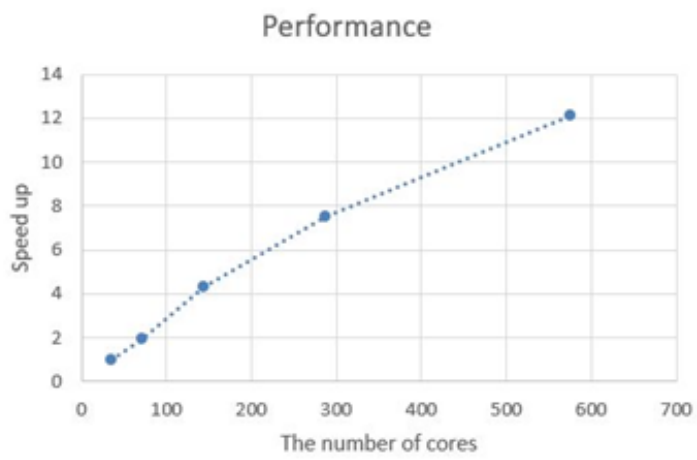


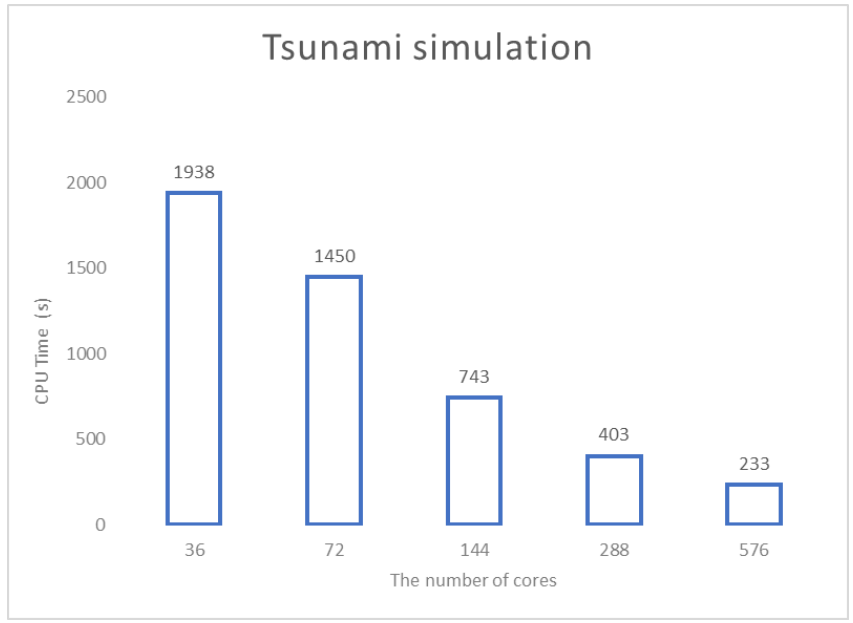
Analysis details and benefits

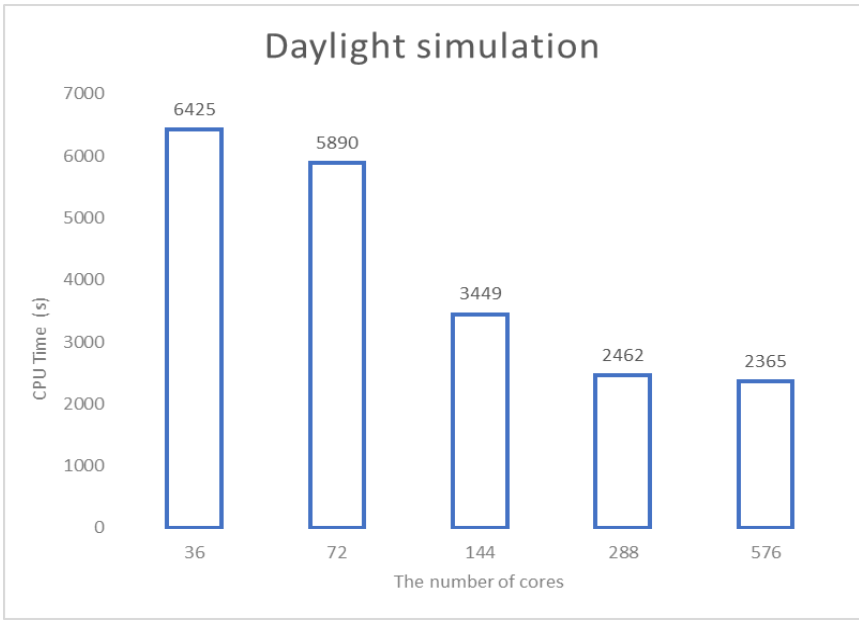
- Mesh Count – Over 50 Million
- Simulation involves solar tracking with shadow effects
- Simulation also includes Radiation effects with over 20,000 rays shot from each face
- Location linked to ASHRAE database
- Effectively harness renewable energy
- Smart infrastructure planning
- Effective solar panel positioning

Large Scale Simulations - Scalability Study









Other Engineering Examples

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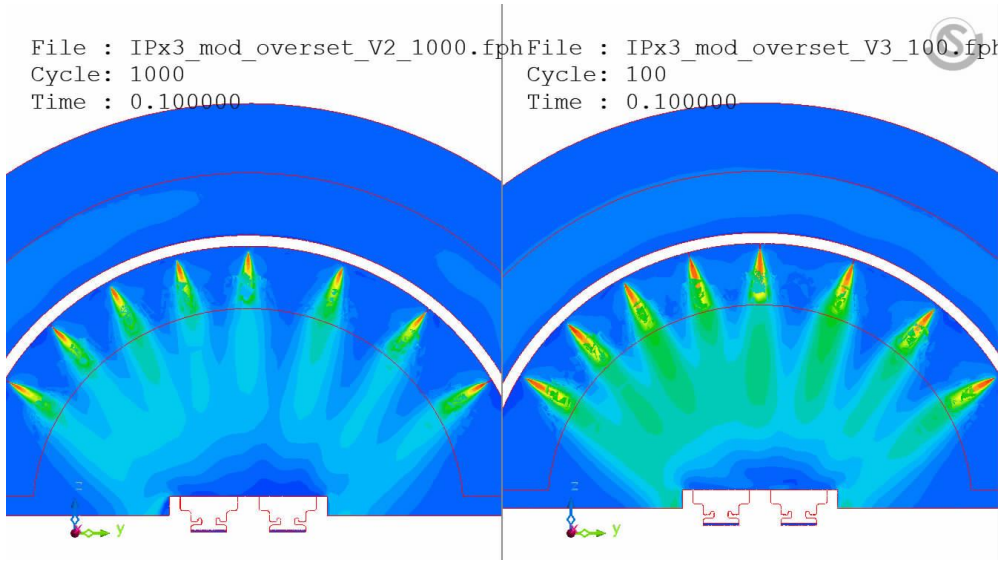
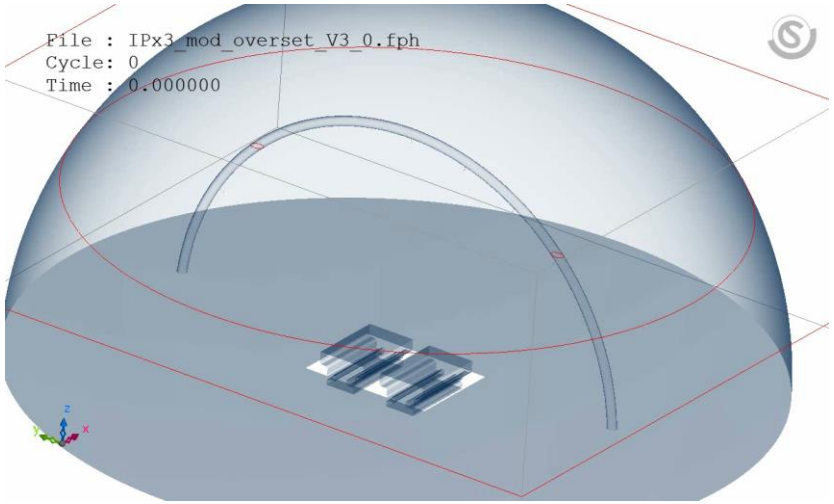
IPx Certification Simulations

Electronic Appliances

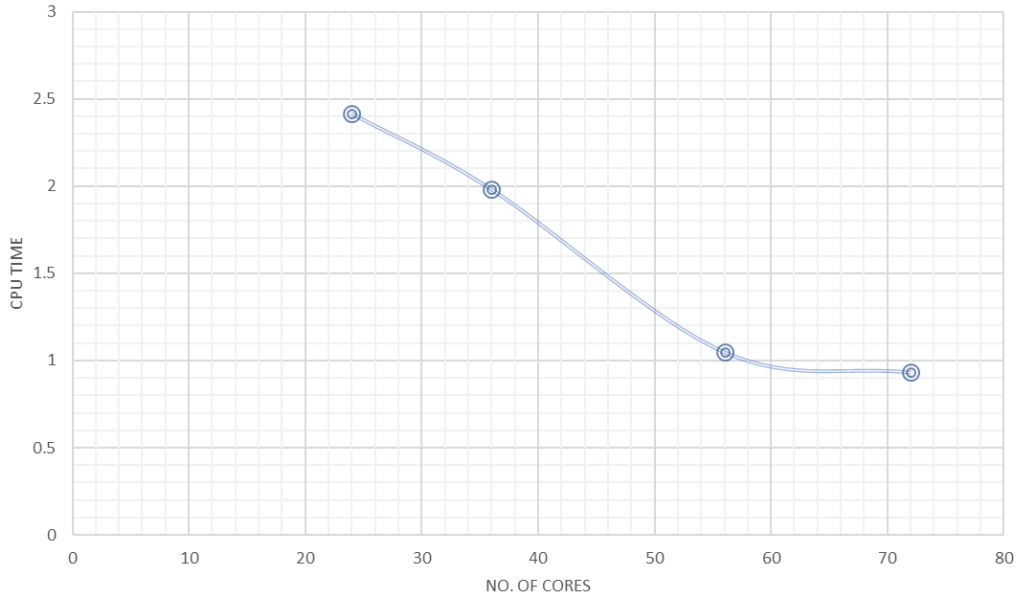


FIRM ICM

	FIRM	ICM
Time Step	0.0001 sec	0.001 sec
Physical Time (for 0.1 sec)	15 Hrs	1 Hr
Cores	100	48



Speed-Up Study



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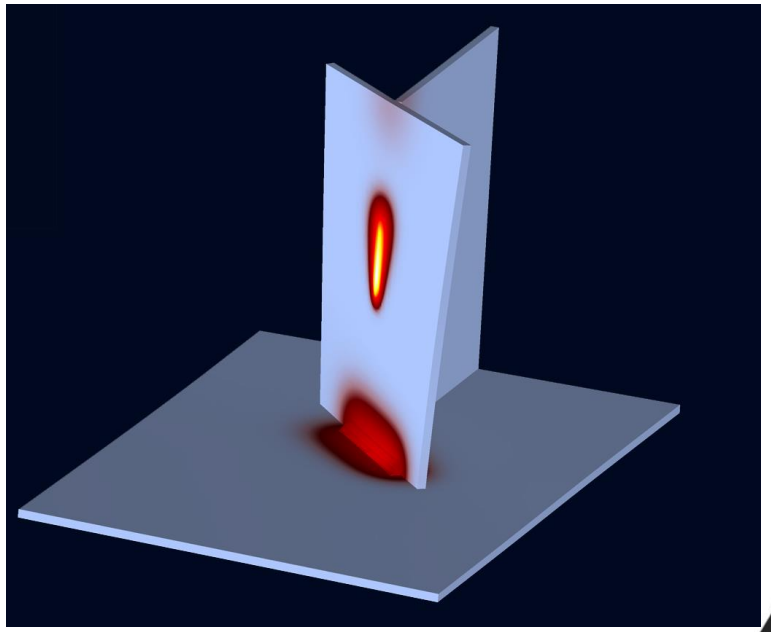
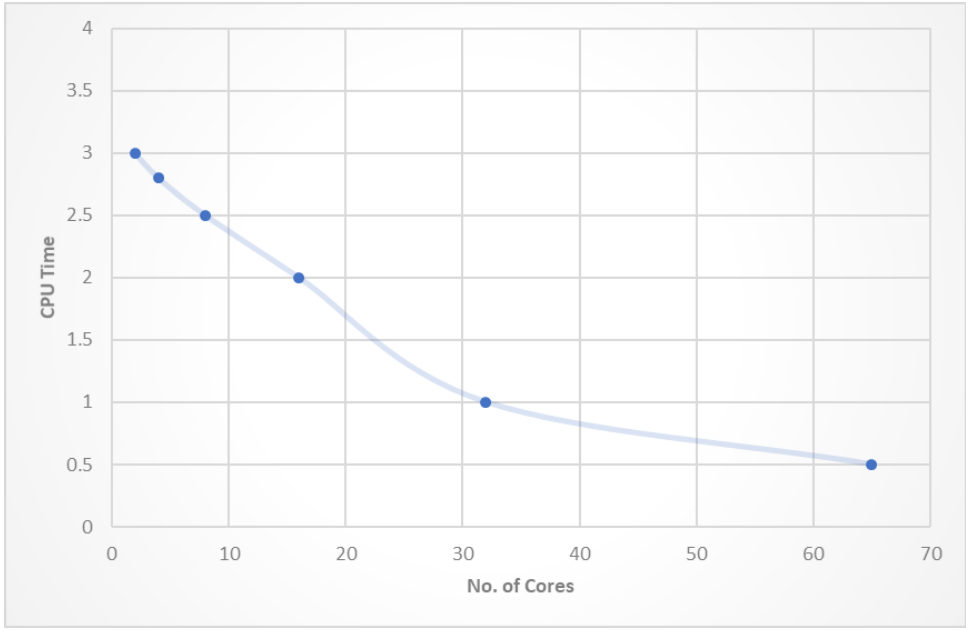
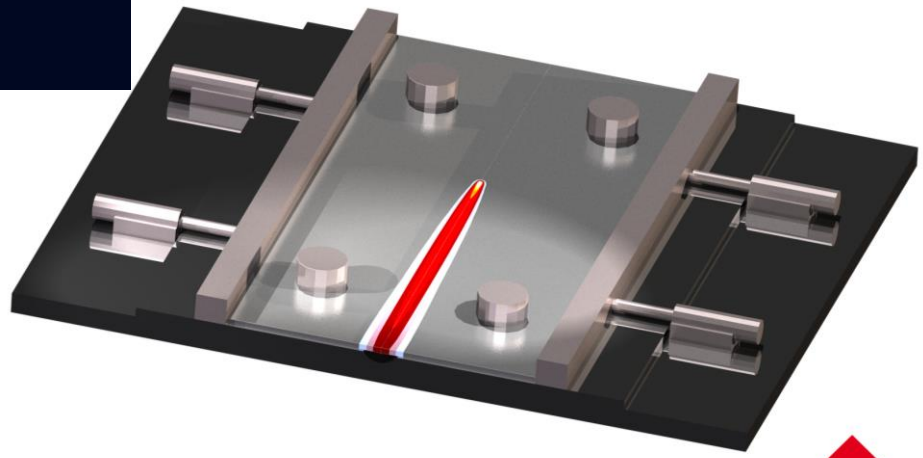
Welding Process Simulations



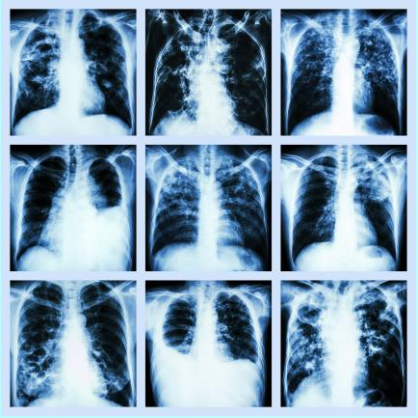




Airway Manipulation & Drug Delivery

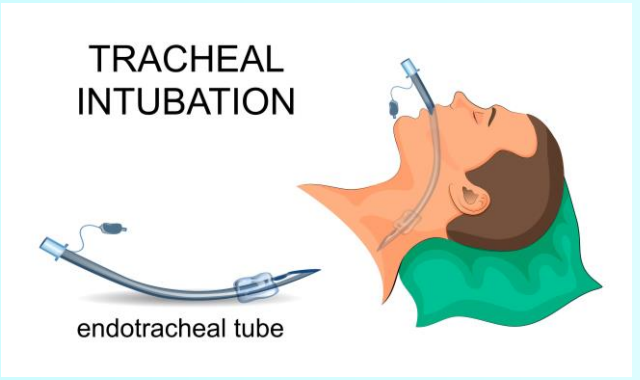
VOLUME GRAPHICS

3D Tomography Of Lungs



AI for Pneumonia Patterns specific to COVID 19

Endotracheal Tube



- Targeted Drug delivery simulation
- Advanced Medication through Aerosol

Technology Integrated Effective Drug Delivery

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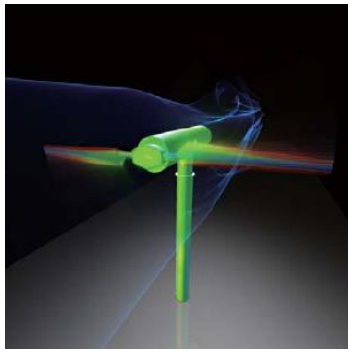
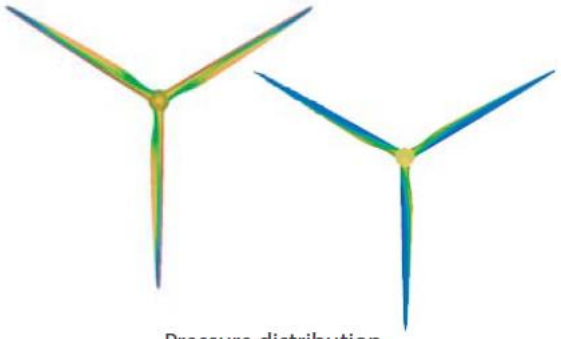
Wind Power Generation

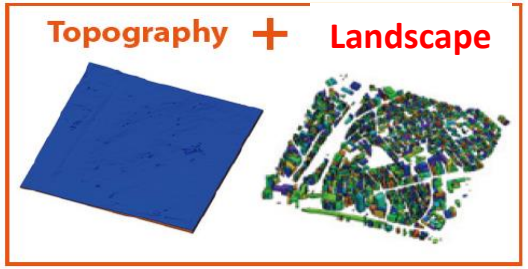
Wind Farm



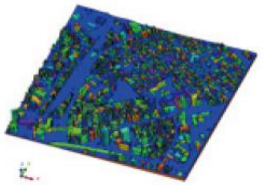
Wind Turbine



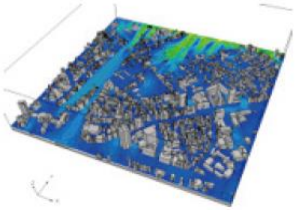
Pressure distribution
(Left: Front & back view / Right: Side view)



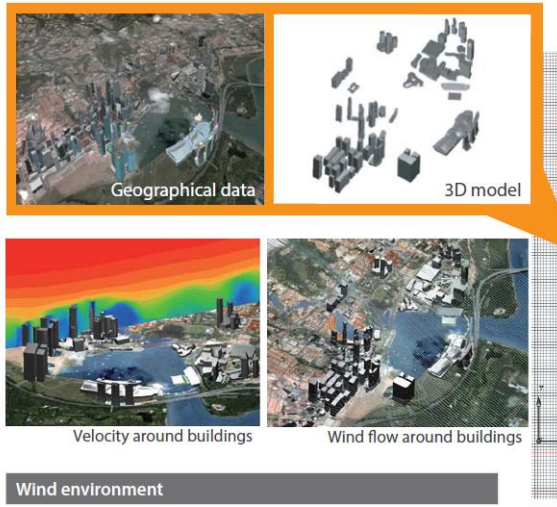
Combine

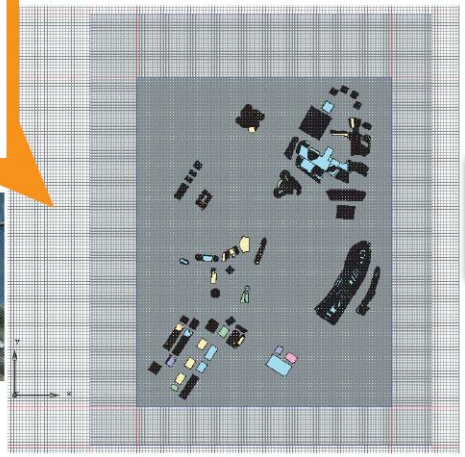


Combined by scSTREAM



Analysis result





Wind Farm Landscape

THANK YOU

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