ANSYS Solutions for the Built Environment - Present Capability and Future Trends

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Ansys

Ansys offers a wide simulation platform

PLATFORMS

FLUIDS

Thermal management
Multiphase flow
Fluid-structure
External Aerodynamics
Internal Flow
Electronics Cooling
Mixing
Combustion

STRUCTURES

Vibration
Optimization
Strength Analysis
Thermal Analysis
Durability Impact
Fatigue
Reliability
Composites

ELECTROMAGNETICS

Antennas – 5G
Microwave
Electronics Cooling
Electric Motors
Power Electronics
Radar Cross Section Radio
Frequency Signal Integrity Power Integrity

OPTICAL

Bright Light
Appearance Material Evaluation Human Ergonomics Dynamic Driving
Sound Analysis
Perceived Quality

SEMICONDUCTOR POWER

SOC Power Integrity IP Power Reliability IC Analysis
TRL Power Efficiency
SOC Reliability
CPS System CO-Design Substrate Noise Automotive IC
7NM Chip Design

MISSION-CRITICAL EMBEDDED SOFTWARE

System prototype
Electric Drives
Power Electronics
Autonomous Vehicles
ADAS
Battery Management
System Functional Safety Analysis Embedded Control Software

3D DESIGN

Additive manufacturing Guided workflows Instant simulation Direct Modeling Concept Design

Leading Construction Companies Use ANSYS

Building Stability & Integrity	Wind Engineering	HVAC	Construction Equipment	Cement Manufacturing
BOUYGUES CONSTRUCTION	HILSON MORAN	zitrón	EMERSON Climate Technologies	CEMEX
PARSONS BRINCKERHOFF	ARUP	Wyeth	TOTO	Sumitomo Osaka Cement CO.,LTD.
VINCI	NYC NEW YORK CITY	Hatch Mott MacDonald	IBIDEN	Holcim
INGÉROP	Vestas	INECO TIFSA	OWENS CORNING	UltraTech CEMENT The Engineer's Choice
IHI	BRUSSELS-CAPITAL REGION	Buro Happold	TRANE	TAIHEIYO CEMENT
LARSEN & TOUBRO It's all about Imagineering	TERRACAP	insight		BORAL
HOCHTIEF				

ANSYS Vision For Simulation In The Construction Industry

Old Paradigms

Design and analysis are correlation and rule based

Single physics in engineering silos

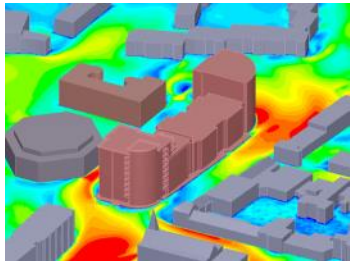
Few Design Points Studied

Hardware and parallel computation limitations

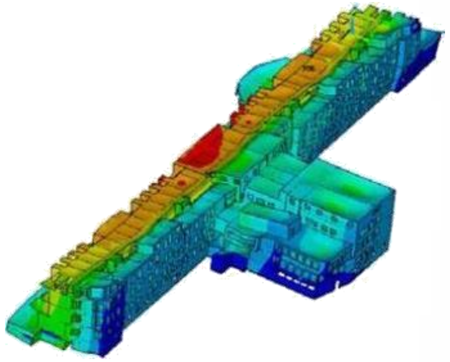
Many specialized niche simulation tools

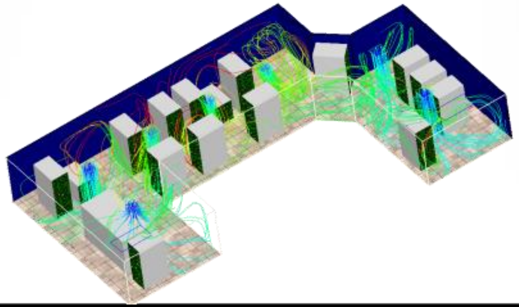
Product development is test dominant

Certification through test



Courtesy BDP





New Paradigms

Single-Platform Multiphysics Simulation Including fluids, structure, seismic, electromagnetic

Collaborative Multi-user and Multiscale Simulation (component to subsystem and system)

High-Performance Computing including cloud and supporting Remote Infrastructure

Higher fidelity simulation

Failure analysis

Multi disciplinary design optimization

Consistence early adoption of simulation in building design

Certification through analysis

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CFD for Built Environment

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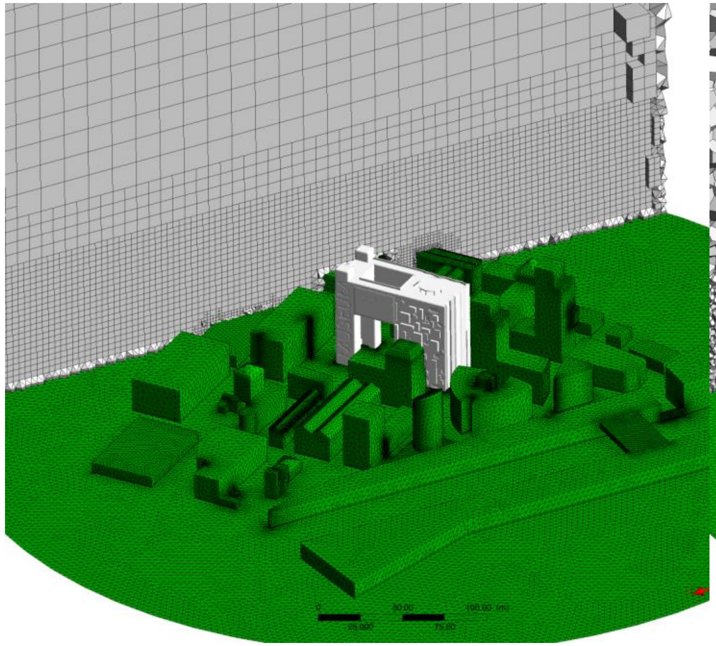
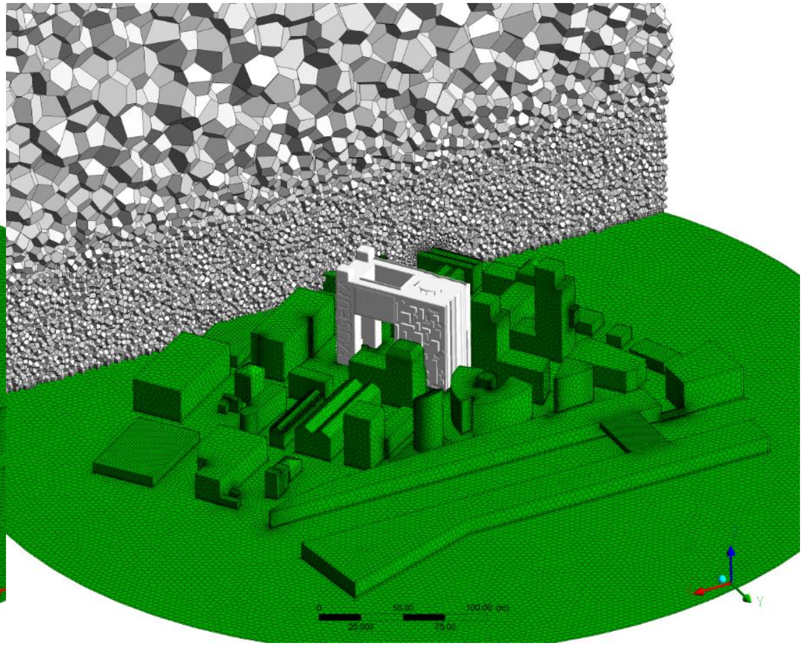
Simulation Methods

- **High Quality Meshing Algorithms**
  - Unstructured
  - Structured Hex
  - Advanced, Automatic Sizing Controls
    - Volume
    - Surface
  - High Quality Prism Layers



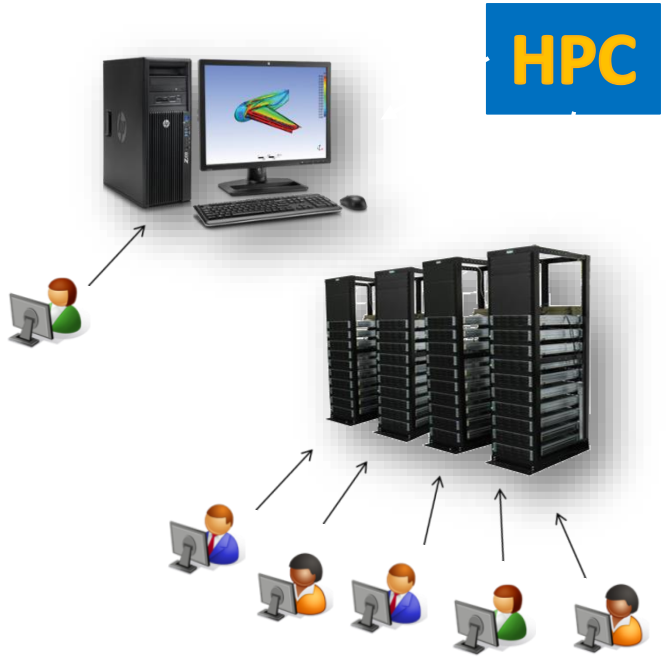
Octree Hexcore



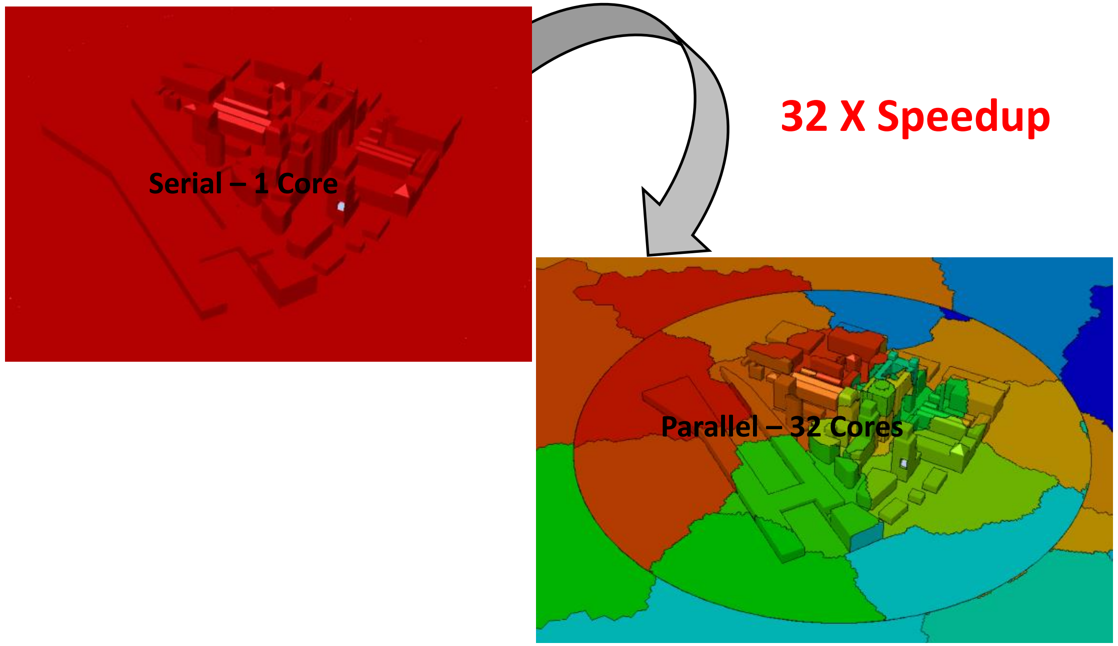
Polyhedral

- **Accurate Physics and Numerics**
  - Segregated and Coupled CFD Solvers
    - Fast transient and steady solutions
  - High order discretisation schemes
  - Best-in-class turbulence modelling capabilities
    - Automatic wall treatment inc. roughness
    - RANS, SAS, DES, LES, SBES
  - Extensive physics options such as
    - Aeroacoustics
    - FEA coupling (Fluid-Structure Interaction)
    - Aerothermal
    - Solar loading
    - Combustion/Species/humidity modeling
    - Particles and multiphase
      - Tsunami/flood modelling with VoF
      - Sand build-up
    - Electromagnetics Coupling

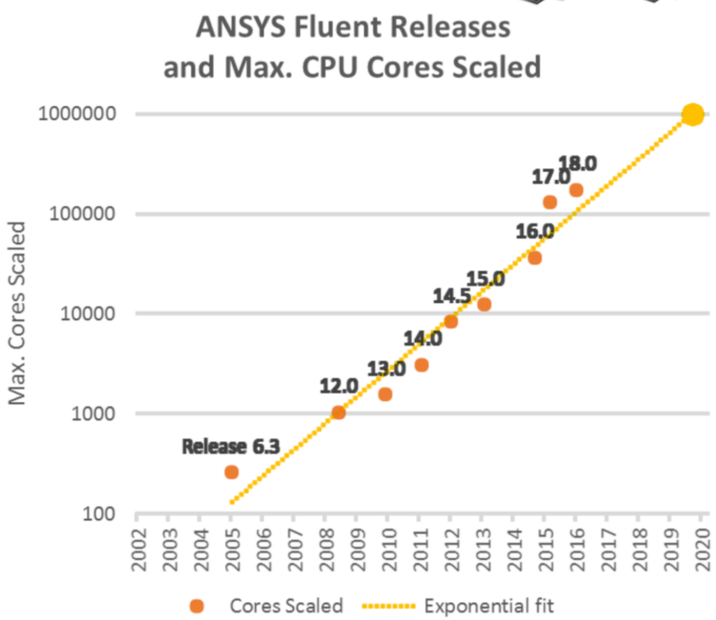
Fast and Scalable CFD & FEA Calculations



- CFD scalable from <10K cells per partition to beyond 1bn cell cases
- Automatic load balancing
- CPU and GPU solver acceleration used

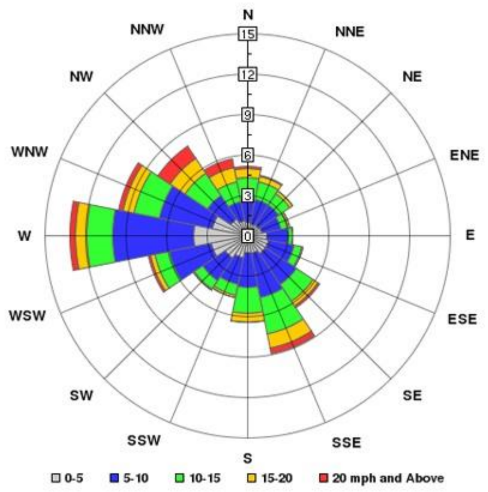


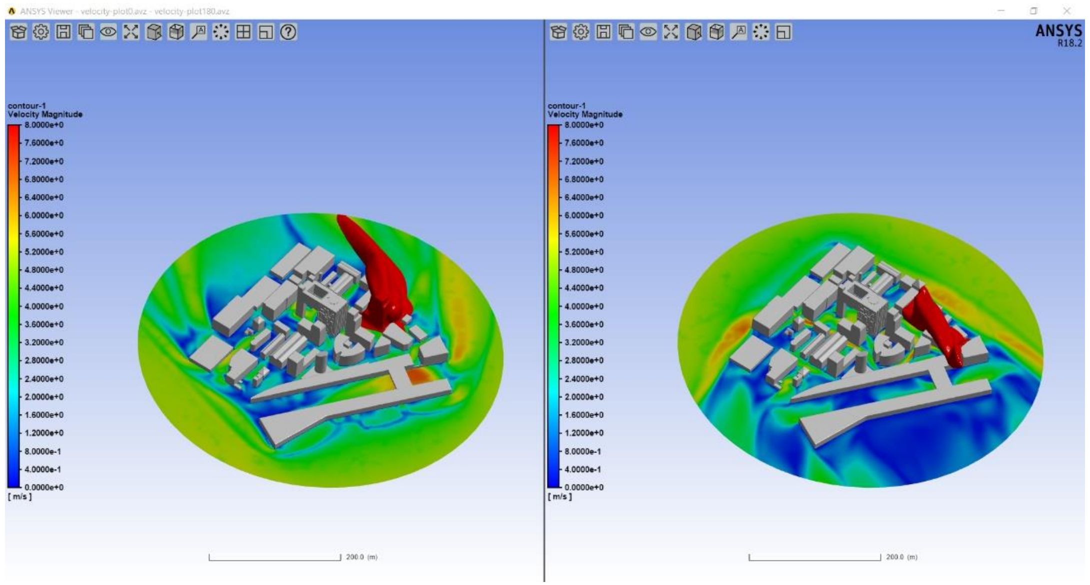
32 X Speedup



Built Environment Application Areas

- Internal/External Aerodynamics
  - Pedestrian comfort
    - Perform sweeps of wind direction
    - Steady flow or gusting
  - Pollution dispersion
    - Inert or reacting
  - Wind loading
  - Aeroacoustics
  - Plume Effects
  - Heating and Ventilation

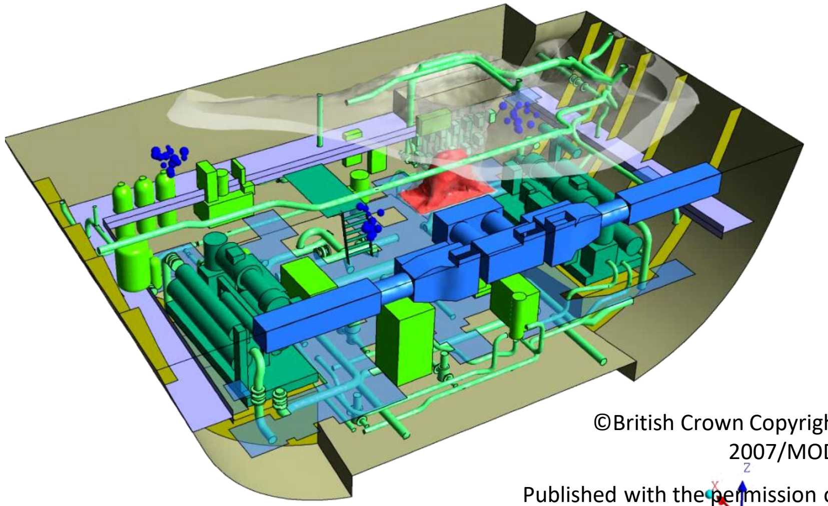


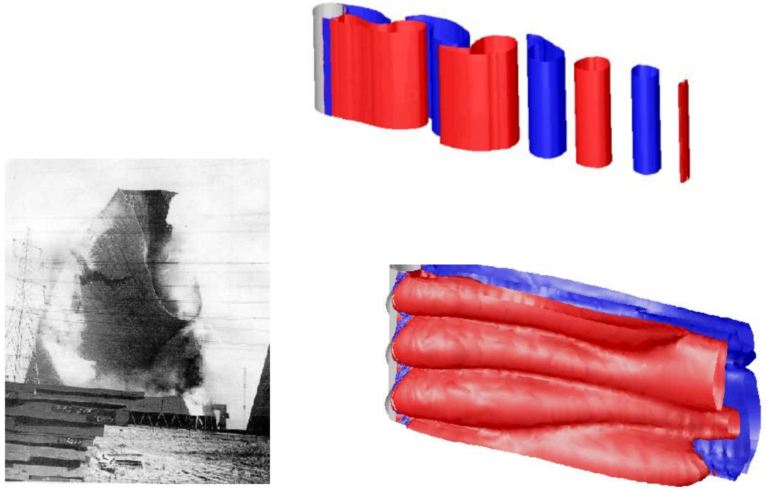


Plume visualisation from different wind directions

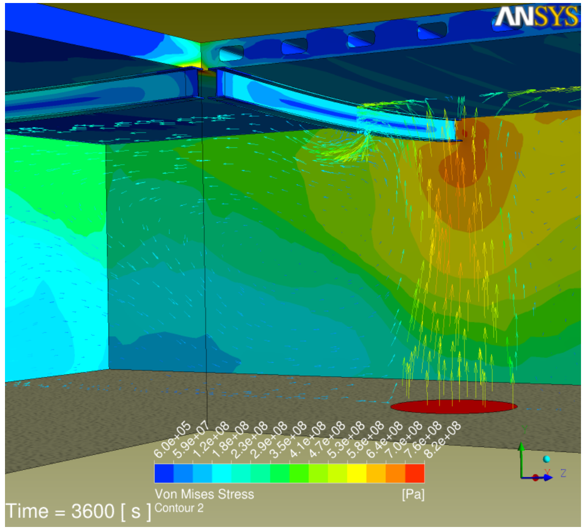
Built Environment Application Areas

- Health and Safety
  - Fire suppression
  - Smoke Management
  - HVAC
  - Structural vibration and thermal response





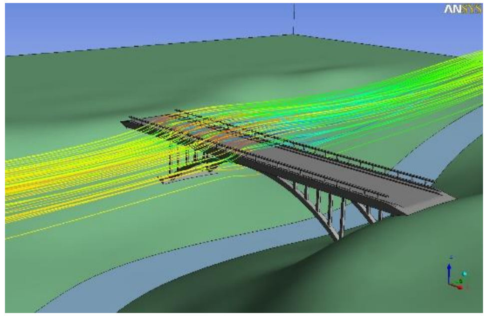
Shedding from chimney with and without helical strakes applied



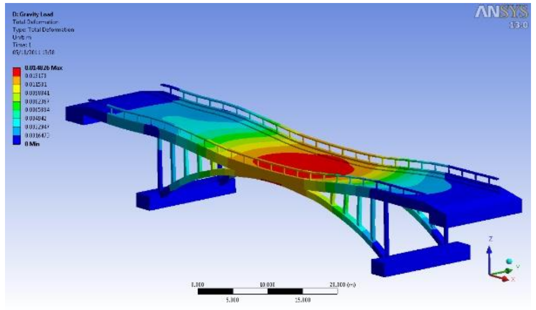
Thermal beam deformation due to fire

Built Environment Application Areas

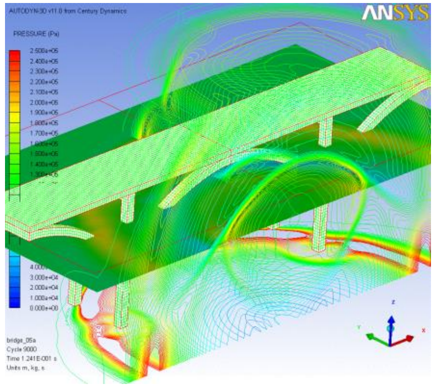
- Extended Physics
  - Solar Loading
  - Structural deformations from wind loading
  - Blast wave propagation
  - Wave modelling
  - Sand Build-up



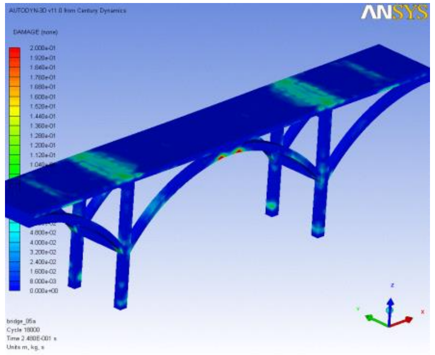
Wind Loading



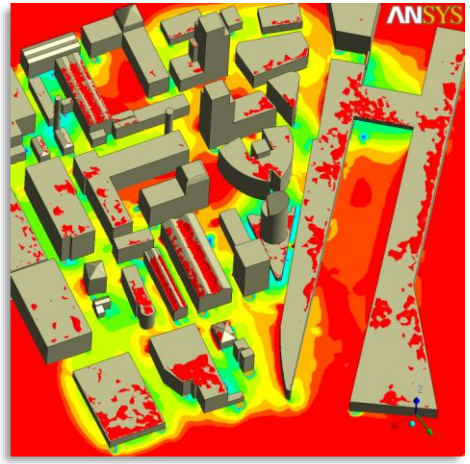
Total Deformation



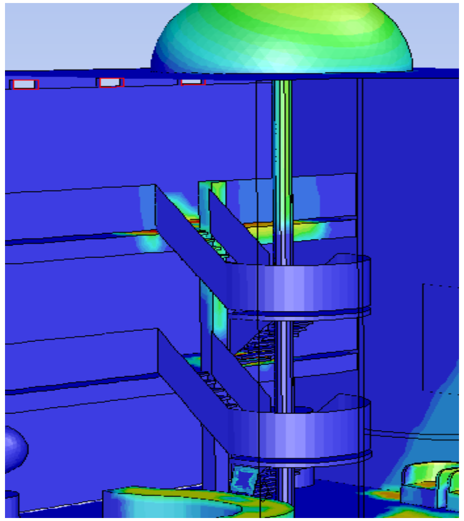
Blast Wave Propagation



Damage



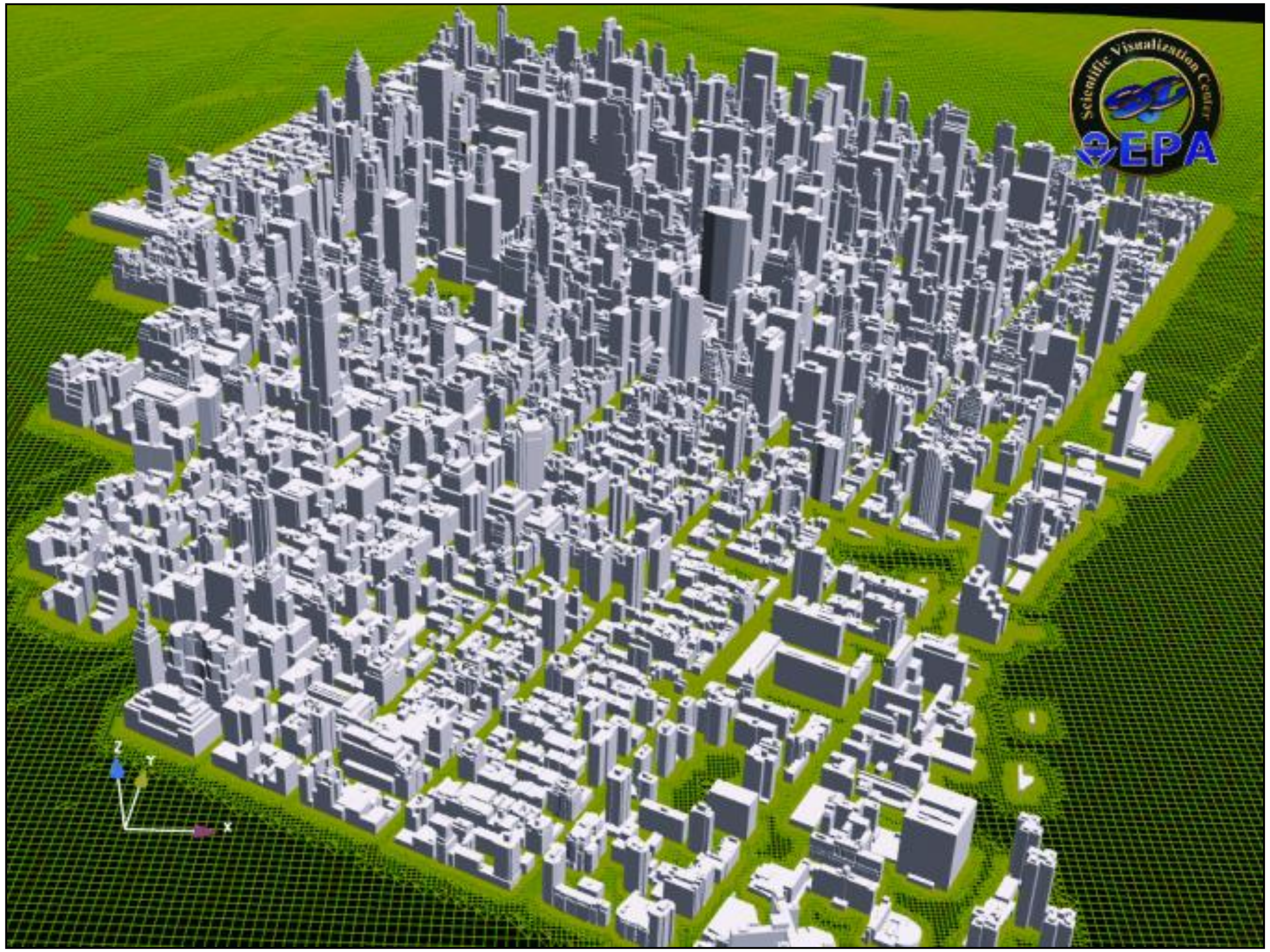
Sand Coloured by Height



Solar Loading in an Atrium

Case Study: September 11th, World Trade Centre

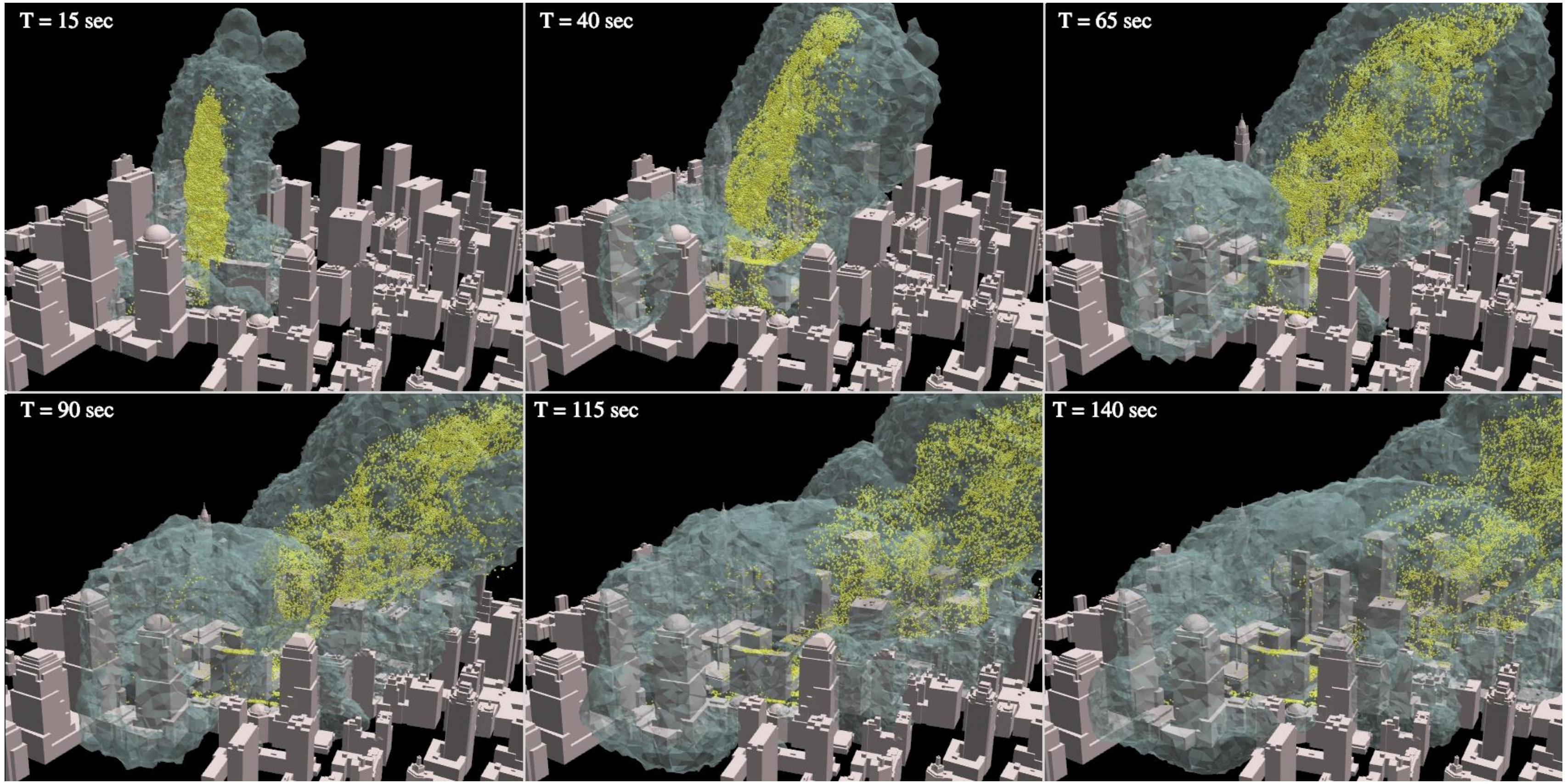
- Investigating the engineering consequences of the attacks



Courtesy of the National Oceanic and Atmospheric Administration, and the U.S. Environmental Protection Agency, National Exposure Research Laboratory, and the U.S. EPA Environmental Modeling and Visualization Laboratory, Lockheed-Martin Operations Support

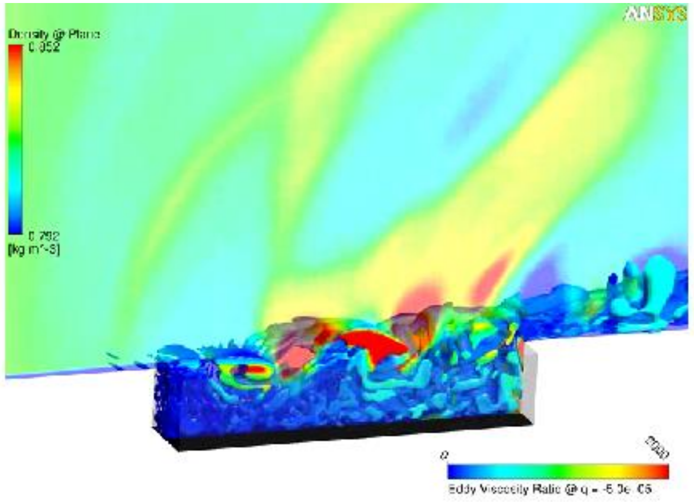
Plume Development: September 11th, World Trade Centre

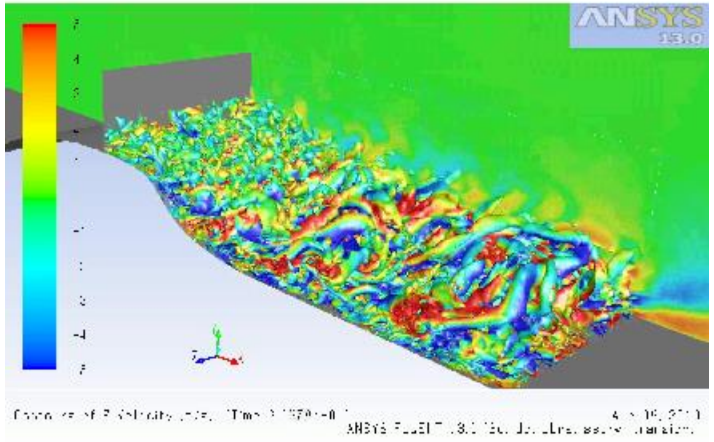
Grey = smoke
Green = particles



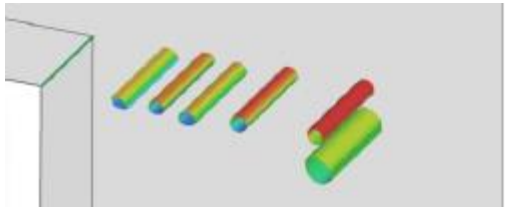
Recent Developments

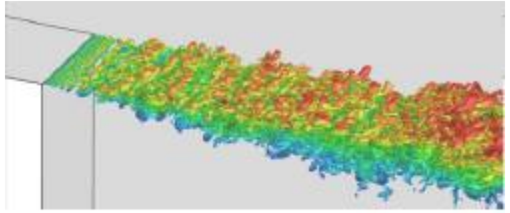
Scale-Resolving Turbulence Models





- **Scale-Adaptive Simulation (SAS)**
  - Reverts to RANS when mesh too coarse
- **Detached Eddy Simulation (DES)**
  - Similar behaviour to SAS
- **Large Eddy Simulation (LES)**
  - Smagorinsky-Lilly and Dynamic model
  - WALE model
  - Algebraic Wall Modeled LES (WMLES)
  - Dynamic kinetic energy subgrid model
- **Embedded or Zonal LES (ELES)**
  - LES in fixed zone with turbulence generator upstream
  - Not suitable for globally unstable flows, e.g. bluff bodies
- **Stress-Blended Eddy Simulation (SBES)**
  - RANS-LES blended at level of Reynolds stress
  - Faster switch to LES mode





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GEKO RANS Model: Introducing Free Coefficients

The functions F_1, F_2, and F_3 contain 6 free coefficients that can be changed without affecting basic validation:

- C_{SEP} – changes separation behaviour
- C_{MIX} – changes spreading rates of free shear flows
- C_{NW} – changes near-wall behaviour
- C_{JET} – Optimizes free jet flows
- C_{CORNER} – Affects corner flows
- C_{CURVE} – Curvature correction

$$\frac{\partial(\rho k)}{\partial t}+\frac{\partial(\rho U_j k)}{\partial x_j}=P_k-\rho C_\mu k\omega+\frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right]$$

$$\frac{\partial(\rho\omega)}{\partial t}+\frac{\partial(\rho U_j\omega)}{\partial x_j}=C_{\omega1}F_1\frac{\omega}{k}P_k-C_{\omega2}F_2\rho\omega^2+F_3\frac{2}{\sigma_\omega}\frac{\rho}{\omega}\frac{\partial k}{\partial x_j}\frac{\partial\omega}{\partial x_j}+\frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_t}{\sigma_\omega}\right)\frac{\partial\omega}{\partial x_j}\right]$$

$$\mu_t=\rho\frac{k}{\max(\omega,S/C_{Real})},$$

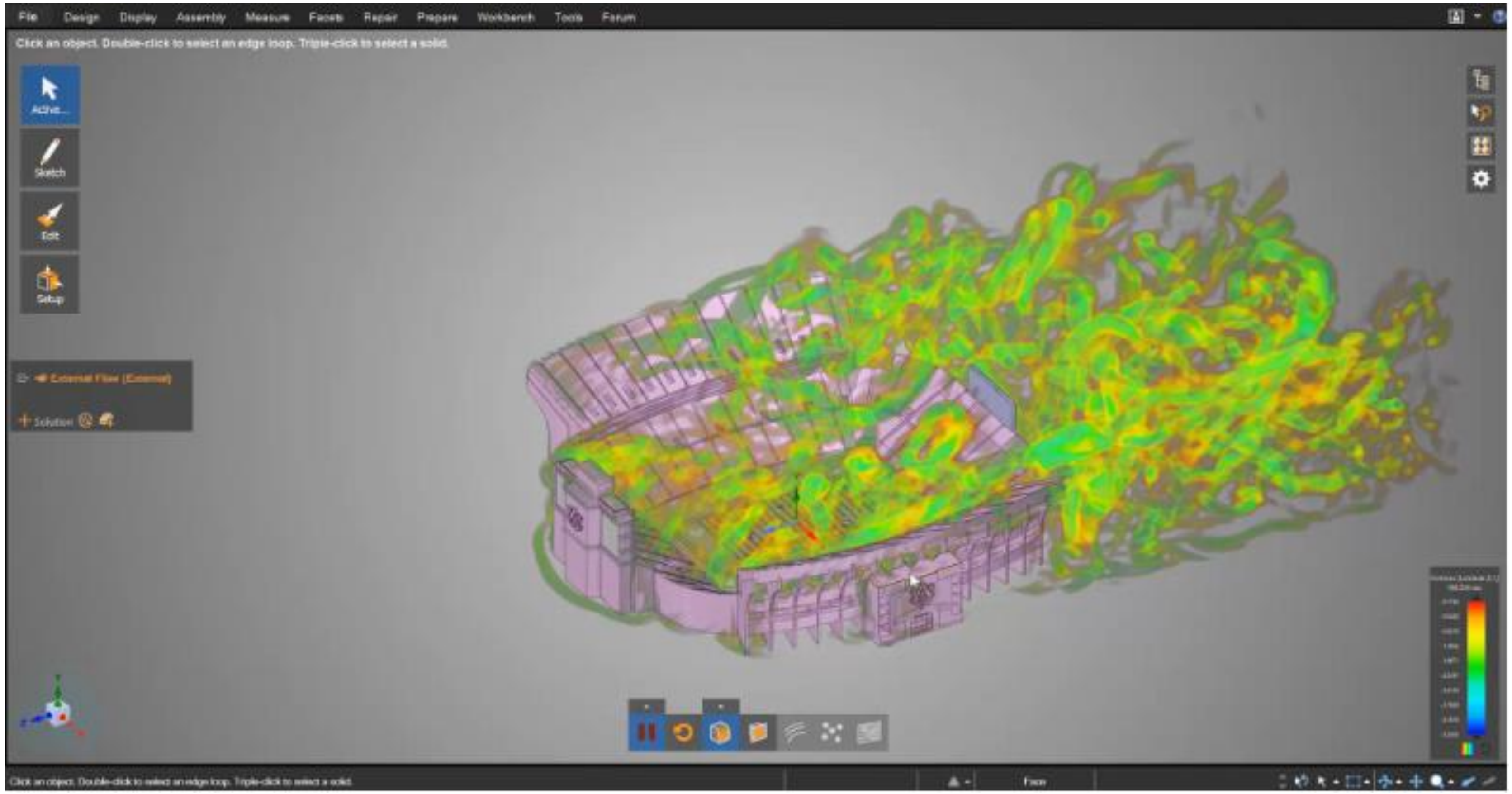
$$\overline{u_i'u_j'}\rightarrow\overline{u_i'u_j'}-\frac{C_{Corner}1.2\,\nu_t}{MAX\left(0.3\omega,\sqrt{(S^2+\Omega^2)/2}\right)}\left(S_{ik}\Omega_{kj}-\Omega_{ik}S_{kj}\right)$$

Coefficients can be changed to give best fit to experiment

Ansys

Discovery Live: Real-Time LES Simulation using GPU

- GPU acceleration can give LES results in real time on large-scale models
- Demo simulation for a stadium showing instantaneous vorticity
- Uses a single GeForce GTX 1080 with 8GB GPU and 2560 CUDA Cores
- Not sufficiently accurate for detailed analysis but can be useful for first design



Reduced Order Model (ROM) as a simplification of a high-fidelity dynamical model

Reduced Order Model (ROM)

Techniques for range of physics including Fluid Flow, Thermal, Mechanical and EM

DX-ROM , Static ROM Builder and Twin Builder Dynamic ROM are few ANSYS ROM technologies

Benefits of ROM

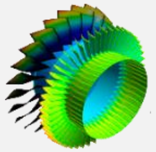
Reduced simulation time (think 10-100x)

- Ideal for Design of Experiments (DoE)/ Parameter sweep
- Integration in Twin Builder for system simulation
- Runtime generation for near real-time applications

Reduced storage size

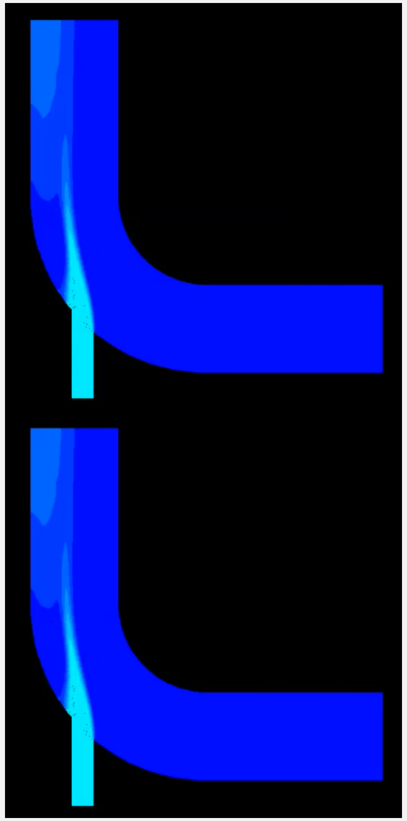
- Reduce the required storage size dramatically

Reuse 3D model



- Utilize validated 3D physics in system model
- Help increase the 3D solver footprint

Fluent CFD Simulation: 3 hours on 12 cores



ROM Simulation Realtime

Summary

- Ansys development driven by customer requirements
- Adoption of LES for Built Environment has been slow over last decade
  - RANS still seen as best option in many cases
  - LES ~100x more expensive and does not always give better results than RANS
  - LES primarily used for visualisation, aeroacoustics and particle dispersion
- Ansys has focused on developments in
  - Geometry and meshing: More complexity and larger meshes
  - Parallel computation and cloud computing: > 1 billion cells
  - Turbulence modelling: GEKO RANS, and hybrid RANS-LES (SBES)
  - Reduced order modelling (Twin Builder)

Ansys