

ENVIRONMENTAL CFD SIMULATION AND VISUALIZATION: Examples in Support of the Reconstruction of the Smoke/Dust Plume from the World Trade Center Site Following the Events of September 11, 2001.

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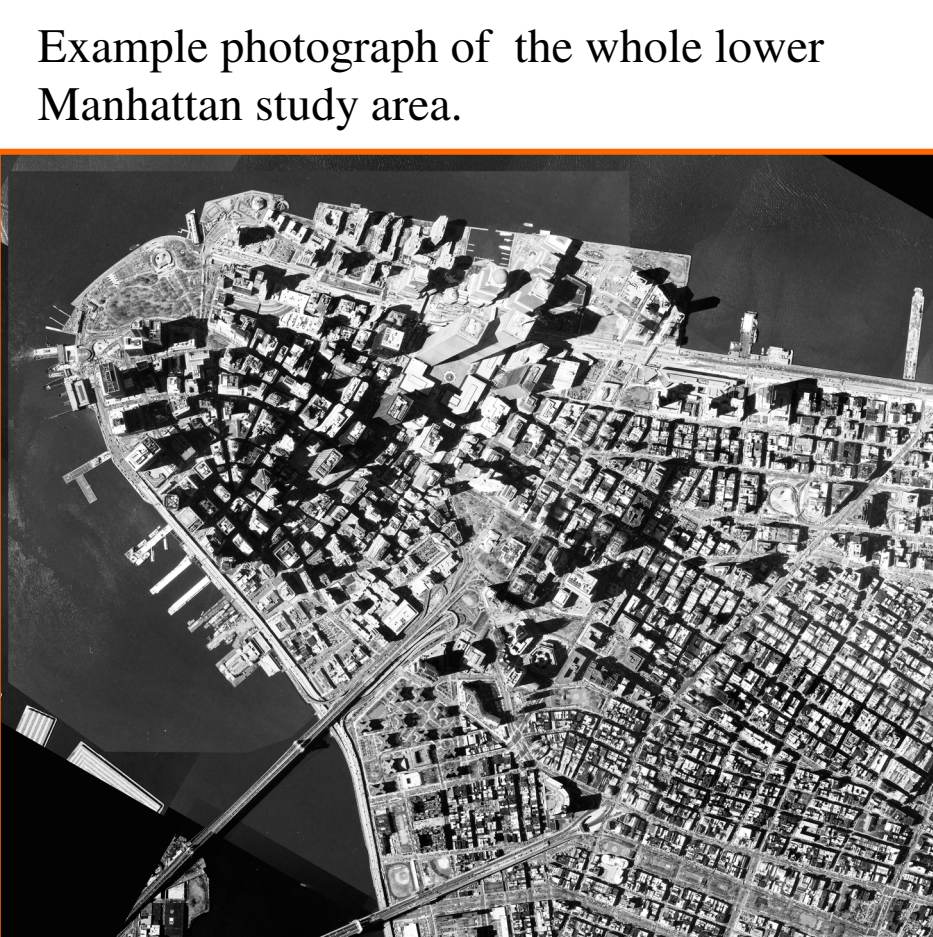
The Challenge

Understanding the pathway of toxic air pollutants from their source to humans finds immediate application in the Agency's role in Homeland Security. The collapse of the New York World Trade Center Towers demonstrated some of the shortcomings in conducting exposure analyses in urban areas where the air flow and hence flow of pollutants around large buildings is poorly understood. Information from CFD simulations can be used to look at events after they have happened or to develop reliable, simple models to support rapid risk assessments. CFD simulations provide the data which then are put into 3-D pictures to understand what is happening.

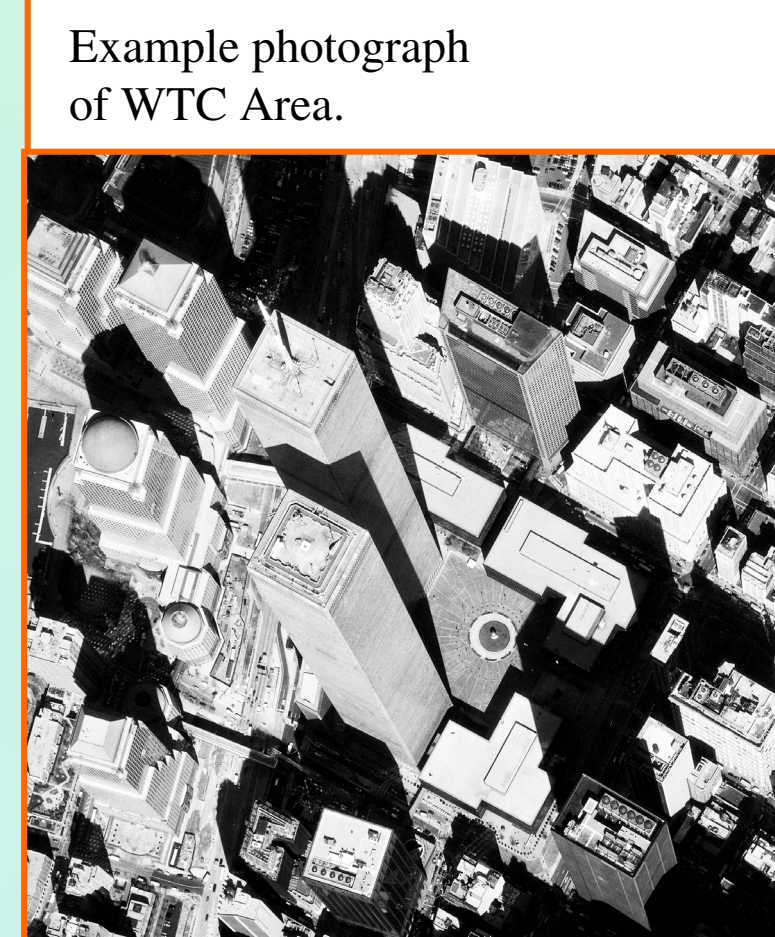
What is Scientific Visualization?

It transforms equations into 3-D pictures, so that researchers can see their computations. Visualization in scientific computing helps us understand the science by seeing it.

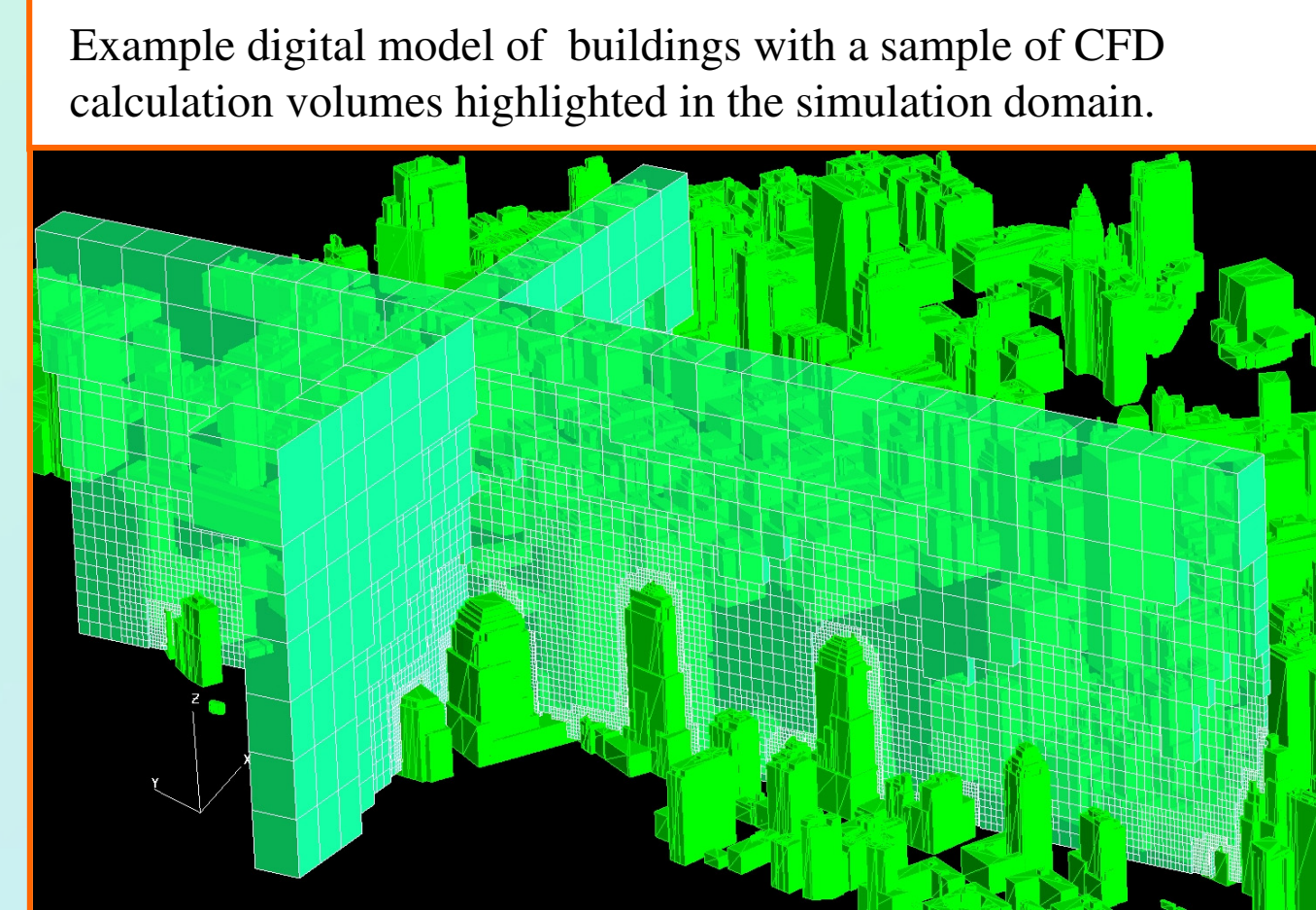
Building geometry constructed using photogrammetry by Vexcel Corporation based on analyses of a series of photographs at different orientations.



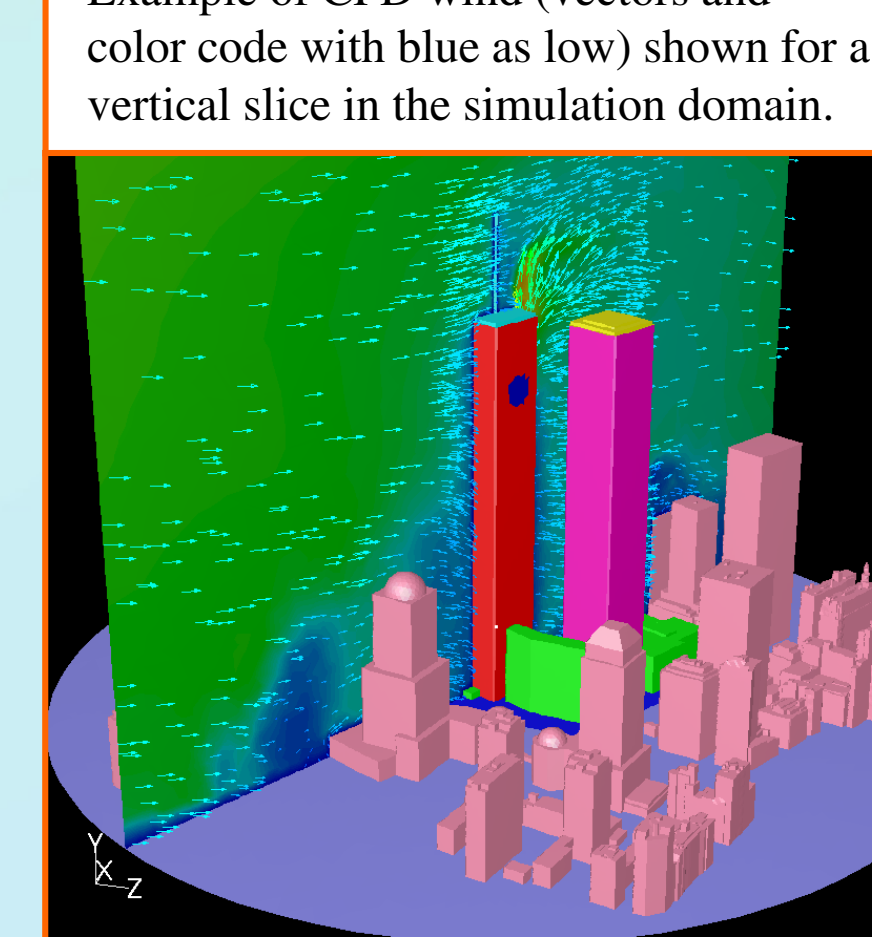
Example photograph of the whole lower Manhattan study area.



Example photograph of WTC Area.



Example digital model of buildings with a sample of CFD calculation volumes highlighted in the simulation domain.



Example of CFD wind (vectors and color code with blue as low) shown for a vertical slice in the simulation domain.

What is Computational Fluid Dynamics (CFD) ?

■ **Computational** (having to do with mathematics & computation)

■ **Fluid Dynamics** (the dynamics of things that flow)

CFD software provides physical models and the ability to closely match the shape of the objects being modeled. CFD simulations use models with full physical processes to develop a 3-D picture of real or predicted events

■ Richard Hamming observed many years ago that *"The purpose of [scientific] computing is insight, not numbers."* CFD can provide realistic insight not otherwise available

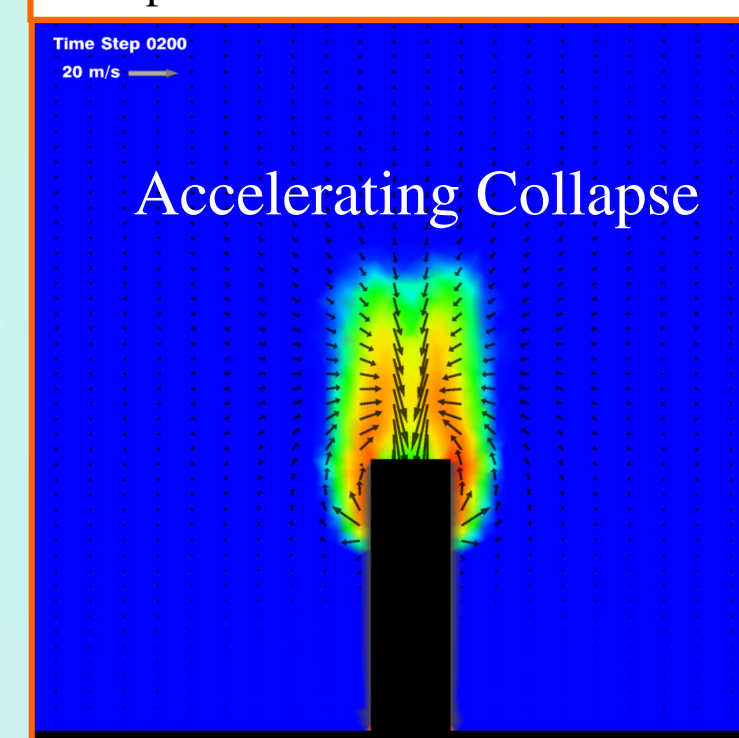
What is being done to support WTC assessments?

Time Sequence of Events being CFD Simulated and Visualized:

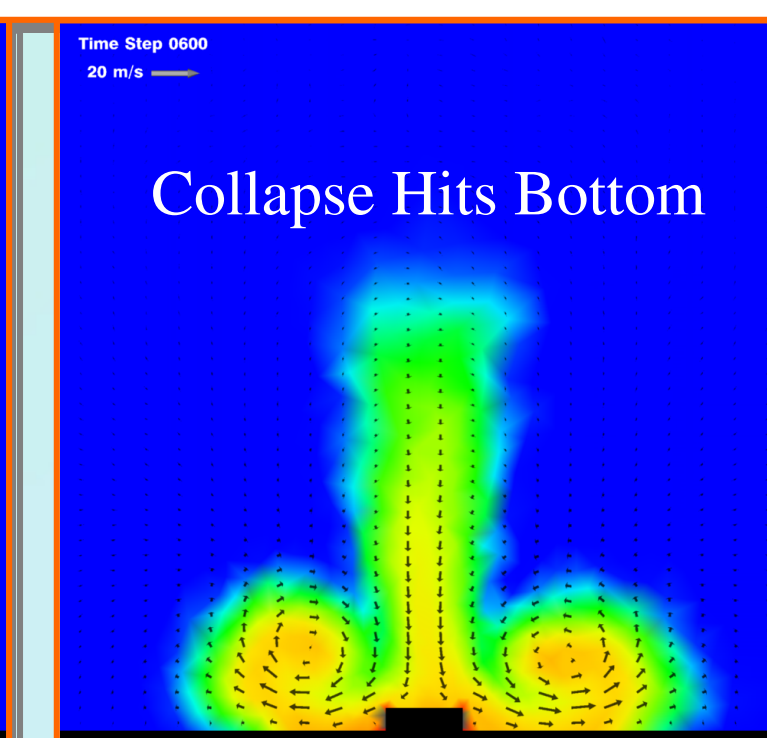
- The plane crash into the building produced a short-lived "fireball" smoke plume
- The burning building produced a continuous elevated smoke plume before the building collapse
- The building collapse produced a short period of high winds and a dense smoke/dust cloud
- The continued burning at "ground zero" produces a continuous smoke plume

Example CFD Application

Smoke&dust cloud following the collapse of the North tower. Vortices that are generated around the collapse transport smoke & dust outward and into a trailing column. The color shading marks areas with smoke&dust vented from collapsing floor. Surface air velocities are high (exceed 100 mph) as the collapse hits bottom.



Accelerating Collapse

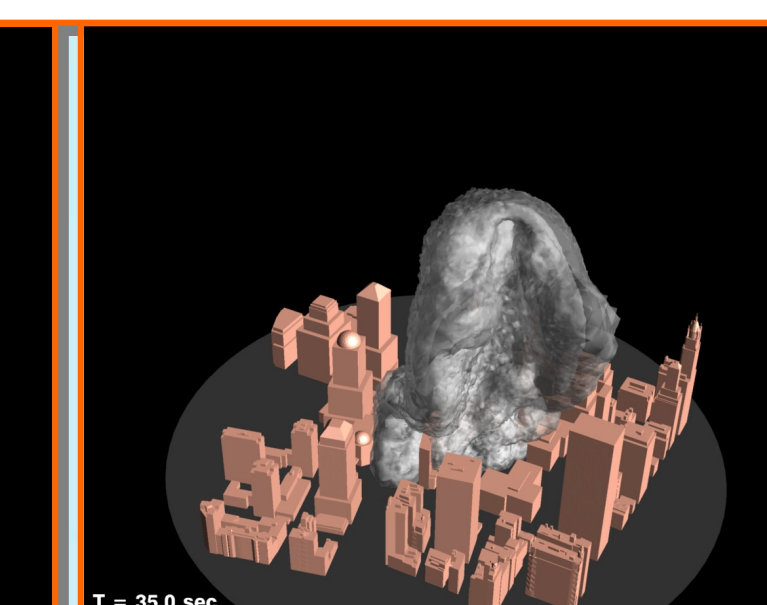


Collapse Hits Bottom

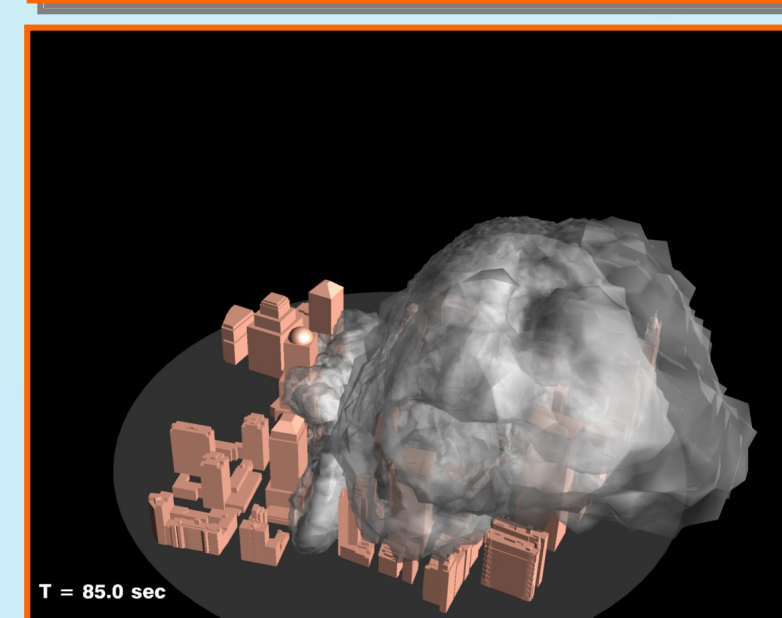
Visualization of outer boundary of the smoke&/dust cloud during the first 3 minutes following the building collapse and subsequent transport. Time sequence below : upper left - upper right - lower left - lower right.



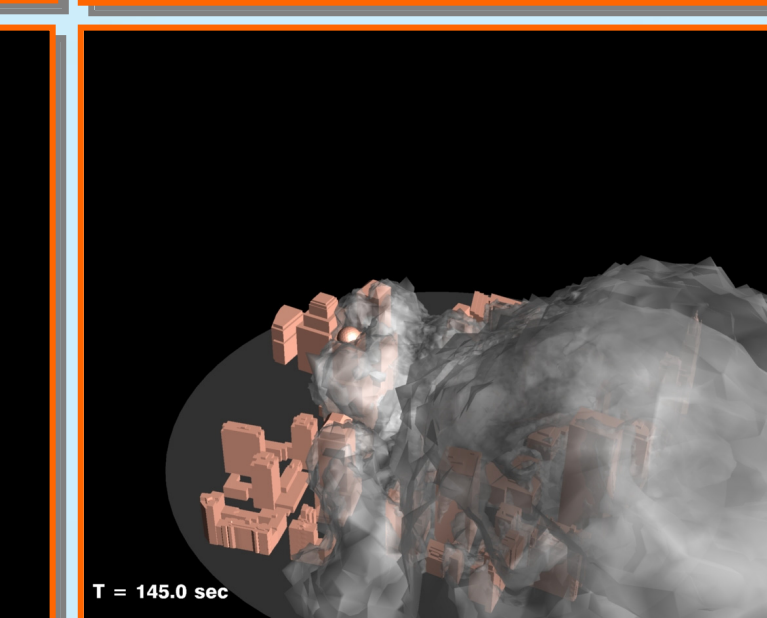
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