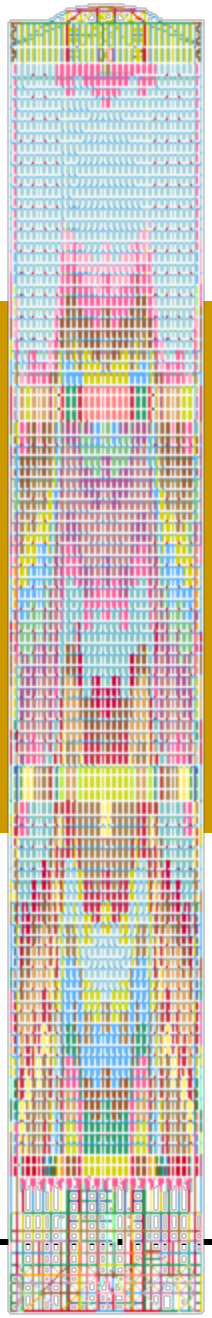


The WTC North Tower on 9/11

Paul Rosen
Christoph Hoffmann
Mete Sozen
Ayhan Irfanoglu

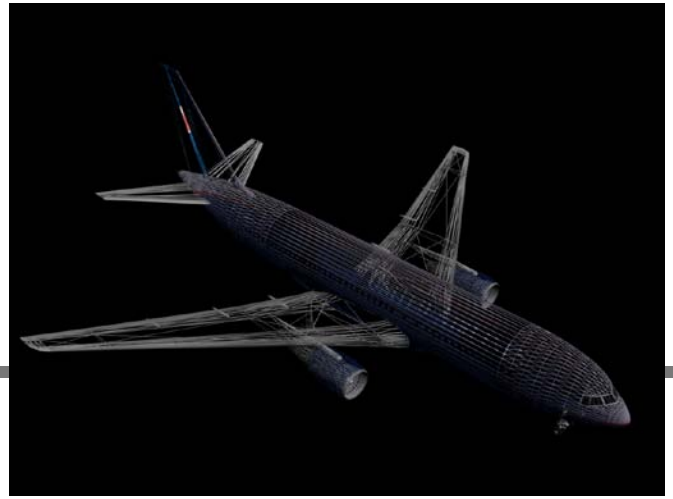
Department of Computer Science

Motivation

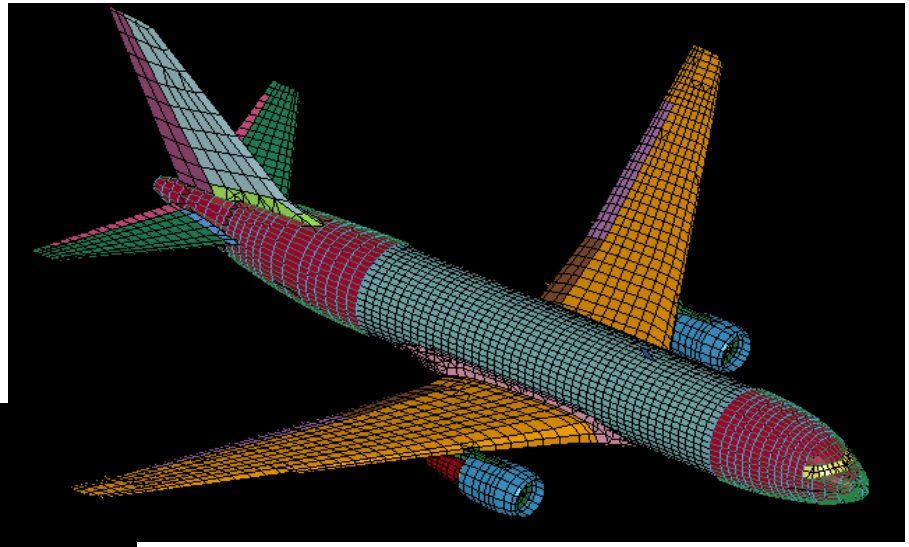
- Simulate as faithfully as possible the effects of crashing an air frame loaded with fuel into a steel and concrete structure similar to the structure of the WTC North Tower
- Understand what the extent of damage done by the impact
- Subsequent fire are not under consideration

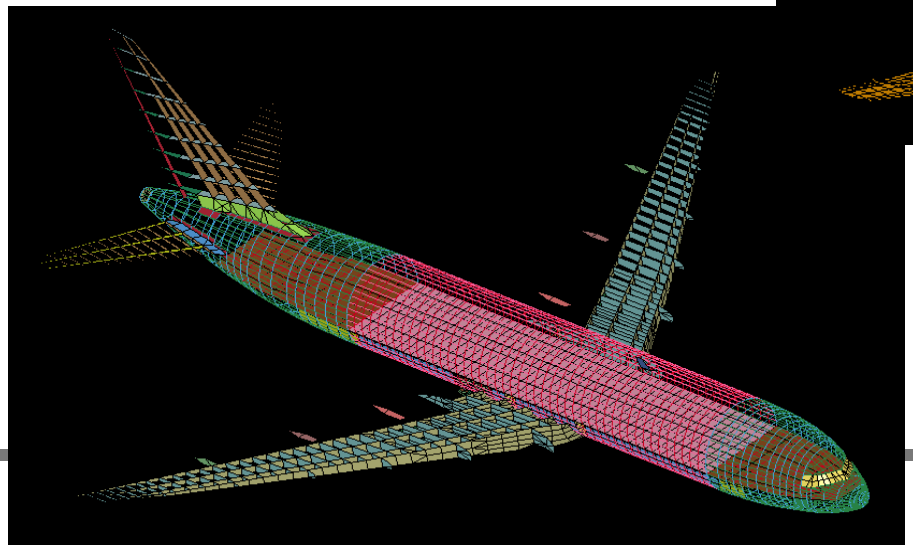
Boeing 767-200ER

- Modeled using
  - Graphics model
  - Cutaway of the internal structure
  - Photographs



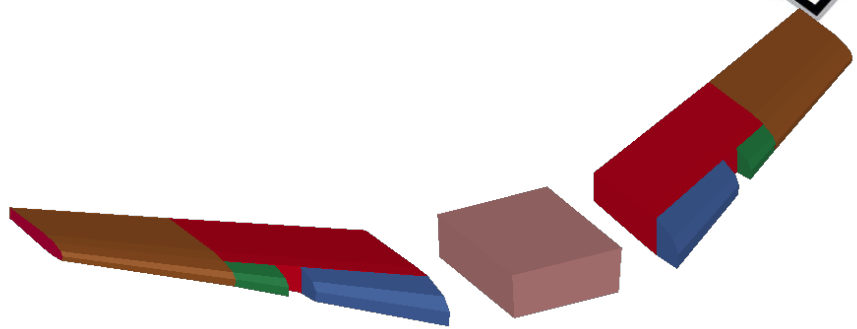
Boeing 767-200ER

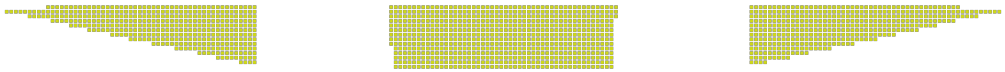


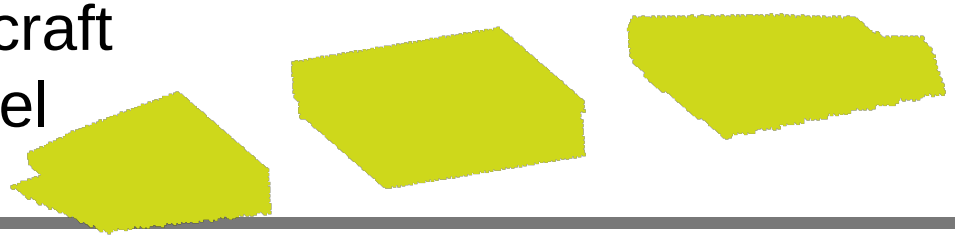


Modeling Jet Fuel

- Used SPH elements
  - Discrete particles
  - Each particle has a position and mass
- 9,118 Gallons of Fuel (NIST 9/11 Report)
- Use regular gird of points
- Fuel placed as if aircraft was straight and level

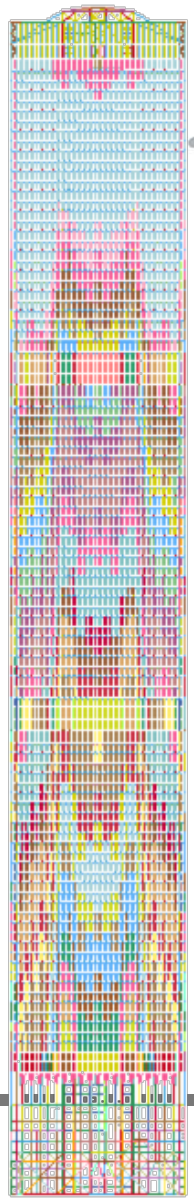






WTC North Tower

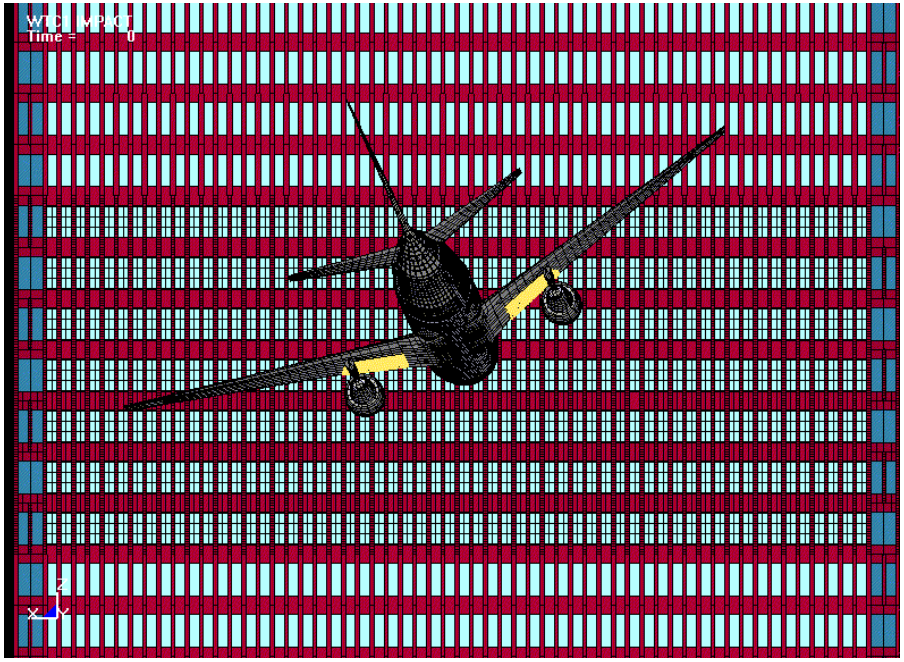
- Entire building model by team members in CE using SAP2000
- Modeling
  - Building was modeled using extensive architectural drawings
  - First hand sources
- Converted into LS-Dyna format
- Simulation only uses top 30 stories

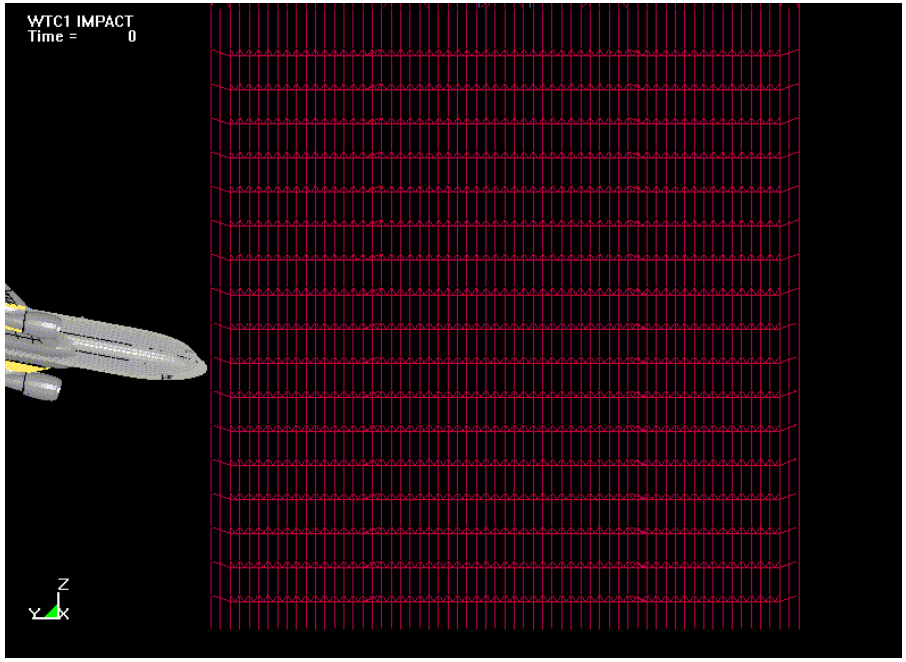


Model Summary

- Aircraft Statistics:
  - 14,341 nodes
  - 11,244 shell elements
  - 9,001 beam elements
  - 674 solid elements
- Fuel Statistics:
  - 87,188 nodes / SPH elements
- Building Statistics (top 30 stories):
  - 231,065 nodes
  - 82,465 shell elements
  - 239,775 beam elements
- Totals:
  - 332,594 nodes
  - 430,347 beam / shell / solid / SPH elements

Latest Results – Run 16





Facade Damage

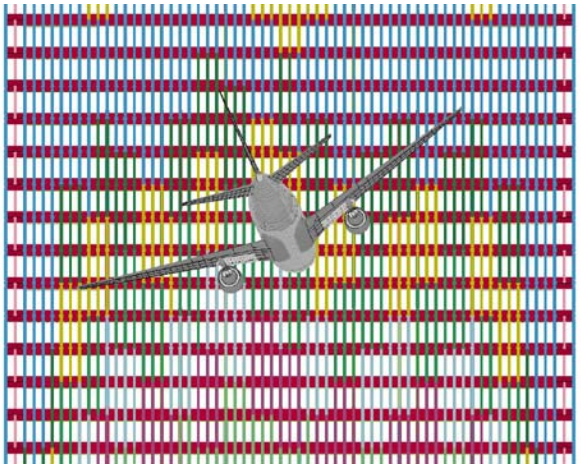


Figure 2-15 Impact damage to the north face of WTC 1.

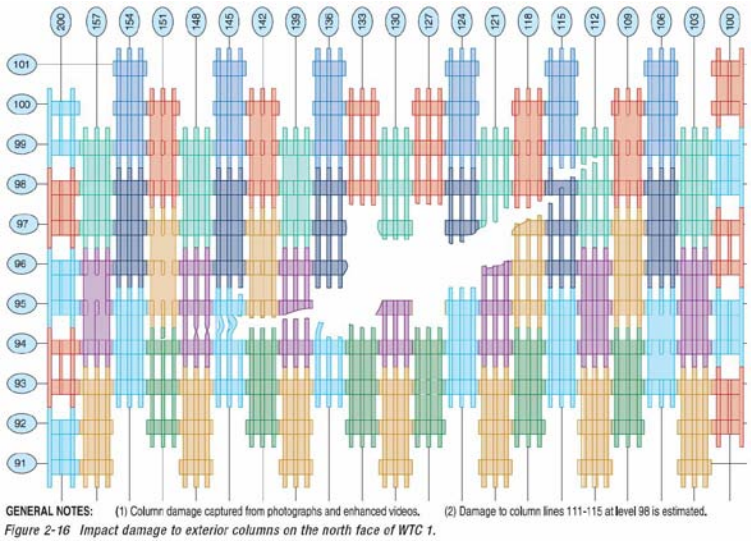
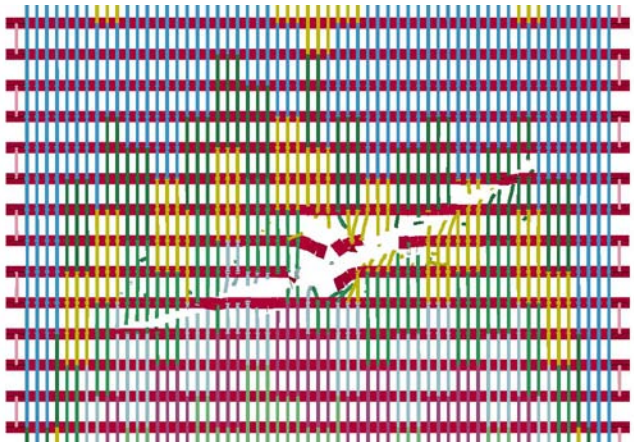


Figure 2-16 Impact damage to exterior columns on the north face of WTC 1.



Damage Diagram (FEMA Report)

Computational Results

Simulation	Time Required
WTC North Run 11	0.5 sec. real time 100 hours nano regatta (8 cpus)
WTC North Run 12	0.37 sec. real time 30 hours nano regatta (16 cpus)
WTC North Run 16	0.5 sec. real time 65 hours nano regatta (16 cpus)

Larger List of Contributors

- Mete Sozen, Civil Engineering
- Christoph Hoffmann, Computer Science, CRI
- Ayhan Irfanoglu, Civil Engineering
- Oscar Ardila-Giraldo, Civil Engineering
- Ingo Brachmann, Civil Engineering
- Paul Rosen, Computer Science
- Santiago Pujol, Civil Engineering
- Voicu Popescu, Computer Science
- Tyler Krahn, Civil Engineering

Thanks

- Support
  - NSF ITR grant DSC-0325227
  - Northwest Indiana Computational Grid
  - Purdue's Network for Computational Nanotechnology
- Websites
  - WTC North Tower Simulation
    - http://www.cs.purdue.edu/homes/cmh/simulation/phase3
  - 9/11 Simulations
    - http://www.cs.purdue.edu/homes/cmh/simulation
  - CS Graphics and Visualization Group
    - http://www.cs.purdue.edu/cgvlab/