High-Fidelity Simulation of Large-Scale Structures

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http://www.caam.rice.edu/~modelreduction

Objectives

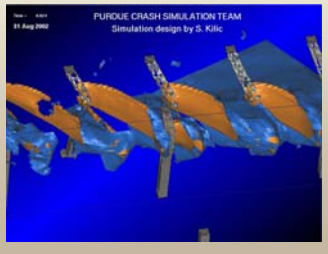
1. A science base for fidelity in model reduction when simulating the performance of large structures.
2. Integration real-time control and active elements into high-value structures
3. Develop sophisticated visualizations of structure performance

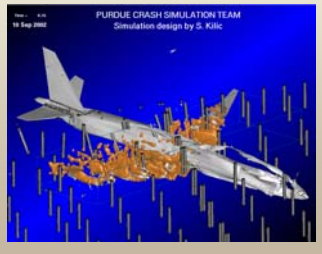
Objective

- Given an FEA model, devise a reduced model that captures the qualitative behavior
- Applications:
  - Active structures
  - Real-time control
  - Prognosis

Model Reduction

- Motivation: Pentagon performance simulations
  www.cs.purdue.edu/homes/cmh/simulation
  - One frame, 68 hrs computation time on an IBM Regatta in September 2002 for 0.25 s real time
  - Power 3 architecture, 16 processors
- Support control, what-if scenarios

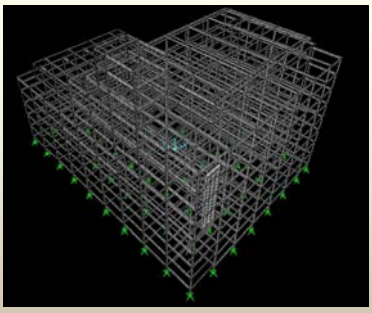




Active Structures

Dongting Lake Bridge (Hunan) has now MR dampers to control wind-induced vibration. Significant reductions.
http://www.cse.polyu.edu.hk/~dynamics/dtl_vc.htm

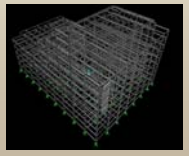
Reducing the State Dimension



i.e. reduce the number of equations describing the "state" of the system

26400 2nd order eqs

50 2nd order eqs



Another Benchmark

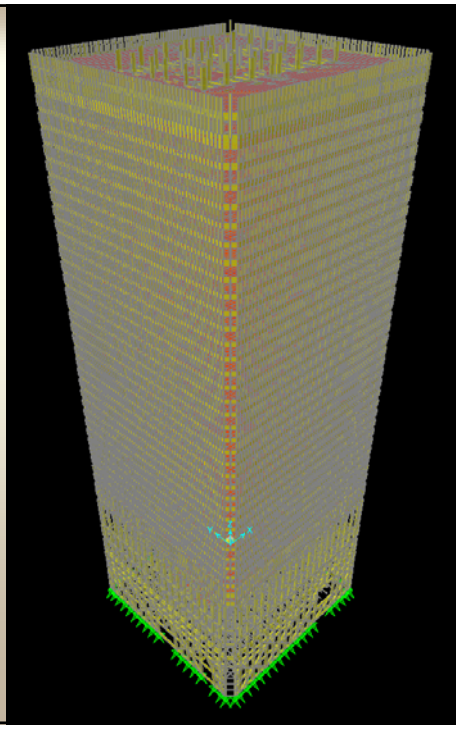
- PU Bowen Lab Structure
  - How does it behave in an earthquake?
  - Can active structures confer resilience?
- Instrument, test and validate
  - 30’ x 50’ x 35’

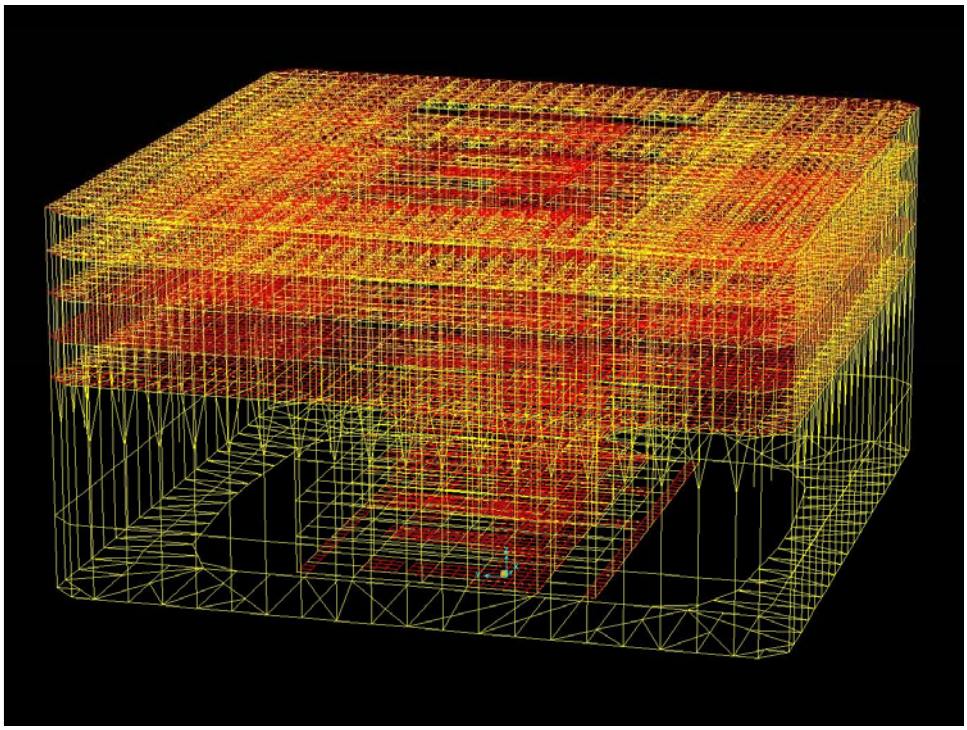
WTC

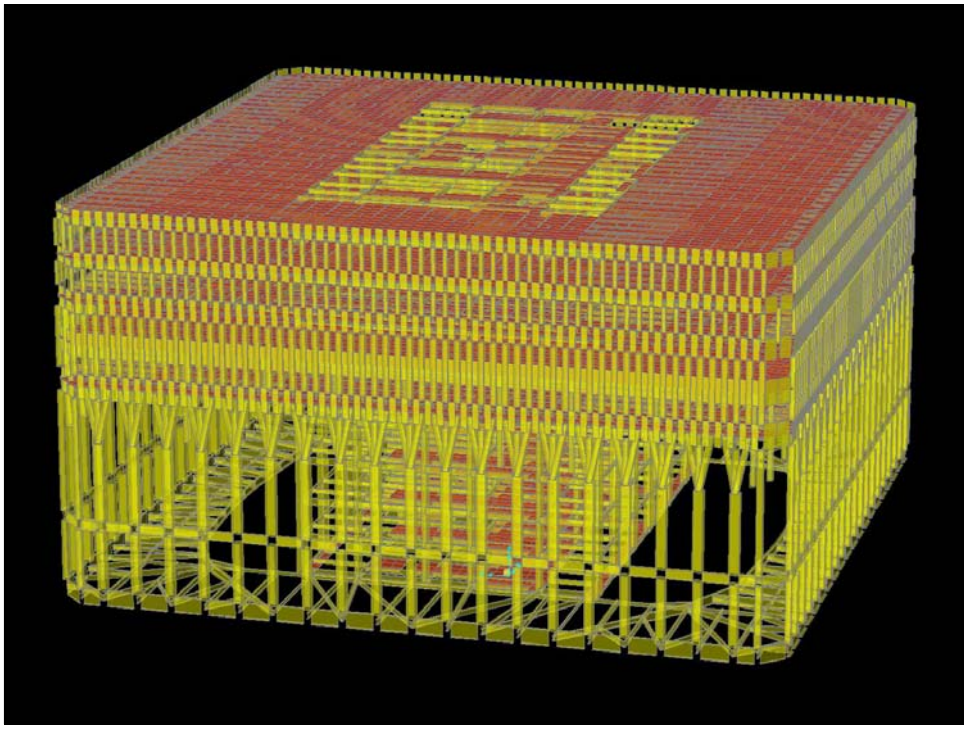
- Model Size Problems:
  - Structural model 1 hour to load in a fast PC
  - Candidate for model reduction
- Rendering Problems:
  - Postprocessors can’t draw well
  - But we can federate with rendering systems

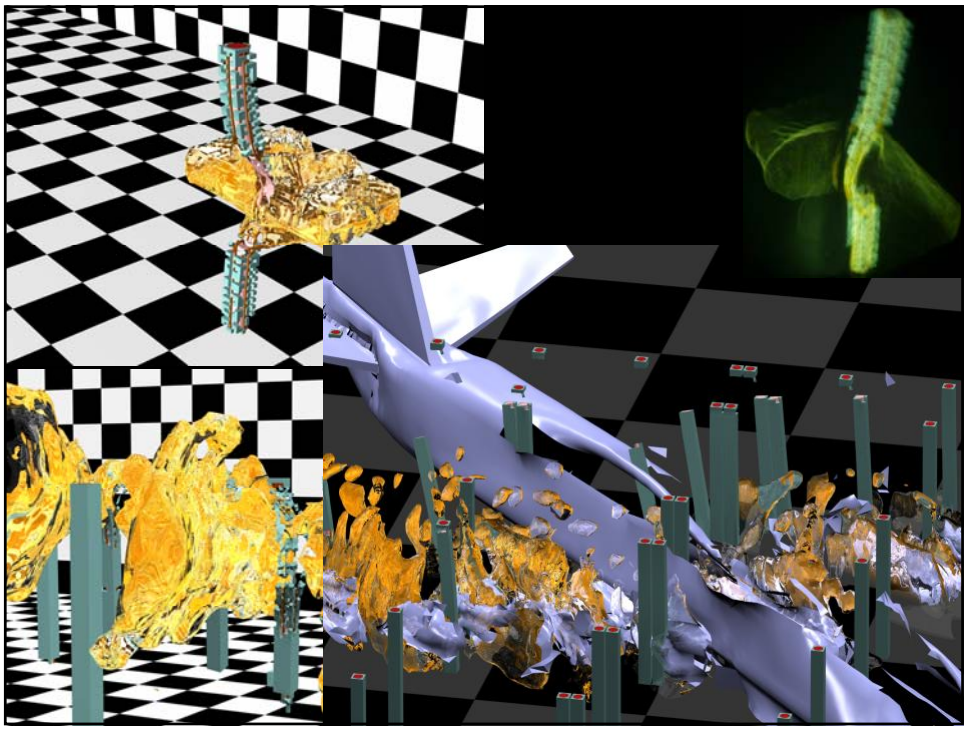
Model Reduction

- Huge job, should be done by computation
- Full simulation not realistic
- 1/3rd of South Tower

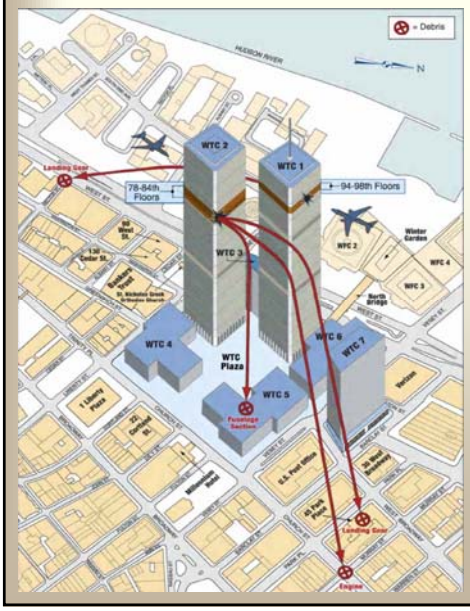


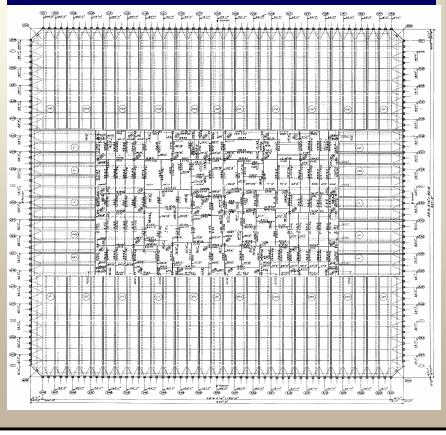






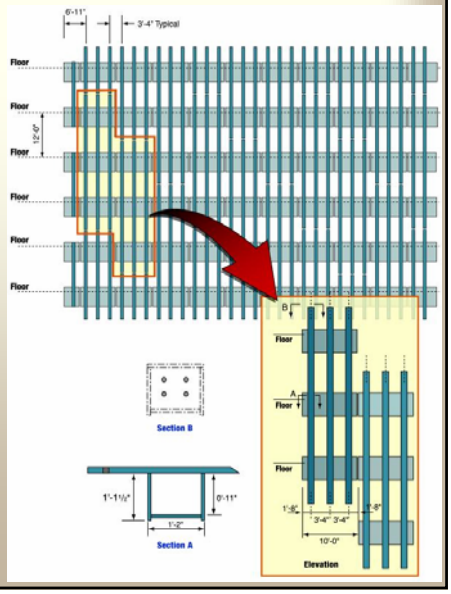
Impact Locations for WTC 1 (96th Floor, North Tower)





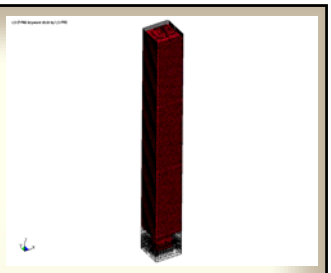
WTC 1 & 2 Information
Structural System & Exterior Columns

Number of Perimeter Columns in typical floor	59
Dimensions Perimeter Column	Cross Section: 14 x 14 in
Spacing between Perimeter Columns	3 ft 4 in
Depth of Spandrel Plates	52 in
Module prefabrication of perimeter columns and spandrel plates	3 Columns (3 story tall) connected w spandrel plates
Connection within the Prefabricated Module	welds
Splices in the Module	Splices are staggered in elevation
Connection to other modules	Cap plates on each column (Attachment)
Connection between Modules (upper Floor Level)	4 Bolts
# of Grades of Steel	12 different (42-100 ksi)
Plate thickness (upper floors)	¼ in
Plate thickness (at base)	4 in



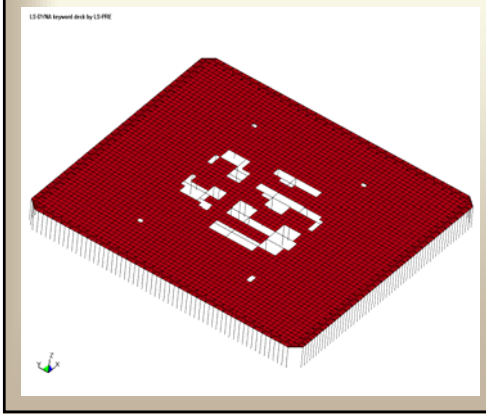
WTC Model

Nodes: 640,000
Beam Elements: 530,000
Shell Elements: 360,000



96th Floor

Shell Element Layout



Beam Element Layout