

**Federal Building and Fire Safety Investigation
of the World Trade Center Disaster**

**Simulating the Coupled Fire, Thermal, Structural
Response of World Trade Center Towers**

October 19, 2004

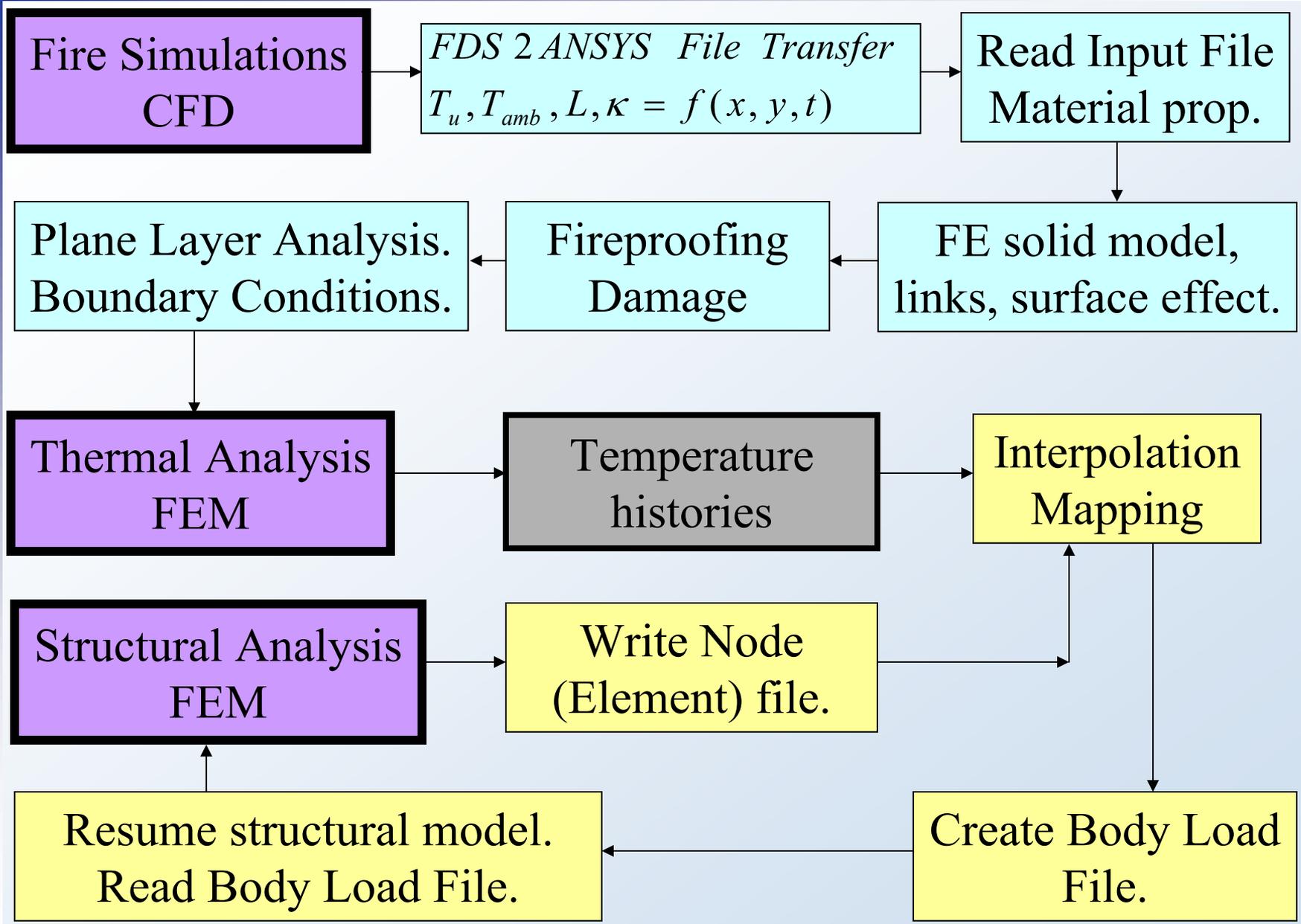
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National Institute of Standards and Technology
U.S. Department of Commerce**

kprasad@nist.gov

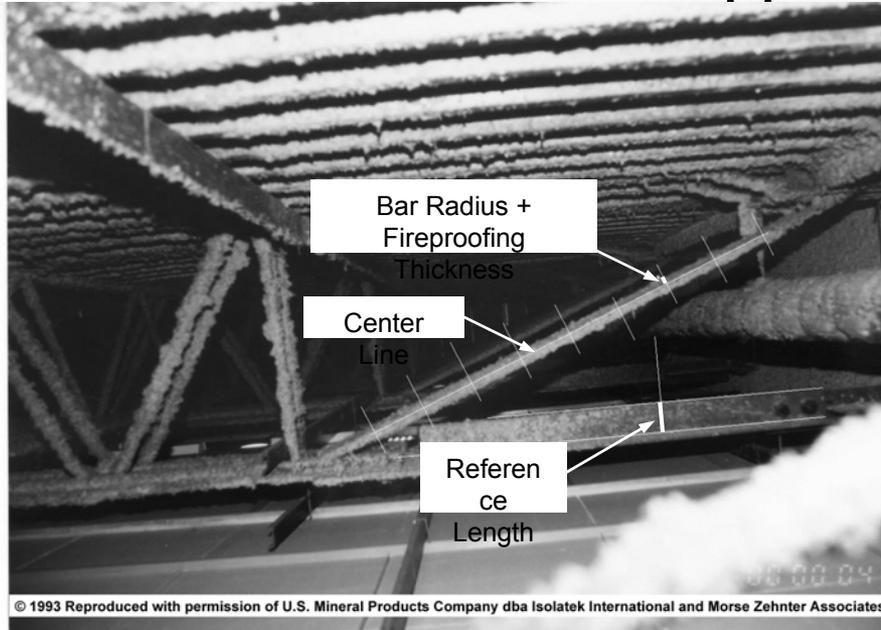
Objectives

- Development of Fire Structure Interface (FSI) to couple the Fire Dynamics Simulator (FDS) with the thermal response of structural elements.
- Reconstruct the time-evolving and spatially evolving temperature fields in the steel and concrete for World Trade Center buildings 1, 2, and 7.
- Construct thermal loading data files (temperature mapping) for the structural models.
- Evaluate the role of variability in fireproofing thickness and damage caused by aircraft on steel temperature.
- Estimate the sensitivity of model parameters.



Pre / Post Impact Damage to Fireproofing

- Insulation was not applied evenly over the trusses.



- **Aircraft impact.**

- **Debris Field.**
- **Acceleration**
- **Deformation**

- Renovations ?
- Effect of vibrations over an extended period.



North Tower

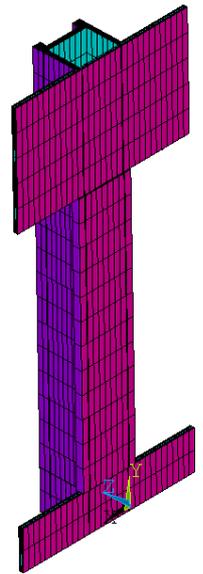
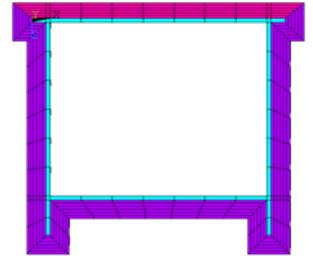
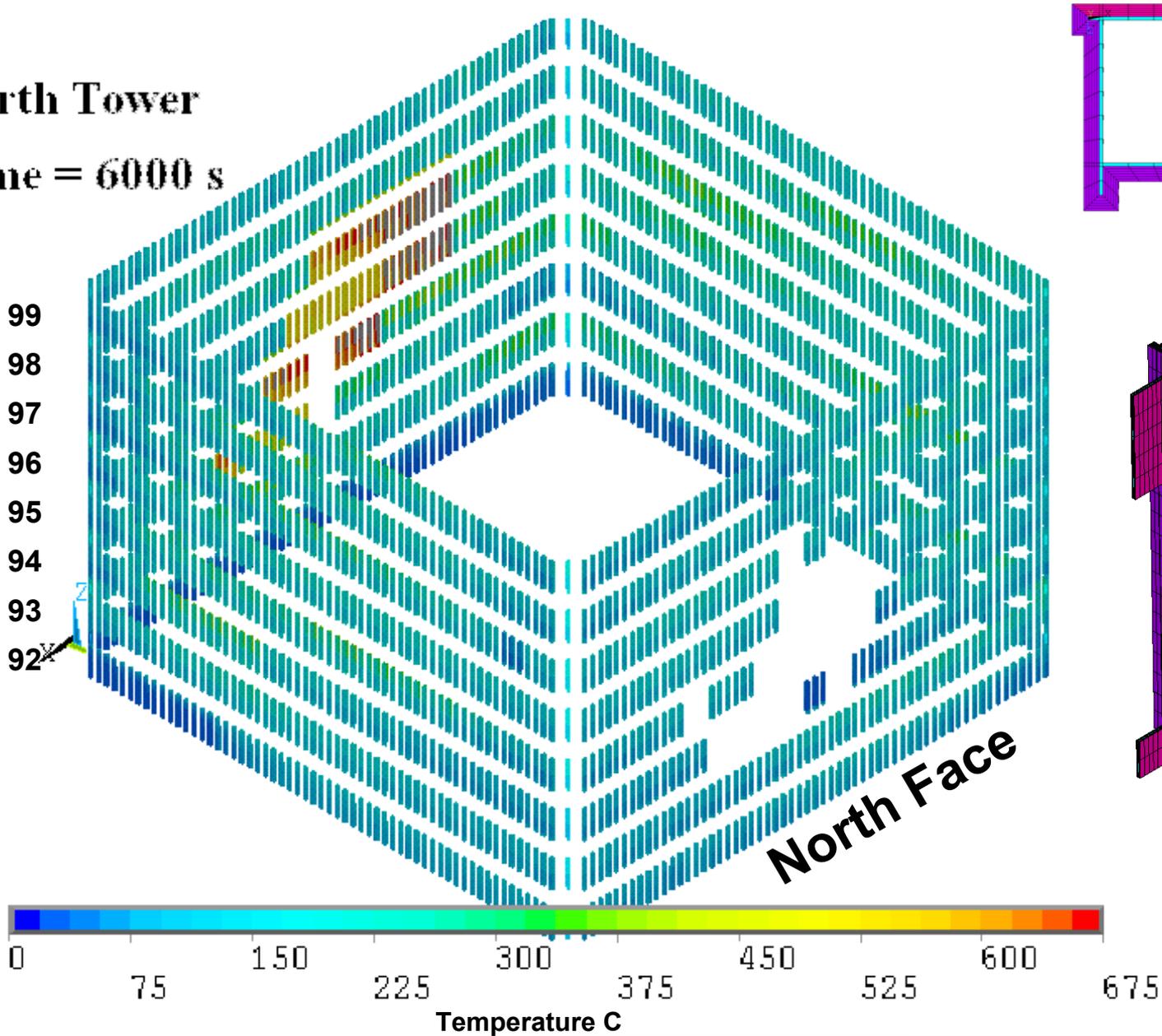
- Aircraft Impact Damage and Fire Scenarios
 - Severe
 - Realistic
- North Tower Model
 - Floors 92-99
 - Model includes structural and fireproofing damage

North Tower : Severe Case

North Tower

Time = 6000 s

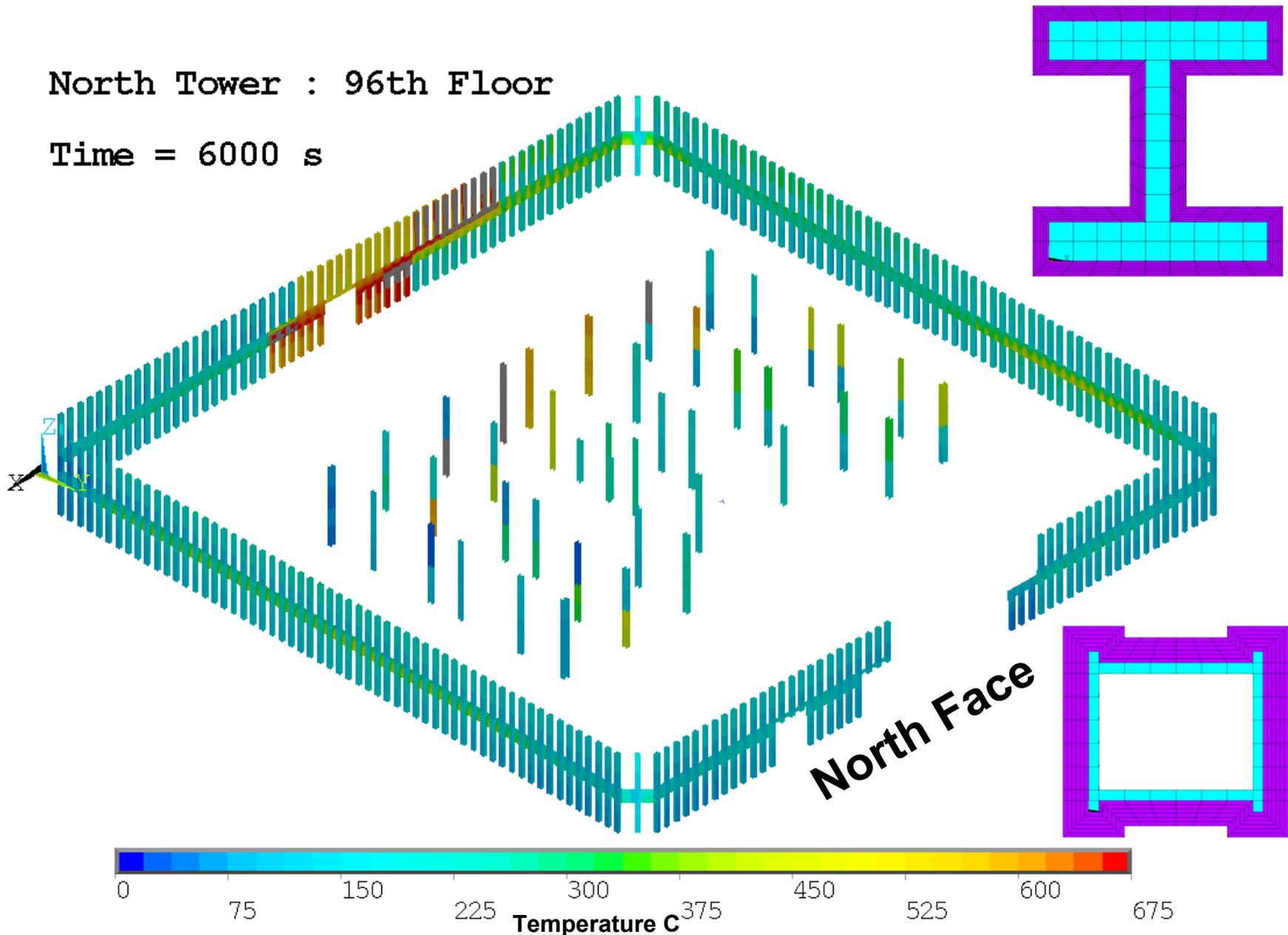
Floor 99
Floor 98
Floor 97
Floor 96
Floor 95
Floor 94
Floor 93
Floor 92



North Tower : Severe Case

North Tower : 96th Floor

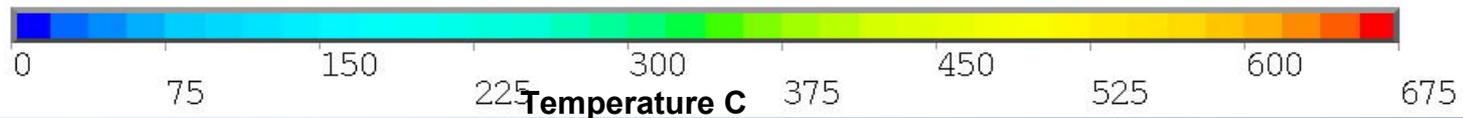
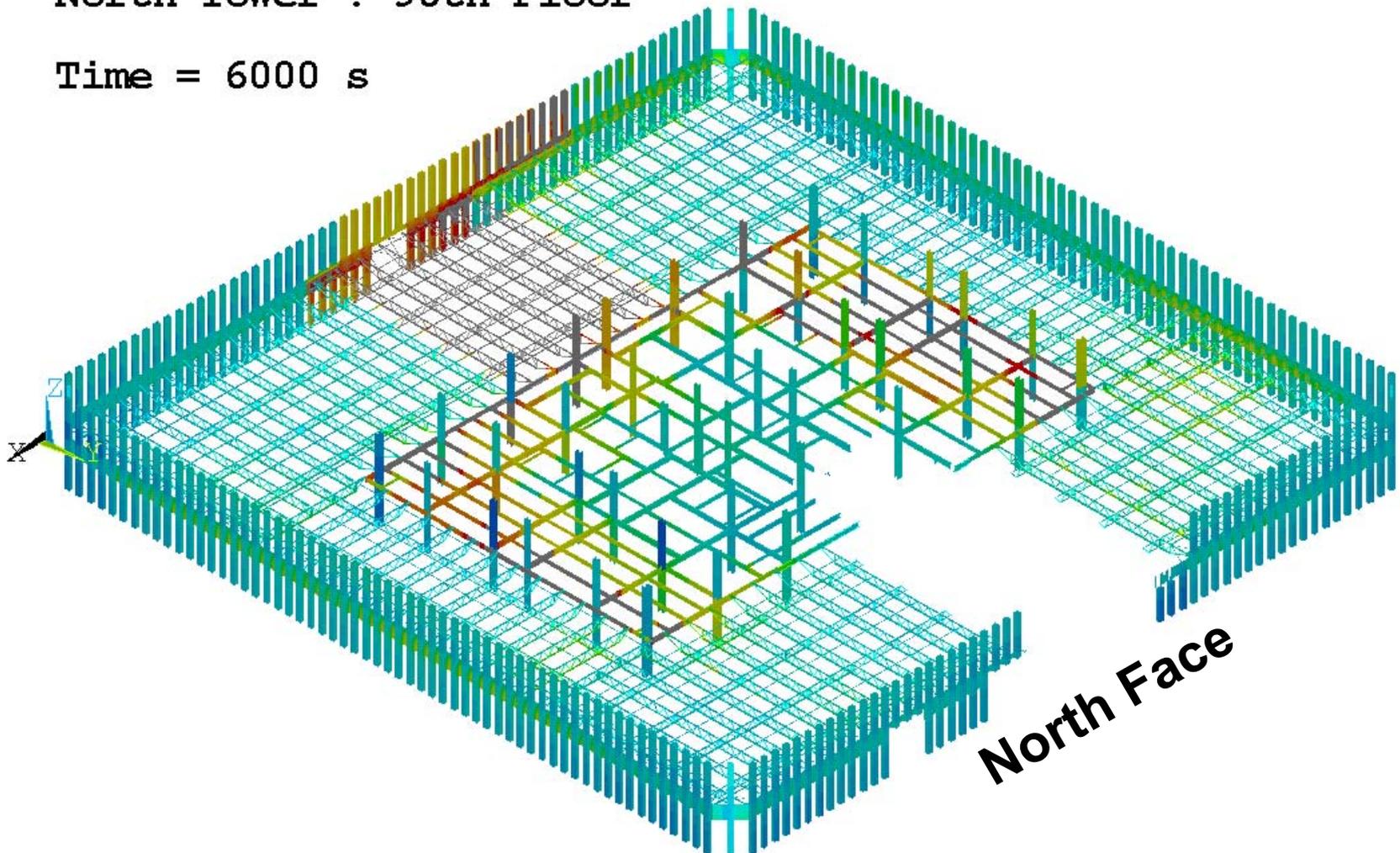
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North Tower : Severe Case

North Tower : 96th Floor

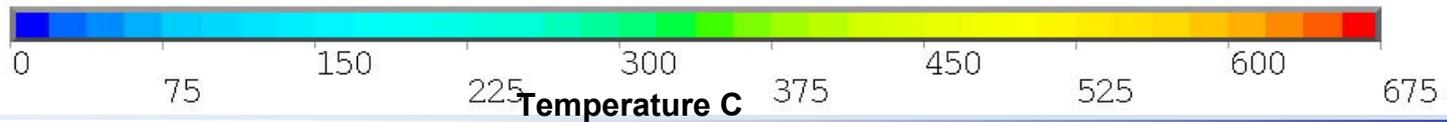
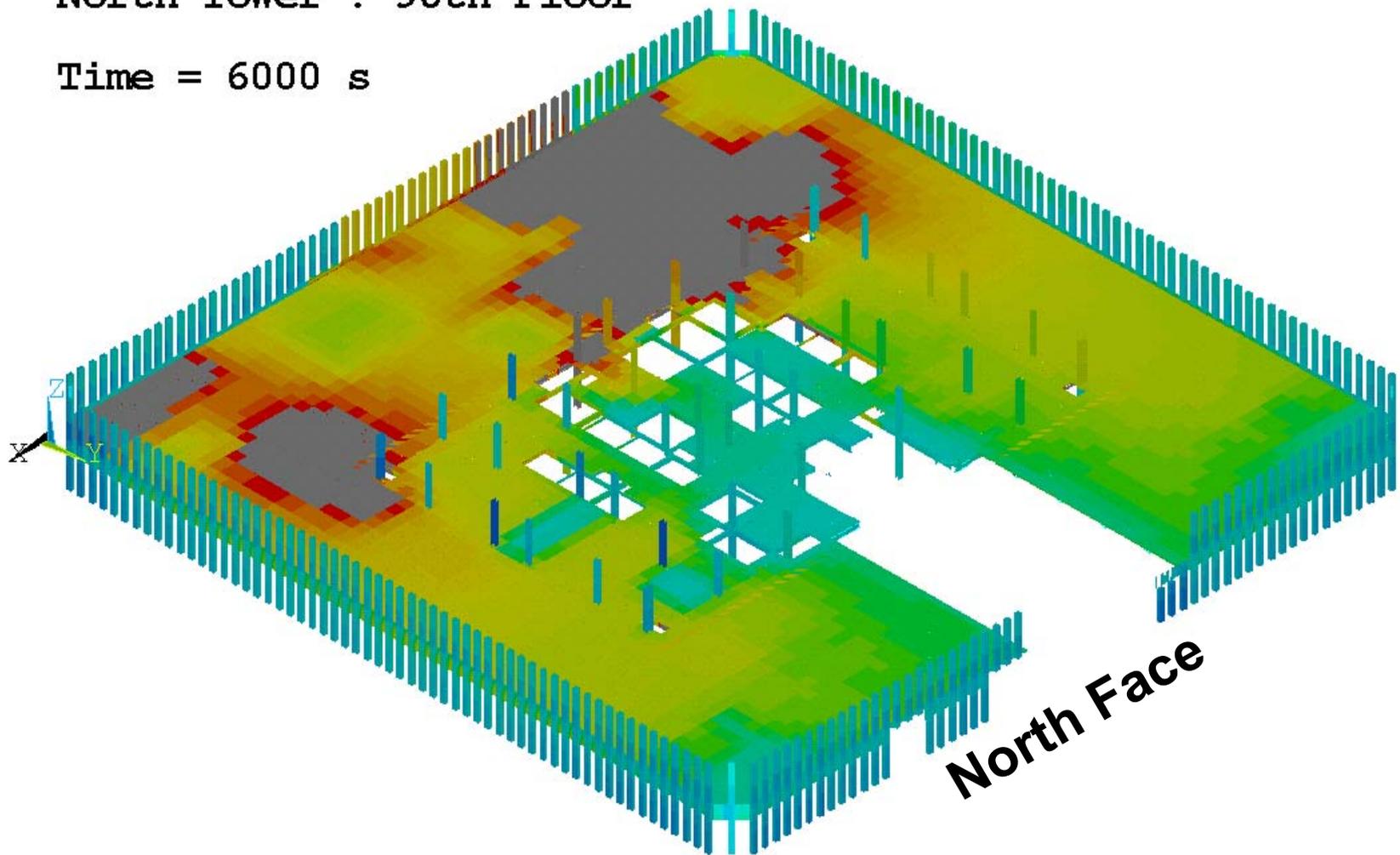
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North Tower : Severe Case

North Tower : 96th Floor

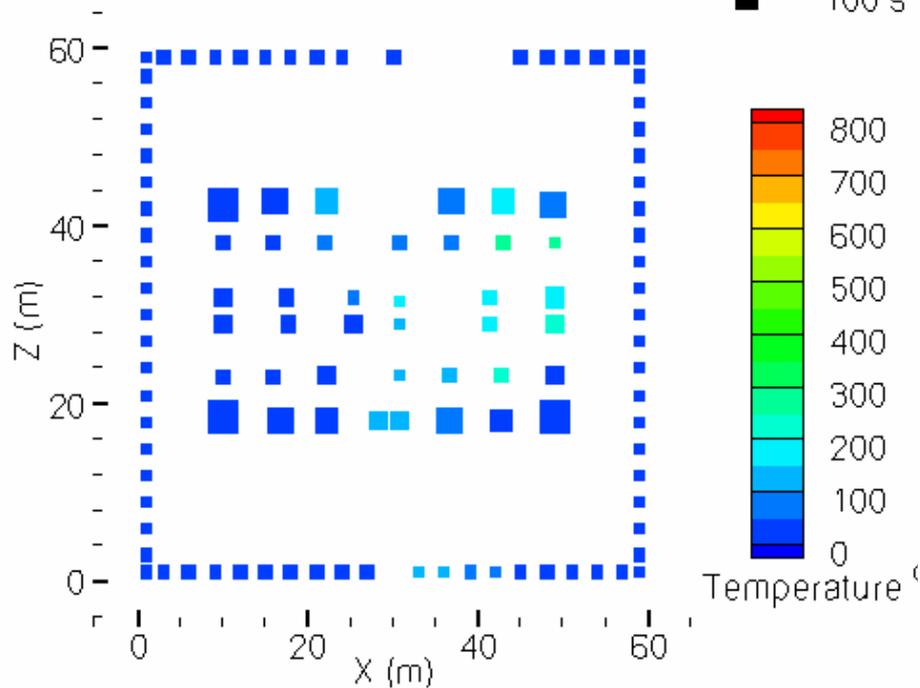
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North Tower : Severe Case

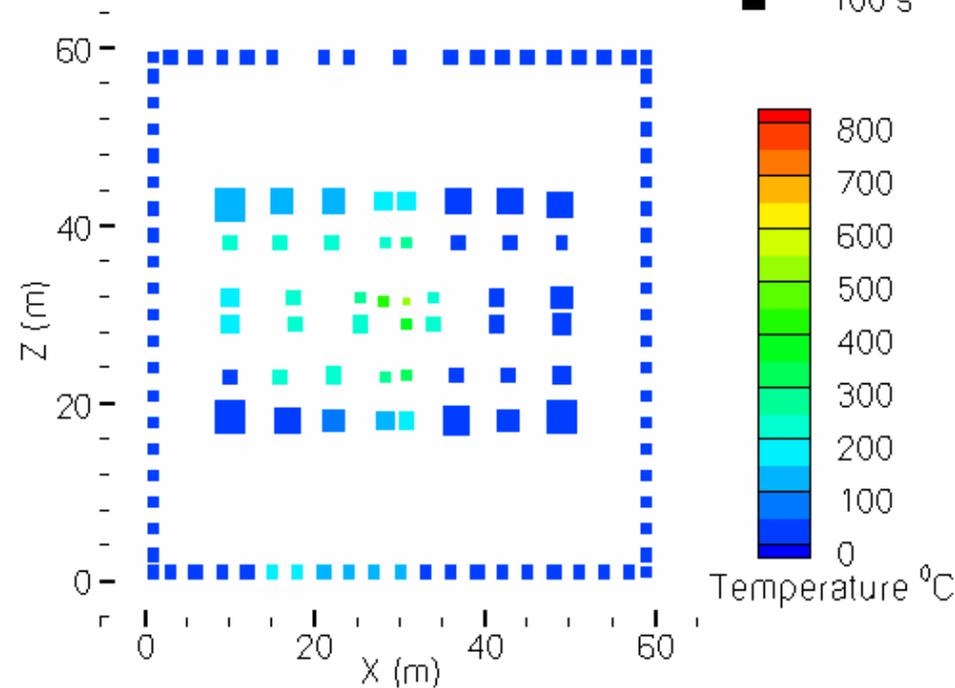
94th Floor

North Tower : 94th Floor
Severe Case



97th Floor

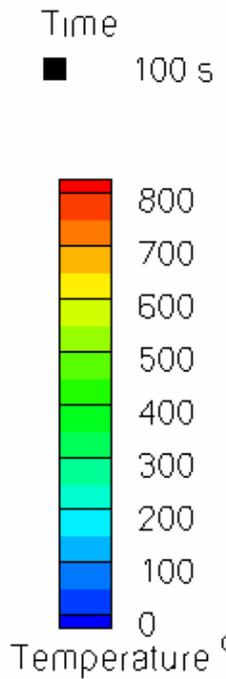
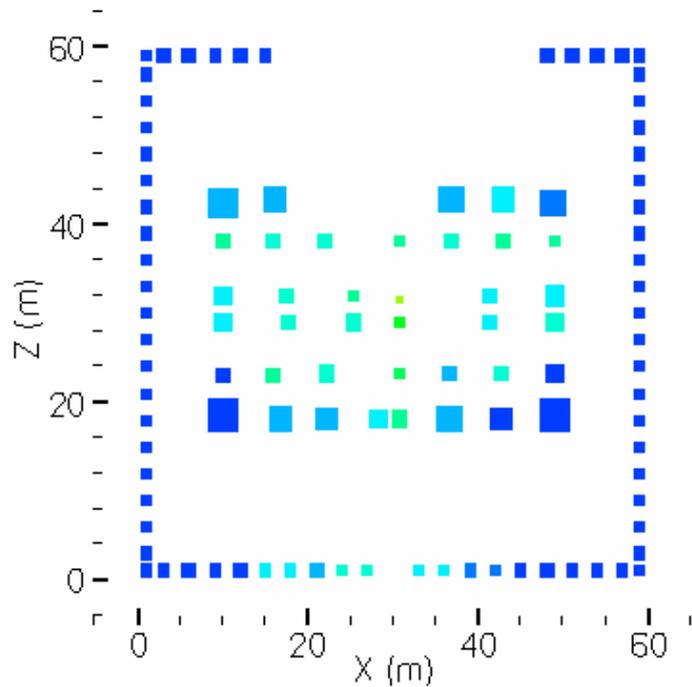
North Tower : 97th Floor
Severe Case



North Tower

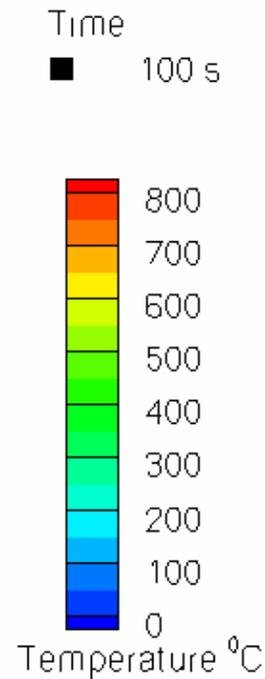
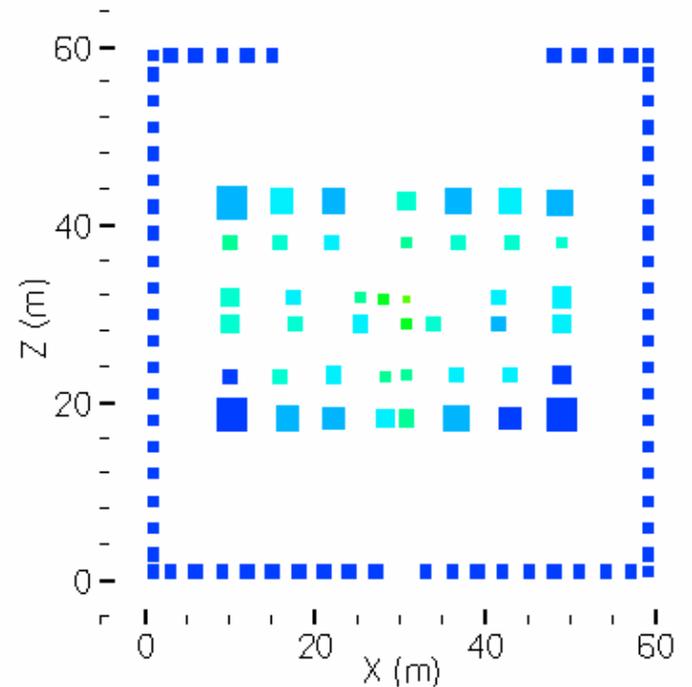
Severe Case

North Tower : All Floors
Severe Case



Realistic Case

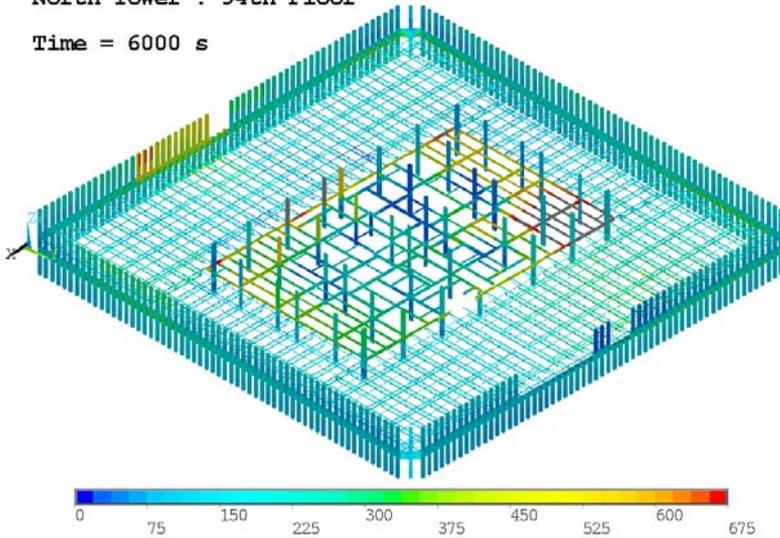
North Tower : All Floors
Realistic Case



North Tower : Severe Case

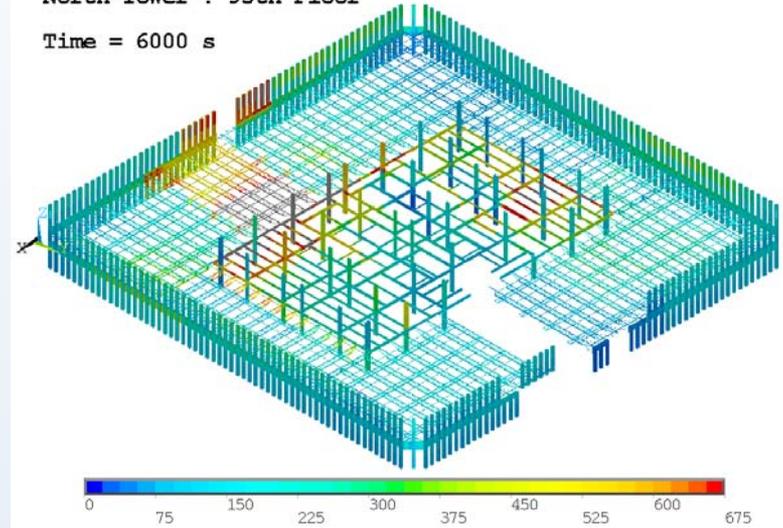
North Tower : 94th Floor

Time = 6000 s



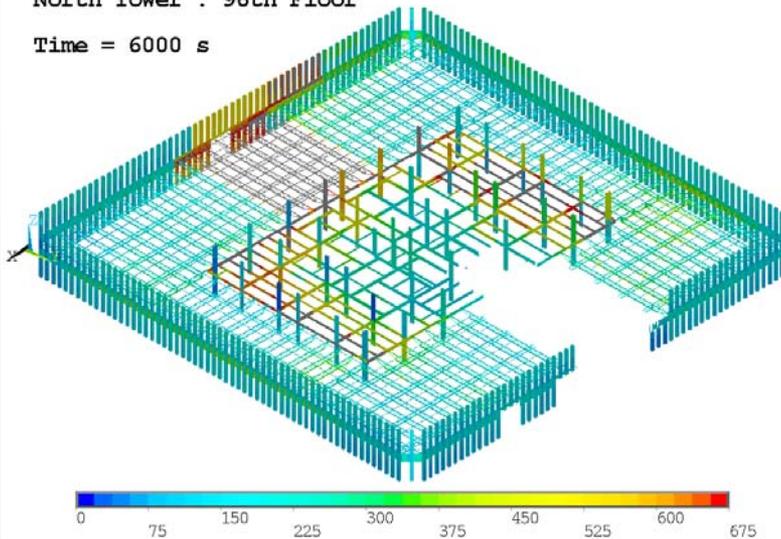
North Tower : 95th Floor

Time = 6000 s



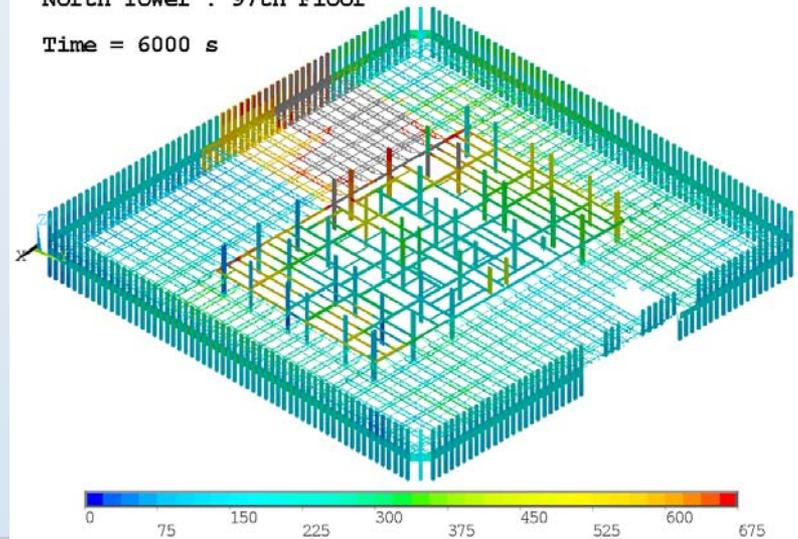
North Tower : 96th Floor

Time = 6000 s



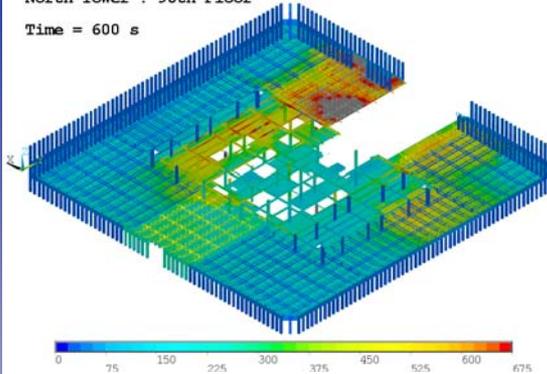
North Tower : 97th Floor

Time = 6000 s

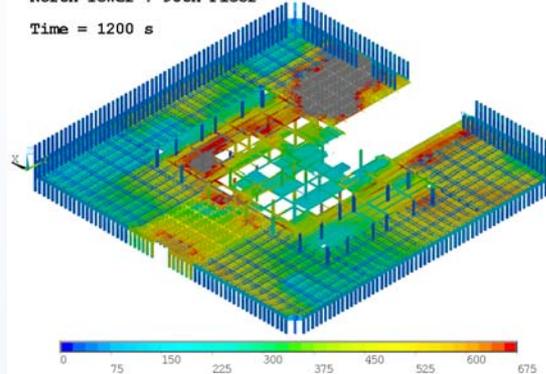


North Tower : Severe Case

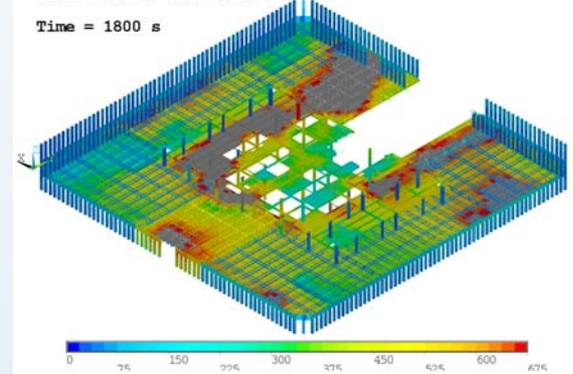
North Tower : 96th Floor
Time = 600 s



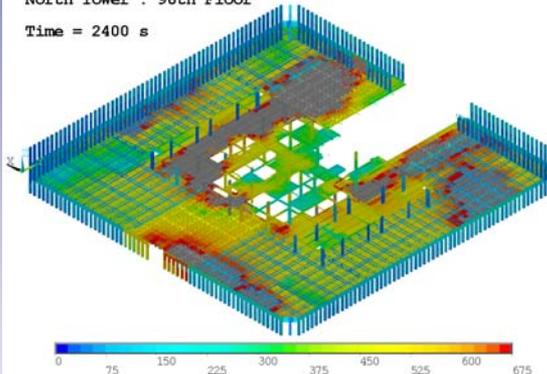
North Tower : 96th Floor
Time = 1200 s



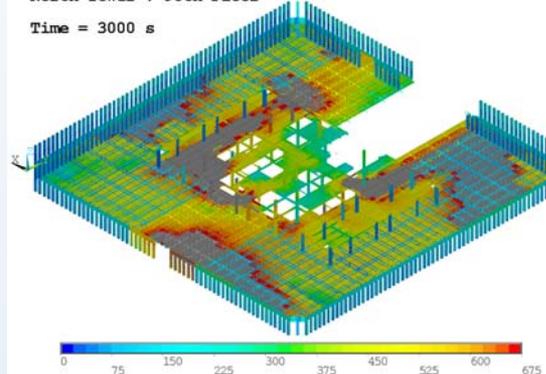
North Tower : 96th Floor
Time = 1800 s



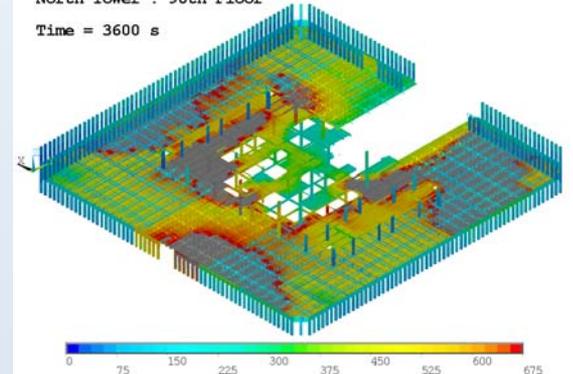
North Tower : 96th Floor
Time = 2400 s



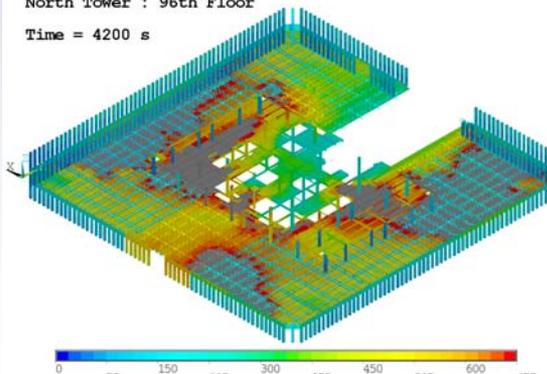
North Tower : 96th Floor
Time = 3000 s



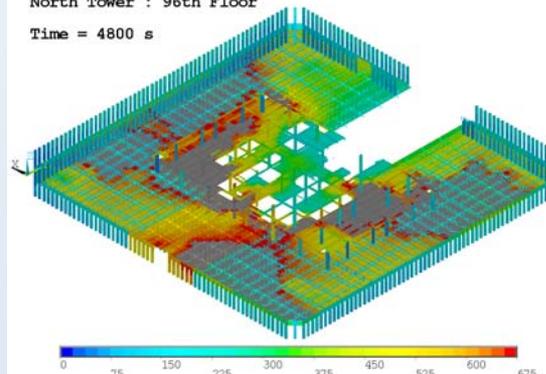
North Tower : 96th Floor
Time = 3600 s



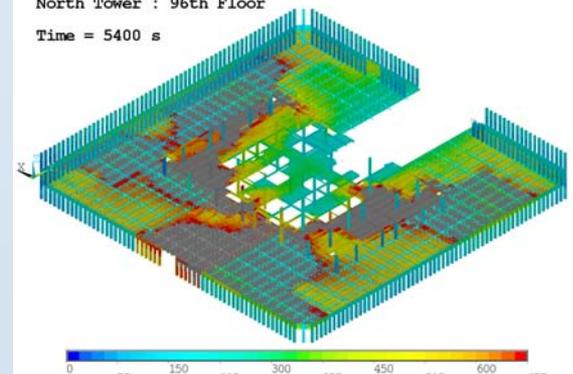
North Tower : 96th Floor
Time = 4200 s



North Tower : 96th Floor
Time = 4800 s

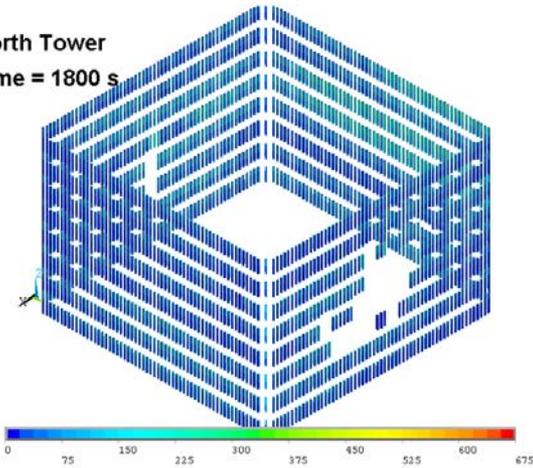


North Tower : 96th Floor
Time = 5400 s

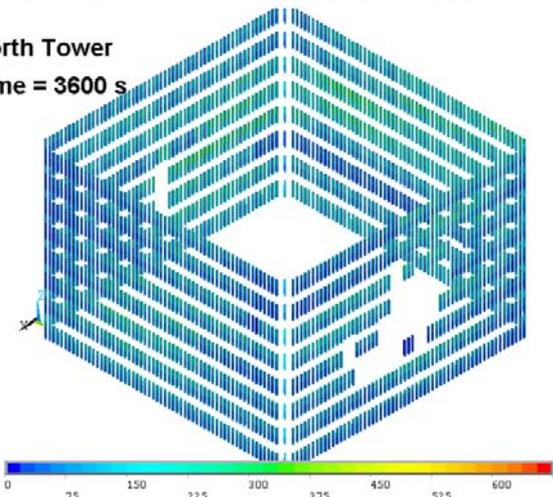


North Tower : Realistic Case

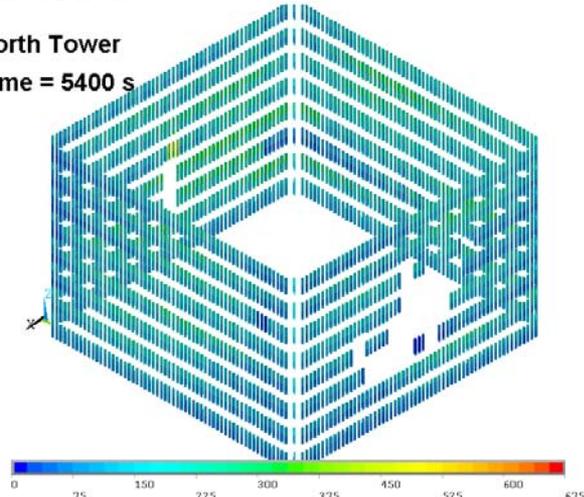
North Tower
Time = 1800 s



North Tower
Time = 3600 s

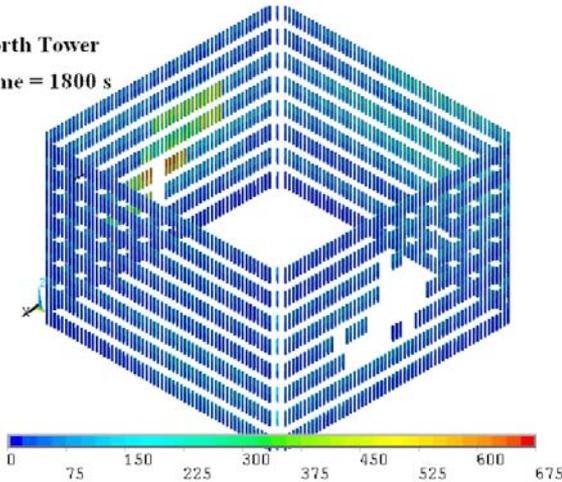


North Tower
Time = 5400 s

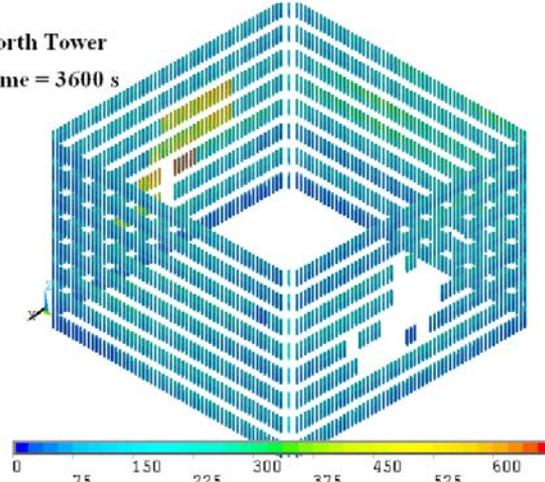


North Tower : Severe Case

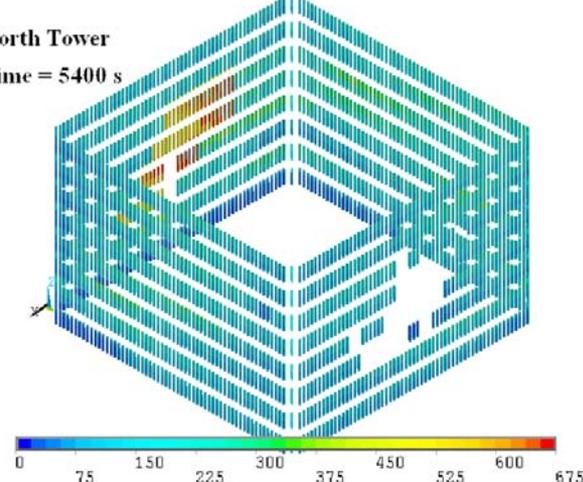
North Tower
Time = 1800 s



North Tower
Time = 3600 s



North Tower
Time = 5400 s

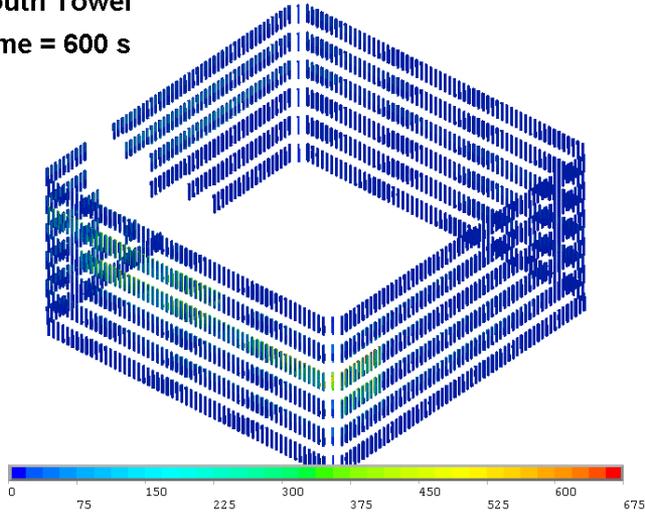


South Tower

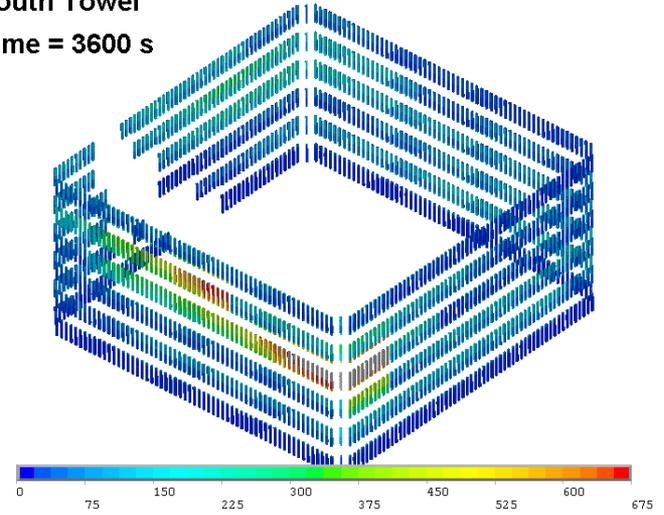
- Aircraft Impact Damage and Fire Scenarios
 - Severe case
 - Realistic case
- South Tower Model
 - Floors 78-83
 - Model includes structural and fireproofing damage

South Tower : Realistic Case

South Tower
Time = 600 s

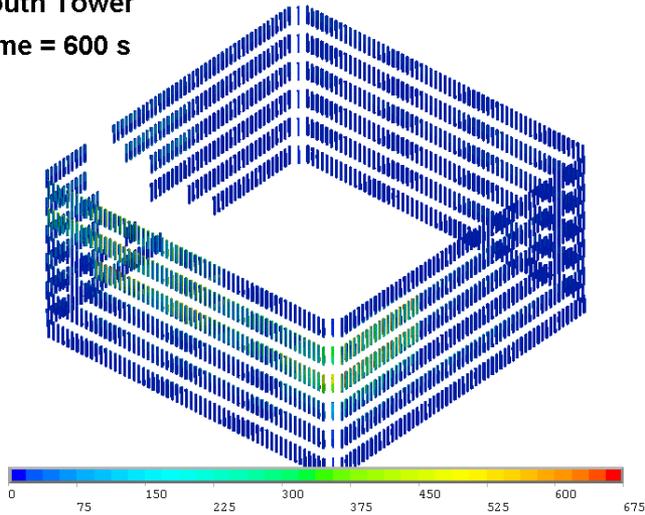


South Tower
Time = 3600 s

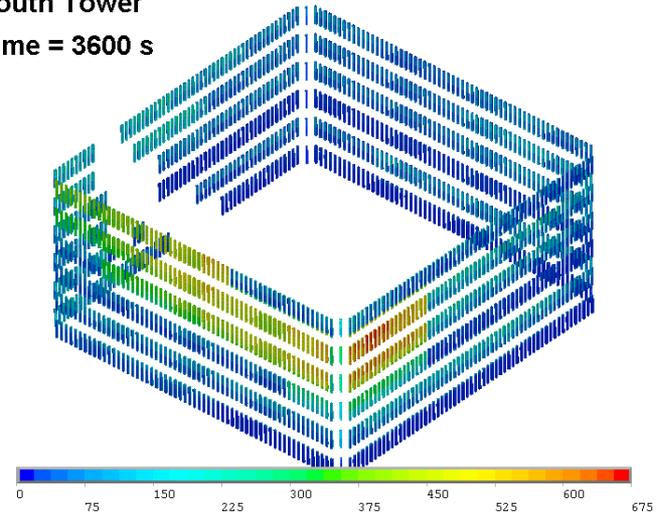


South Tower : Severe Case

South Tower
Time = 600 s



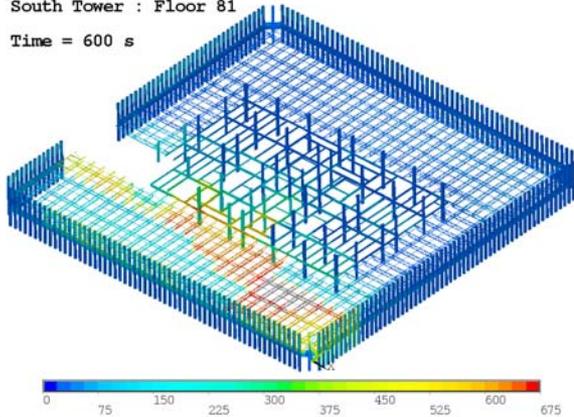
South Tower
Time = 3600 s



South Tower : Realistic Case

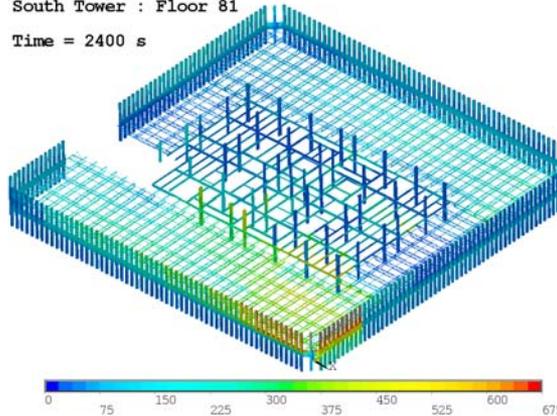
South Tower : Floor 81

Time = 600 s



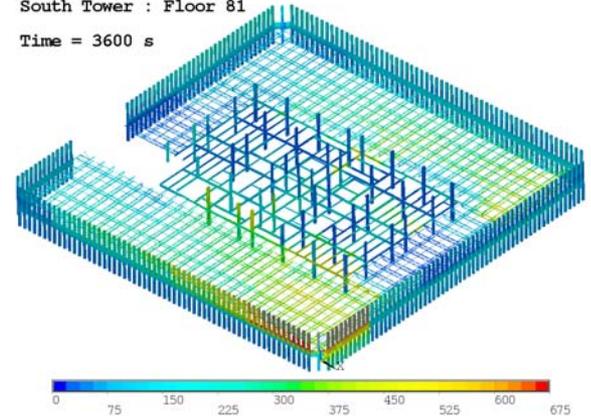
South Tower : Floor 81

Time = 2400 s



South Tower : Floor 81

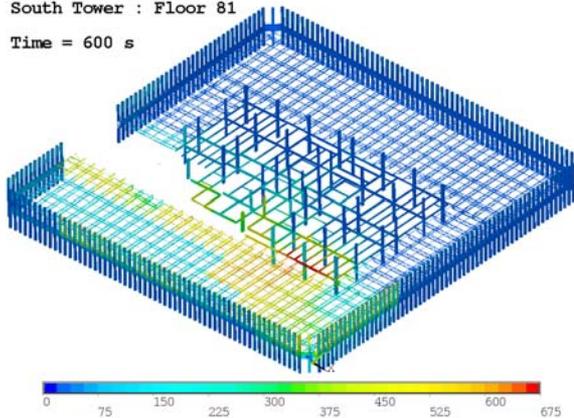
Time = 3600 s



South Tower : Severe Case

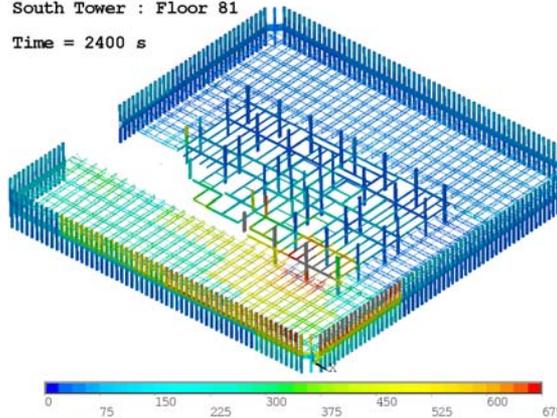
South Tower : Floor 81

Time = 600 s



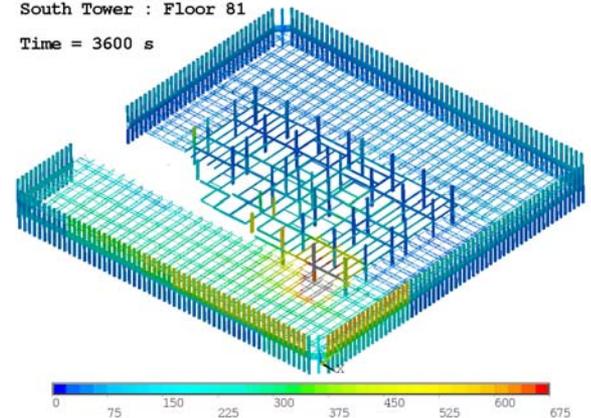
South Tower : Floor 81

Time = 2400 s



South Tower : Floor 81

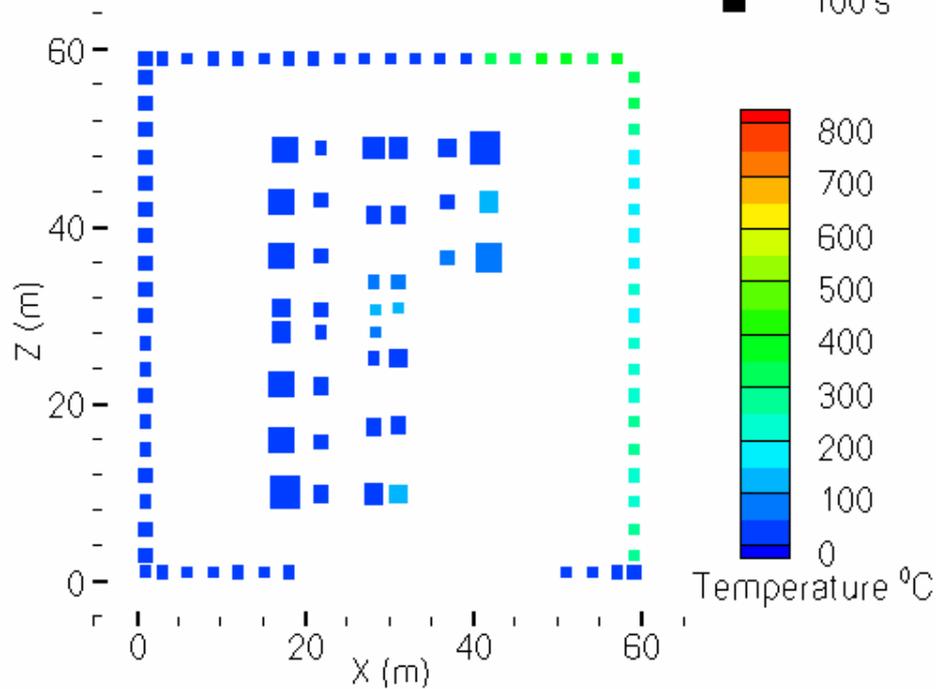
Time = 3600 s



South Tower

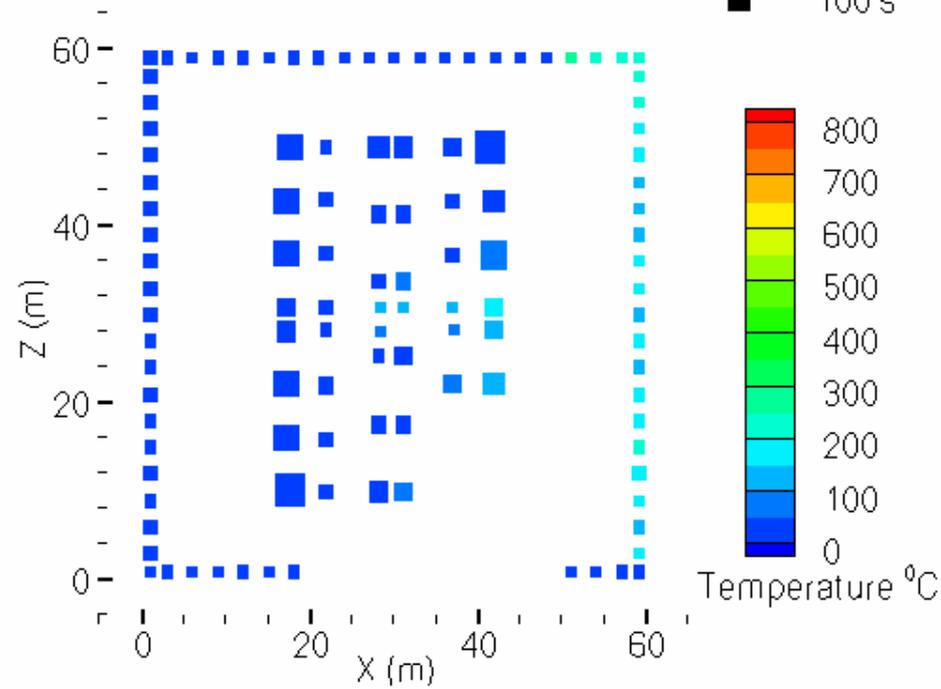
Severe Case

South Tower : All Floors
Severe Case



Realistic Case

South Tower : All Floors
Realistic Case



Status:

- ❑ Fire Structure Interface (FSI) – completed.
- ❑ Sensitivity to model parameters – completed.
- ❑ Component analysis – completed.
- ❑ Standard cases for evaluating collapse hypotheses
 - Realistic Scenario for North and South Tower – completed.
 - Severe Scenario for North and South Tower – completed.
 - Other Fire and Aircraft Impact Damage Scenarios – underway.
- ❑ Thermal loading files provided to SGH for structural analysis.

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Response of World Trade Center Towers**

Thank you

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