Earthquakes, Floods, and Winds
Why a Multihazard Approach?

Will disasters increase in the Future?

Potentially:
- Increase in damage to the built environment
- More people occupying high risk areas
- Consumption of natural resources
- Variations in macro and micro climate
- Increase in disaster victims

World Population 1950-2050

<table>
<thead>
<tr>
<th>Year</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950</td>
<td>2,518,629</td>
</tr>
<tr>
<td>1960</td>
<td>2,981,659</td>
</tr>
<tr>
<td>1970</td>
<td>3,692,492</td>
</tr>
<tr>
<td>1980</td>
<td>4,434,682</td>
</tr>
<tr>
<td>1990</td>
<td>5,263,593</td>
</tr>
<tr>
<td>2000</td>
<td>6,070,581</td>
</tr>
<tr>
<td>2010</td>
<td>6,830,283</td>
</tr>
<tr>
<td>2020</td>
<td>7,540,237</td>
</tr>
<tr>
<td>2030</td>
<td>8,130,149</td>
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<tr>
<td>2040</td>
<td>8,593,591</td>
</tr>
<tr>
<td>2050</td>
<td>9,187,244</td>
</tr>
</tbody>
</table>
Why a Multihazard Approach?

Katrina’s economic loses were in excess of $125 billion

Northridge’s economic loses were in excess of $140 billion

Flooding affects over 20,000 local jurisdictions. The Floods of ’93 loses were in excess of $15 billion

9/11 economic losses were estimated in $105 billion
• Different locations can be affected by a range of natural and manmade hazards

• Resilience against those hazards is important. A multihazard approach is the most effective way to reach building safety

• By designing against a particular hazard and disregarding others the levels of protection and performance can be compromised
FEMA 452 Methodology

1. Threat Identification and Rating (Step 1)
2. Asset Value Assessment (Step 2)
3. Vulnerability Assessment (Step 3)
4. Risk Assessment (Step 4)
5. Consider Mitigation Options (Step 5)
6. Decision (Risk Management)

- Cost Analysis: Analyze how mitigation options affect asset criticality and ultimately risk.
- Benefits Analysis: Analyze how mitigation options change vulnerability and ultimately risk.
Man-Made Threat

- Explosive Blast due to vehicle bomb
- Chemical / Biological / Radiological (CBR) release
- Technological accident
- Armed attack
- Civil Disruption
- Cyber Attack
- Kidnapping / Hostage

Natural Hazards

- Wind (hurricane or tornado)
- Severe Storm / Lightning
- Earthquake
- Flooding (surface water, not broken pipes)
Two Part Process

Core Functions
- Indefinite core functions can be added according to building’s functions

Building Infrastructure
- 12 elements can be analyzed
<table>
<thead>
<tr>
<th>Core Functions</th>
<th>Building Infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administration</td>
<td>Site</td>
</tr>
<tr>
<td>Engineering</td>
<td>Structural Systems</td>
</tr>
<tr>
<td>Warehousing</td>
<td>Envelope Systems</td>
</tr>
<tr>
<td>Data Center</td>
<td>Utility Systems</td>
</tr>
<tr>
<td>Food Service</td>
<td>Mechanical Systems</td>
</tr>
<tr>
<td>Security</td>
<td>Plumbing and Gas Systems</td>
</tr>
<tr>
<td>Housekeeping</td>
<td>Electrical Systems</td>
</tr>
<tr>
<td>Day Care</td>
<td>Fire Alarm Systems</td>
</tr>
<tr>
<td>Others</td>
<td>IT/Communications Systems</td>
</tr>
<tr>
<td>Threat /Hazard</td>
<td>Threat/hazard is defined as any indication, circumstance, or event with the potential to cause loss of, or damage to an asset</td>
</tr>
<tr>
<td>---------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Asset Value</td>
<td>The degree of debilitating impact that would be caused by the incapacity or destruction of an asset</td>
</tr>
<tr>
<td>Vulnerability</td>
<td>A any weakness that can be exploited by an aggressor or caused by a natural disaster to make an asset susceptible to hazard damage</td>
</tr>
</tbody>
</table>

| Risk          | Threat Rating x Asset Value |
# Threat / Hazard Rating

<table>
<thead>
<tr>
<th>Threat / Hazard Rating</th>
<th>Rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very High</td>
<td>10</td>
<td>There is an <strong>extremely high likelihood</strong> of one or more threats/hazards impacting the site and a history of <strong>numerous damages</strong> at the site from past events.</td>
</tr>
<tr>
<td>High</td>
<td>8–9</td>
<td>It is <strong>high likelihood</strong> of one or more threats / hazards impacting the site and there is a history of at least one event causing <strong>significant damages</strong>.</td>
</tr>
<tr>
<td>Medium High</td>
<td>7</td>
<td>There is a <strong>high likelihood</strong> of one or more threats / hazards impacting the site and a history of <strong>some damages</strong> from past events.</td>
</tr>
<tr>
<td>Medium</td>
<td>5–6</td>
<td>There exists a <strong>significant possibility</strong> of one or more threats / natural hazards impacting the site. There <strong>may or may not be a damage</strong> history at the site.</td>
</tr>
<tr>
<td>Medium Low</td>
<td>4</td>
<td>There exists a <strong>moderate to low possibility</strong> of one or more threats / hazards impacting the site. <strong>There may or may not be a damage</strong> history at the site.</td>
</tr>
<tr>
<td>Low</td>
<td>2–3</td>
<td>There exists a <strong>slight possibility</strong> of one or more threats / natural hazards impacting the site. There is <strong>little or no history of damages</strong> from past events.</td>
</tr>
<tr>
<td>Very Low</td>
<td>1</td>
<td>There is little or <strong>no likelihood</strong> of one or more threats / natural hazards impacting the site. There is <strong>no history of damages</strong> from past events.</td>
</tr>
<tr>
<td><strong>Very High</strong></td>
<td>10</td>
<td>Loss or damage of the building’s assets would have exceptionally grave consequences, such as extensive loss of life, widespread severe injuries, or total loss of primary services, core processes, and functions.</td>
</tr>
<tr>
<td><strong>High</strong></td>
<td>8–9</td>
<td>Loss or damage of the building’s assets would have grave consequences, such as loss of life, severe injuries, loss of primary services, or major loss of core processes and functions for an extended period of time.</td>
</tr>
<tr>
<td><strong>Medium High</strong></td>
<td>7</td>
<td>Loss or damage of the building’s assets would have serious consequences, such as serious injuries or impairment of core processes and functions for an extended period of time.</td>
</tr>
<tr>
<td><strong>Medium</strong></td>
<td>5–6</td>
<td>Loss or damage of the building’s assets would have moderate to serious consequences, such as injuries or impairment of core functions and processes.</td>
</tr>
<tr>
<td><strong>Medium Low</strong></td>
<td>4</td>
<td>Loss or damage of the building’s assets would have moderate consequences, such as minor injuries or minor impairment of core functions and processes.</td>
</tr>
<tr>
<td><strong>Low</strong></td>
<td>2–3</td>
<td>Loss or damage of the building’s assets would have minor consequences or impact, such as a slight impact on core functions and processes for a short period of time.</td>
</tr>
<tr>
<td><strong>Very Low</strong></td>
<td>1</td>
<td>Loss or damage of the building’s assets would have negligible consequences or impact.</td>
</tr>
</tbody>
</table>
### Vulnerability Rating

<table>
<thead>
<tr>
<th>Rating</th>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very High</td>
<td>10</td>
<td>One or more major weaknesses have been identified that make the asset <strong>extremely susceptible</strong> to an aggressor or hazard. The building lacks redundancies/physical protection and the entire building would be only functional again after a very long period of time after the attack.</td>
</tr>
<tr>
<td>High</td>
<td>8–9</td>
<td>One or more major weaknesses have been identified that make the asset <strong>highly susceptible</strong> to an aggressor or hazard. The building has poor redundancies/physical protection and most parts of the building would be only functional again after a long period of time after the attack.</td>
</tr>
<tr>
<td>Medium High</td>
<td>7</td>
<td>An important weakness has been identified that makes the asset <strong>very susceptible</strong> to an aggressor or hazard. The building has inadequate redundancies/physical protection and most critical functions would be only operational again after a long period of time after the attack.</td>
</tr>
<tr>
<td>Medium</td>
<td>5–6</td>
<td>A weakness has been identified that makes the asset <strong>fairly susceptible</strong> to an aggressor or hazard. The building has insufficient redundancies/physical protection and most part of the building would be only functional again after a considerable period of time after the attack.</td>
</tr>
<tr>
<td>Medium Low</td>
<td>4</td>
<td>A weakness has been identified that makes the asset <strong>somewhat susceptible</strong> to an aggressor or hazard. The building has incorporated a fair level of redundancies/physical protection and most critical functions would be only operational again after a considerable period of time after the attack.</td>
</tr>
<tr>
<td>Low</td>
<td>2–3</td>
<td>A minor weakness has been identified that <strong>slightly increases the susceptibility</strong> of the asset to an aggressor or hazard. The building has incorporated a good level of redundancies/physical protection and the building would be operational within a short period of time after an attack.</td>
</tr>
<tr>
<td>Very Low</td>
<td>1</td>
<td><strong>No weaknesses exist.</strong> The building has incorporated excellent redundancies/physical protection and the building would be operational immediately after an attack.</td>
</tr>
</tbody>
</table>
Building Vulnerability Checklist

Over 700 questions

Explosive Blast – and related hazards
Chemical, Biological, Radiological
Earthquakes
Floods,
High Winds

Site
Architectural
Structural Systems
Building Envelope
Utility Systems
Mechanical Systems (heating, ventilation, and air conditioning [HVAC] and CBR)
Plumbing and Gas Systems
Electrical Systems
Fire Alarm Systems
Communications and Information
Technology (IT) Systems
Equipment Operations and Maintenance
Security Systems
<table>
<thead>
<tr>
<th>Section</th>
<th>Vulnerability Question</th>
<th>Guidance</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>What major structures surround the facility (site or building(s))?</td>
<td>Critical infrastructure to consider includes:</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Telecommunications infrastructure</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Facilities for broadcast TV, cable TV; cellular networks; newspaper offices; production, and distribution; radio stations; satellite base stations; telephone trunking and switching stations, including critical cable routes and major rights-of-way</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Electric power systems</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Power plants, especially nuclear facilities; transmission and distribution system components; fuel distribution, delivery, and storage</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gas and oil facilities</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hazardous material facilities, oil/gas pipelines, and storage facilities</td>
<td></td>
</tr>
</tbody>
</table>

- Key tool of the risk assessment
- 4 checklists
- Over 700 questions related to CBRE, earthquakes, floods, and high winds
- Contemplating to add checklists for critical infrastructure (tunnels, bridges, dams, etc.)
FEMA 452 – Database (Risk Matrices)

Critical Infrastructure Matrix -- Page 1

<table>
<thead>
<tr>
<th>No.</th>
<th>Critical Infrastructure</th>
<th>No.</th>
<th>Critical Infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Site</td>
<td>2</td>
<td>Architectural</td>
</tr>
<tr>
<td>3</td>
<td>Structural Systems</td>
<td>4</td>
<td>Envelope Systems</td>
</tr>
<tr>
<td>5</td>
<td>Utility Systems</td>
<td>6</td>
<td>Mechanical Systems</td>
</tr>
<tr>
<td>7</td>
<td>Plumbing and Gas Systems</td>
<td>8</td>
<td>Electrical Systems</td>
</tr>
<tr>
<td>9</td>
<td>Fire Alarm Systems</td>
<td>10</td>
<td>IT/Communications Sys</td>
</tr>
<tr>
<td>11</td>
<td>Other CI-1</td>
<td>12</td>
<td>Other CI-2</td>
</tr>
<tr>
<td>12</td>
<td>Other CI-2</td>
<td>13</td>
<td>Other CI-3</td>
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<td>Other CI-3</td>
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</tr>
<tr>
<td>14</td>
<td>Other CI-4</td>
<td>15</td>
<td>Other CI-5</td>
</tr>
<tr>
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<td>Other CI-5</td>
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<td>Other CI-6</td>
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<td>Other CI-6</td>
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<td>Other CI-7</td>
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<td>Other CI-8</td>
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<td>Other CI-8</td>
<td>19</td>
<td>Other CI-9</td>
</tr>
<tr>
<td>19</td>
<td>Other CI-9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Assessment Date: 02/02/2007
Assessment Type: CI-BC

High risk (> 175)
Medium risk (61-175)
Low Risk (1-60)
FEMA 452 – Database (Load Preferences)
Example of Risk Assessment Scores

- Earthquake: 3.0%
- Wind: 5.5%
- Lava Flow: 0.4%
- Landslide/Sinkhole: 0.53%
- Severe Storm/Lightning: 8.9%
- Drought/Extreme Heat: 1.0%
- Tsunami: 0.7%
- Fire: 0.8%
- Flood: 3.2%
- Manmade: 75.9%
- Wind: 5.5%
## Example Unit Plan Results

<table>
<thead>
<tr>
<th>Row</th>
<th>Category</th>
<th>Critical Function/Infrastructure</th>
<th>Hazard-Threat</th>
<th>Risk Level</th>
<th>Vulnerability</th>
<th>Level 2 Observation</th>
<th>Level 2 Mitigation</th>
<th>Level 2 Recommendation</th>
<th>ROM Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Function</td>
<td>CIO Communications/Downlinks</td>
<td>Explosive Blast</td>
<td>630 Site</td>
<td>Site: Lacks minimum setbacks between building and parking</td>
<td>Capital Infrastructure</td>
<td>Harden, erect protective elements, redundancy</td>
<td>$500,000 - $750,000 New OFEO project</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Function</td>
<td>Collections Storage</td>
<td>Explosive Blast</td>
<td>630 Site</td>
<td>Site: Lacks minimum setbacks between building and parking</td>
<td>Capital Infrastructure</td>
<td>Harden, erect protective elements, redundancy</td>
<td>$500,000 - $750,000 New OFEO project</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Function</td>
<td>Exhibition Galleries</td>
<td>Explosive Blast</td>
<td>630 Site</td>
<td>Site: Lacks minimum setbacks between building and parking</td>
<td>Capital Infrastructure</td>
<td>Harden, erect protective elements, redundancy</td>
<td>$500,000 - $750,000 New OFEO project</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Function</td>
<td>Exhibition Galleries</td>
<td>Civil Disruption</td>
<td>630 Architectural</td>
<td>Architectural: High visitor activity near critical assets</td>
<td>Plans, Policies and Procedures</td>
<td>Secure area in increasing threat levels</td>
<td>$25,000 - $50,000 Operations Cost</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Infrastructure</td>
<td>Electrical Systems</td>
<td>Explosive Blast</td>
<td>630 Site</td>
<td>Site: Lacks minimum setbacks between building and parking</td>
<td>Capital Infrastructure</td>
<td>Harden, erect protective elements, redundancy</td>
<td>$500,000 - $750,000 New OFEO project</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Infrastructure</td>
<td>Mechanical Systems</td>
<td>Explosive Blast</td>
<td>630 Site</td>
<td>Site: Lacks minimum setbacks between building and parking</td>
<td>Capital Infrastructure</td>
<td>Harden, erect protective elements, redundancy</td>
<td>$500,000 - $750,000 New OFEO project</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Function</td>
<td>Computer Labs / I Specific Data Centers</td>
<td>Explosive Blast</td>
<td>567 Site</td>
<td>Site: Lacks minimum setbacks between building and parking</td>
<td>Capital Infrastructure</td>
<td>Harden, erect protective elements, redundancy</td>
<td>$500,000 - $750,000 New OFEO project</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Function</td>
<td>Security Control Centers</td>
<td>Explosive Blast</td>
<td>567 Site</td>
<td>Site: Lacks minimum setbacks between building and parking</td>
<td>Capital Infrastructure</td>
<td>Harden, erect protective elements, redundancy</td>
<td>$500,000 - $750,000 New OFEO project</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Infrastructure</td>
<td>Architectural</td>
<td>Explosive Blast</td>
<td>567 Site</td>
<td>Site: Lacks minimum setbacks between building and parking</td>
<td>Capital Infrastructure</td>
<td>Harden, erect protective elements, redundancy</td>
<td>$500,000 - $750,000 New OFEO project</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Infrastructure</td>
<td>Communications and Information Technology Systems</td>
<td>Explosive Blast</td>
<td>567 Site</td>
<td>Site: Lacks minimum setbacks between building and parking</td>
<td>Capital Infrastructure</td>
<td>Harden, erect protective elements, redundancy</td>
<td>$500,000 - $750,000 New OFEO project</td>
<td></td>
</tr>
</tbody>
</table>

### Checklist Question Number

<table>
<thead>
<tr>
<th>Checklist Question Number</th>
<th>Level 3 Question</th>
<th>Level 3 Vulnerability Observation</th>
<th>Level 3 Mitigation Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-57</td>
<td>Architectural: Are ceiling systems secured to resist collapse?</td>
<td>Ceilings were not installed at the time of the assessment. The building has been renovated to meet BOCA 1996 and ASCE 5-96.</td>
<td>The vulnerabilities of the structure must have been identified but no significant structural improvements were observed. Since the mechanical and electrical systems observed were minimally braced, it is assumed that other non-structural elements such as ceilings, lights, and architectural elements will be mitigated for the seismic risk identified by BOCA 1996. No additional mitigation is recommendation at this time.</td>
</tr>
<tr>
<td>2-68</td>
<td>Architectural: Are light fixtures independently secured and braced?</td>
<td>Light fixtures are minimally braced against lateral movement per requirements of BOCA 1996.</td>
<td>The vulnerabilities of the structure must have been identified but no significant structural improvements were observed. Since the mechanical and electrical systems observed were minimally braced, it is assumed that other non-structural elements such as ceilings, lights, and architectural elements will be mitigated for the seismic risk identified by BOCA 1996. No additional mitigation is recommendation at this time.</td>
</tr>
<tr>
<td>2-59</td>
<td>Architectural: How are walls around stair enclosures connected to the primary structural system?</td>
<td>Yes, primary stair access is in the central core of the building.</td>
<td>No mitigation required.</td>
</tr>
<tr>
<td>2-70</td>
<td>Architectural: Are there cabinets, shelf systems or other items with a height to width ratio of 3:1?</td>
<td>Cabinets and shelves were removed from the building during the renovation.</td>
<td>When the cabinets, shelving, and displays are re-installed after the renovation, ensure they are secured to resist lateral motion and displacement.</td>
</tr>
</tbody>
</table>
Selecting Mitigation Measures

Three Options:

- Do nothing and accept the risk
- Perform a risk assessment and manage the risk by installing reasonable mitigation measures
- Protect the building against all
### Building System Protection Methods: Reinforcements and Conflicts

<table>
<thead>
<tr>
<th>System ID</th>
<th>Existing Conditions or Proposed Protection Methods</th>
<th>The Hazards</th>
<th>Earthquake</th>
<th>Flood</th>
<th>Wind</th>
<th>Security/Blast (FEMA 428)</th>
<th>Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Site</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Architectural</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2A</td>
<td>Configuration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2A-1</td>
<td>Large roof overhangs</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2A-2</td>
<td>Re-entrant corner (L-, U-shape, etc.) building forms</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2A-3</td>
<td>Enclosed courtyard building forms</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2A-4</td>
<td>Very complex building forms</td>
<td>X</td>
<td>X</td>
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<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>3</td>
<td>Structural Systems</td>
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</tr>
<tr>
<td>4</td>
<td>Building Envelope</td>
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<tr>
<td>5</td>
<td>Utilities</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Mechanical</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Key
- **✓**: Indicates desirable condition or method for designated component/system
- **X**: Indicates undesirable condition or method for designated component/system
- **☐**: Indicates little or no significance for designated component/system
- **☐** Split box indicates significance may vary, see discussion issues
• FEMA has a cadre of publications directed at multihazard design
• FEMA 452 is a comprehensive tool for risk assessment addressing all hazards
• Multihazard design is cost effective since all hazards can be addressed early during the design process
• Multihazard design produces efficiencies when mitigating potential damage against buildings
• http://www.fema.gov/plan/prevent/rms/index.shtml