G-2: U.S. Seismic Hazard – A New View. Update to the AIR Earthquake Model for the U.S.

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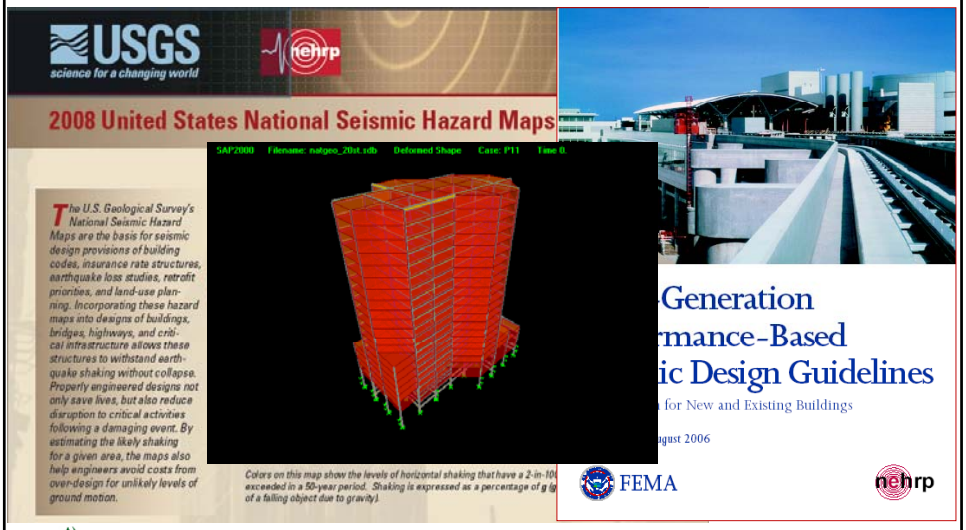
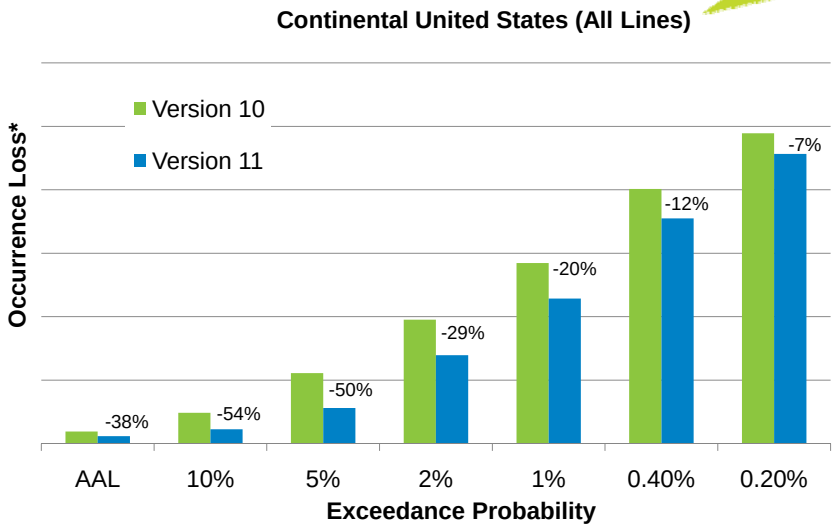
Summary

- AIR Worldwide scientists were key participants in the USGS process and the AIR model is fully consistent with the 2008 USGS Hazard Maps
- Next Generation Attenuation (NGA) equations are based on updated ground motion data and are more reliable and scientifically defensible than previous GMPEs
- The AIR model incorporates high resolution soil data, explicit modeling of basin effects and spatial ground motion correlation
- Vulnerability functions have been updated based on engineering analyses, literature reviews, damage data, detailed claims and loss data, building practices and evolution of codes in time

New Research Was Substantial and Produced Large Model Changes



Modeled Losses Have Decreased at All Exceedance Probabilities for the U.S.



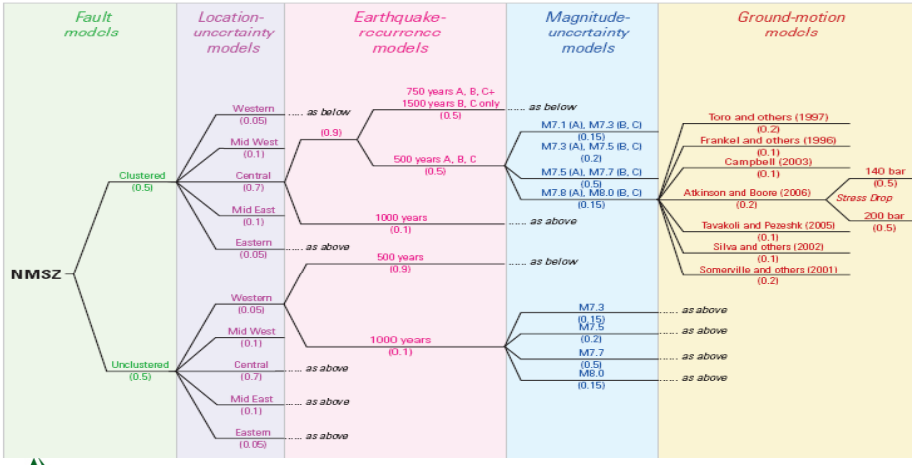
*Results are insurable losses net of limits and deductibles using AIR's time dependent catalog, shake only, exposures have been held constant

The AIR Model is Fully Consistent with the 2008 USGS Hazard Maps

- 552 faults and faults segments in the western U.S.
- 138 cascading scenarios for the 6 well studied Type-A faults in California
- The complex geometry of the Cascadia subduction zone with variable width
- The various branches of the New Madrid seismic zone with special consideration for the longer recurrence and smaller magnitudes for the northern segment
- The correlated triplets on the New Madrid seismic zone
- The detail magnitude rate distribution of the many branches of the logic tree formulated by the USGS model
- Improved background gridded seismicity that is derived from a 1,000,000-year catalog using an optimization procedure that preserves the seismicity and loss distribution
- Time-dependent seismicity for the characteristic earthquakes on most faults in California and large Cascadia subduction interface earthquakes

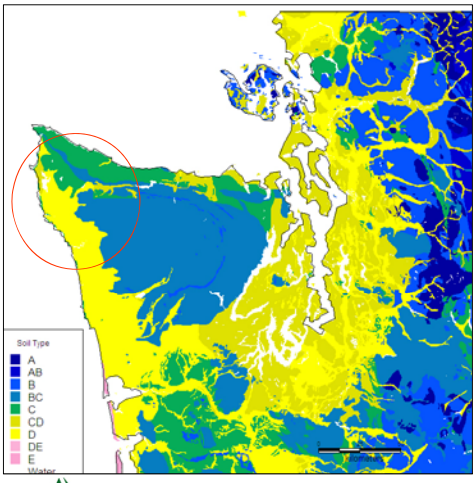
AIR Seismologists have Reviewed and Validated Every Component of the 2008 USGS Hazard Maps

- **For example, the 2008 USGS update employs a more rigorous approach to capture uncertainty**

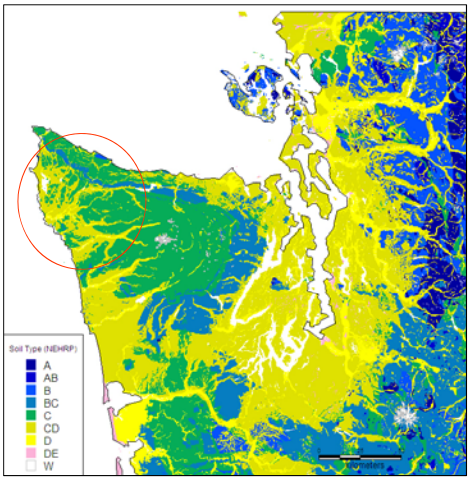


AIR Employs State or Local Maps with More Detailed Geologic Information and Higher Spatial Resolution

Nationwide Base Soil Map (500 meter Res)

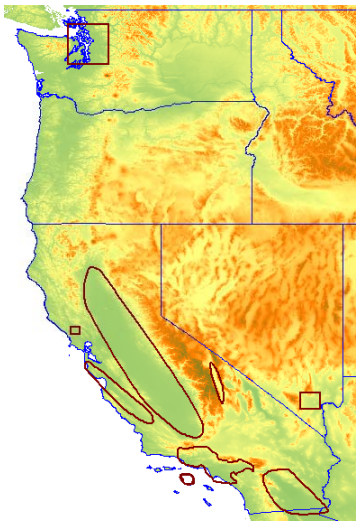


Higher Resolution State Soil Map (200 meter Res)



AIR

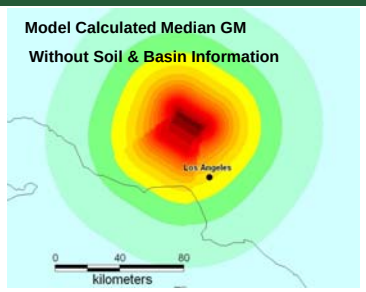
AIR Explicitly Models Ground Motion Effects for Major Basins in California, Washington, and Nevada

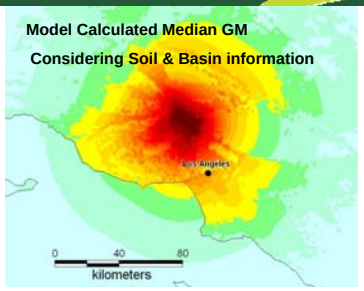


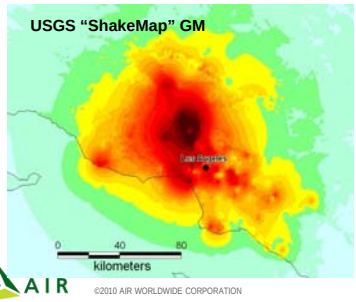
- The USGS model uses a uniform basin depth that cancels out any significant amplifying or de-amplifying effects
- NGA equations can account for basin effects if the basin depth is provided as an input to the attenuation equation
- AIR uses high (0.2 km) resolution depth information for major basins in California, Washington and Nevada to take full advantage of the capabilities of the NGA equations
- Basin effects predominantly impact tall, flexible structures

AIR

Observed Ground Motion (Sa0.3s) for the 1994 Northridge Earthquake Reveals Spatial Correlation



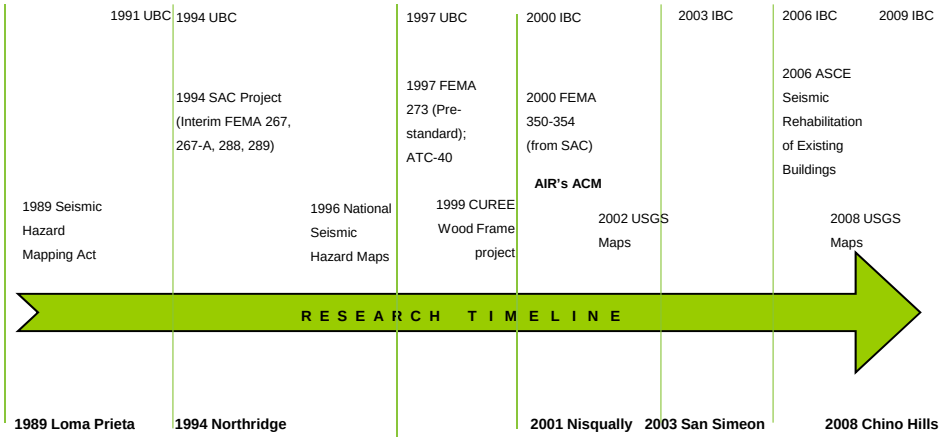




- Even after accounting for soil and basin effects, there are areas with higher and areas with lower ground motion than expected

AIR

Evolution of Major Research Projects Addressing Building Response to Earthquake Induced Ground Motion



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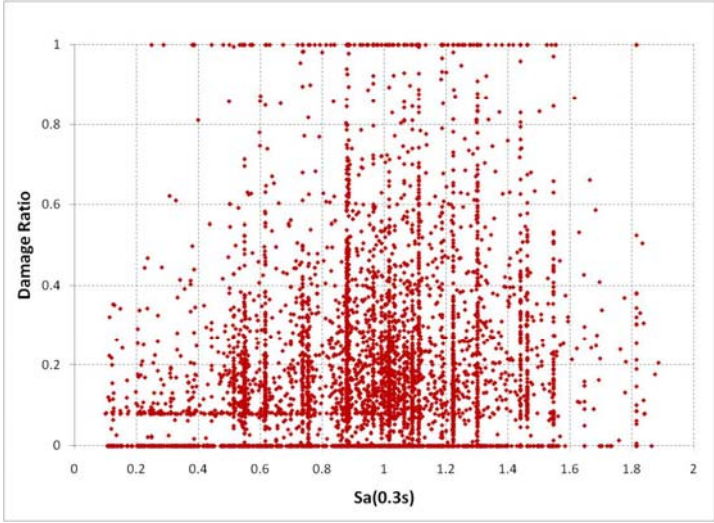
Claims Data for Wood Frame Structures Built Between 1976 and 1995



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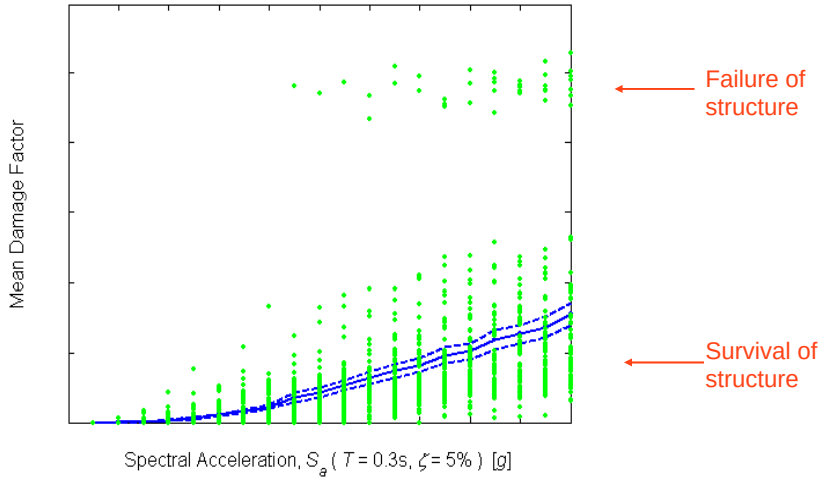
Response of Wood Frame Structures to Varying Ground Motion Based on Engineering Analysis



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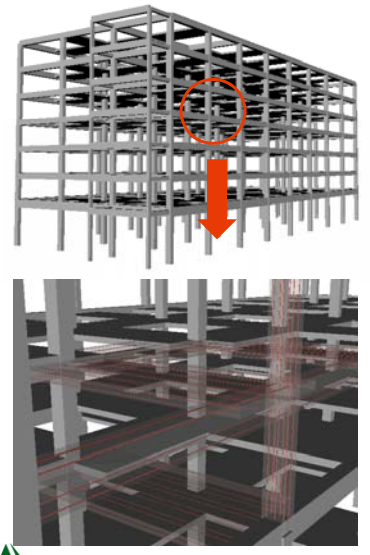
AIR Developed Damage Functions for Reinforced Concrete Structures as Part of a Study Funded by USGS



- AIR developed a computer model of a Reinforced Concrete Frame building that suffered damage in Northridge
- The building was instrumented when Northridge occurred and the displacement of the ground and each story was recorded
- The computer model was subject to the recorded motion of the group and the computed displacement at each story was compared with the recorded displacement

AIR

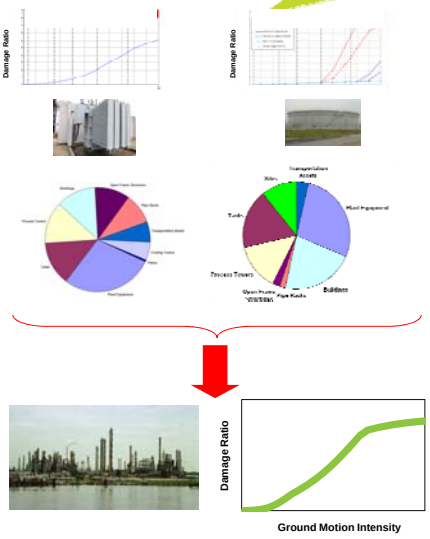
Steel Structures Have Been Extensively Investigated Since Northridge

- The SAC Joint Venture was formed to investigate the damage to welded steel moment-resisting frame (SMRF) buildings in the 1994 Northridge earthquake and the project was concluded in 2000.
- 3-story, 9-story, and 20-story SMRF structures designed for Los Angeles, Seattle and Boston were analyzed to review their performance across the country.
- A number of full-size connection tests were carried out to examine their behavior under severe cyclic loads.

AIR

The AIR Model Includes a Component-Based Industrial Facilities Model

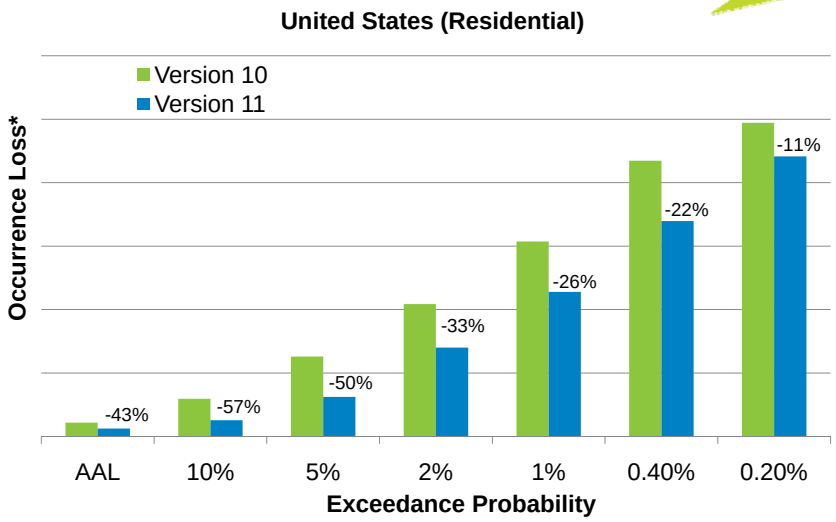
- Build vulnerability of components based on **component characteristics**
- Develop distribution of components for **different plant types**
- Build vulnerability of plants from previous two items



AIR Damage Functions Have Been Peer Reviewed

- Covers methodology and entire set of earthquake damage functions
- Reviewers
  - Professor **Greg Deierlein**: Stanford University, Director of the John A. Blume Earthquake Engineering Center, Deputy Director for Research of the Pacific Earthquake Engineering Research (PEER) center
  - Dr. **Charlie Kircher**: Structural Engineer and Principal at Charles Kircher & Associates, Key Developer of HAZUS
- Process
  - Initial meeting and presentation
  - Providing **all** information requested by reviewers including the damage functions; background data; additional analyses; Q&A

For Residential Lines, Modeled Loss Reductions are Less Significant at Lower Exceedance Probabilities



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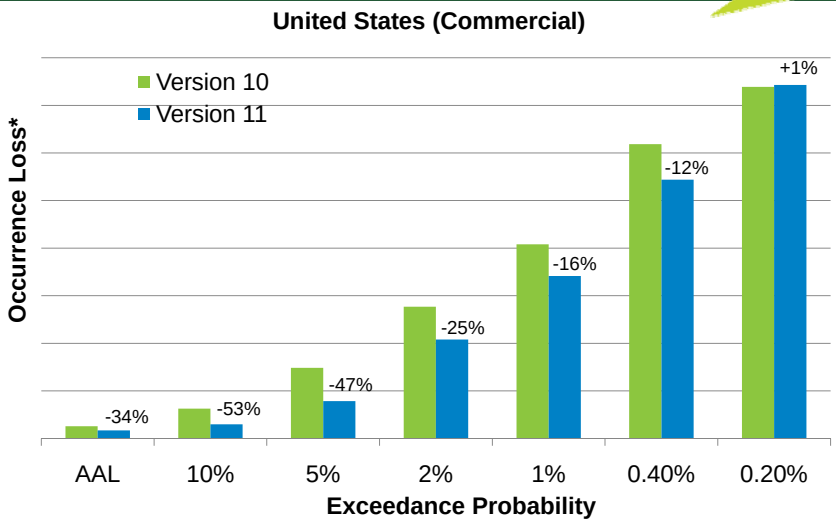
For Residential Lines, Reductions in Loss Are Driven Primarily by Vulnerability Changes

- Impacts of catalog changes driven by updated USGS hazard data are relatively neutral
- Incorporation of Next Generation Attenuation equations and updated soil maps generally lead to reduced losses
- Vulnerability changes generally lead to reduced losses throughout the EP curve

	Hazard		Vulnerability	
Exceedance Probability	Catalog Change	Ground Motion & Soil Change	Damage Function Changes	Combined Changes
AAL	-10% to -15%	-10% to -15%	-15% to -25%	-40% to -45%
1% (100 Year)	+10% to 0%	-10% to -15%	-15% to -35%	-25% to -45%
0.4% (250 Year)	0% to -5%	0% to -10%	-10% to -25%	-15% to -40%
0.2% (500 Year)	0% to -15%	+20% to -5%	-10% to -30%	+5% to -45%

For Commercial Lines, Modeled Loss Reductions are Less Significant at Lower Exceedance Probabilities



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For Commercial Lines, Reductions in Loss Are Driven Primarily by Ground Motion and Soil Data Changes

- Impacts of catalog changes driven by updated USGS hazard data are relatively neutral
- Incorporation of Next Generation Attenuation equations and updated soil maps generally lead to reduced losses throughout the EP curve
- Impacts of vulnerability changes resulting from engineering analyses and validation data are relatively neutral

	Hazard		Vulnerability	
Exceedance Probability	Catalog Change	Ground Motion & Soil Change	Damage Function Changes	Combined Changes
AAL	-5% to -10%	-25% to -30%	+10% to +5%	-25% to -35%
1% (100 Year)	+5% to 0%	-30% to -40%	+20% to +10%	-10% to -25%
0.4% (250 Year)	+5% to -5%	-20% to -35%	+20% to +10%	-5% to -25%
0.2% (500 Year)	+5% to -10%	-15% to -25%	+20% to +10%	+5% to -20%