Earthquake Modeling in the Insurance Value Chain: Using Catastrophe Models to Better Understand Risk

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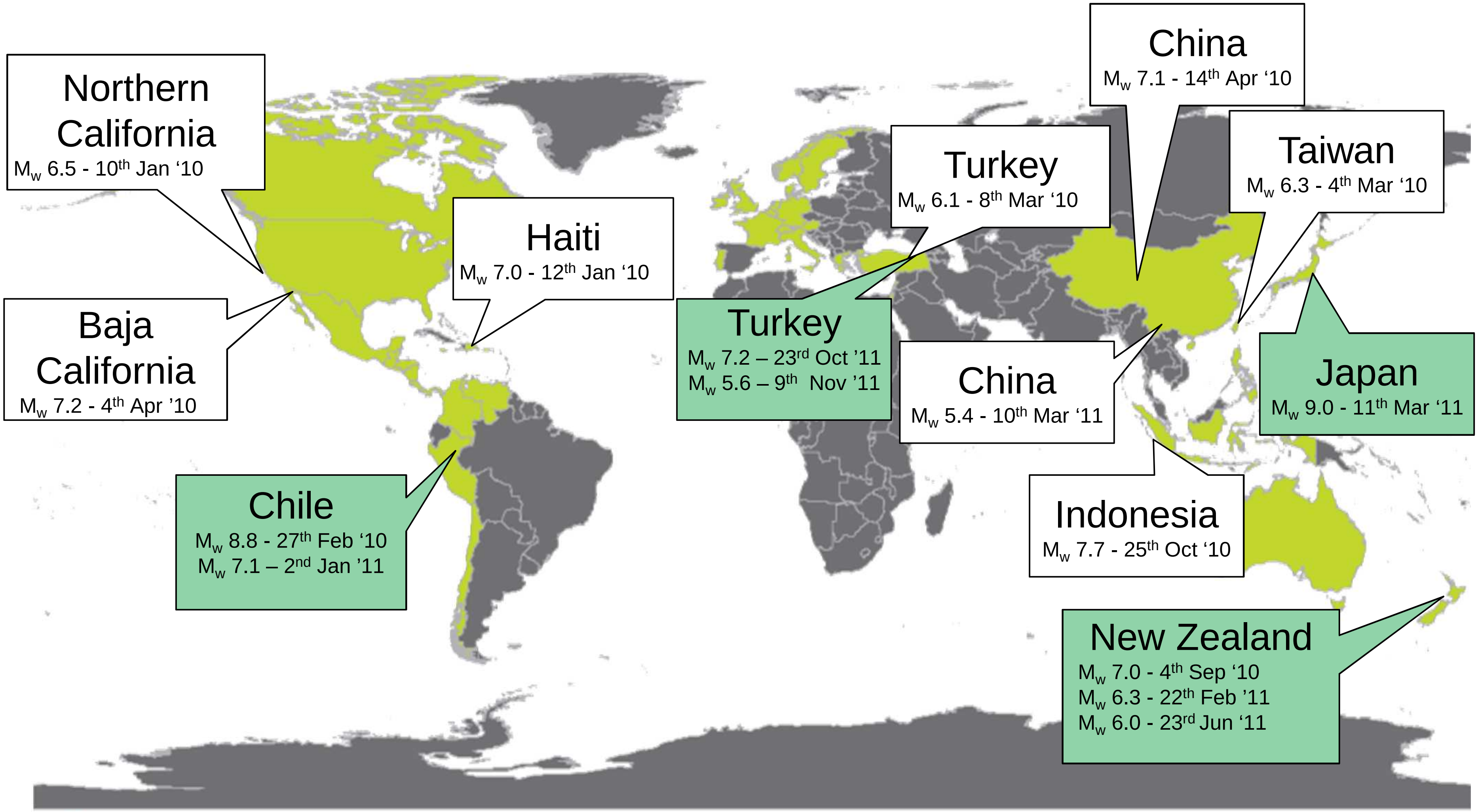
AIR Worldwide

Agenda

- Assessing risk using historical losses versus catastrophe modeling
- AIR's approach to modeling catastrophe risks
- Understanding earthquake fundamentals
  - Plate tectonics and causes of seismicity
  - Key elements that define earthquakes
  - Causes of earthquake damages
- Building response to earthquakes
  - Building behaviors to earthquake shake
  - Damage mitigation measures
- Modeled and non-modeled losses
- Using catastrophe modeling in the insurance industry

Summary of High Impact Earthquake Events in 2010 and 2011



Northern California
M_w 6.5 - 10th Jan '10

Baja California
M_w 7.2 - 4th Apr '10

Haiti
M_w 7.0 - 12th Jan '10

Chile
M_w 8.8 - 27th Feb '10
M_w 7.1 – 2nd Jan '11

Turkey
M_w 6.1 - 8th Mar '10

Turkey
M_w 7.2 – 23rd Oct '11
M_w 5.6 – 9th Nov '11

China
M_w 7.1 - 14th Apr '10

China
M_w 5.4 - 10th Mar '11

Taiwan
M_w 6.3 - 4th Mar '10

Japan
M_w 9.0 - 11th Mar '11

Indonesia
M_w 7.7 - 25th Oct '10

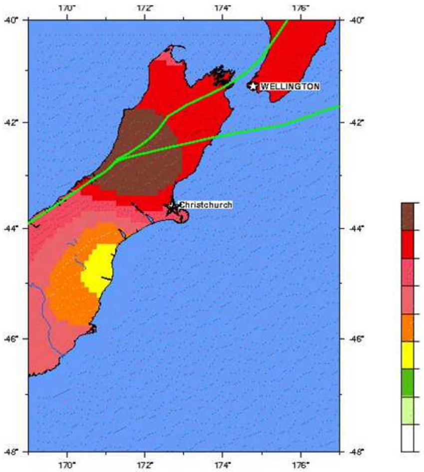
New Zealand
M_w 7.0 - 4th Sep '10
M_w 6.3 - 22nd Feb '11
M_w 6.0 - 23rd Jun '11

Historical Data is Insufficient for Catastrophic Risk Analysis

- Low credibility – there is not enough of it relative to the exposed risk
- Normalization problems – failure to portray today's conditions
  - Exposure growth as population migrates toward risky coastal areas
  - Replacement cost increases for structures
  - Expansion of policy coverage and endorsements (loss of use, etc.)
  - Effect of stronger building codes
- By contrast, cat model simulations offer
  - Volumes of data at low marginal cost (up to 100,000 years each run)
  - Reflection of today's reality (exposure profiles, policy conditions)
  - Scenario testing on property and geographic attributes

What Questions Are Catastrophe Models Designed to Answer?

- Where are future events likely to occur?
- How intense are they likely to be?
- For each potential event, what is the estimated range of damage and insured loss?
- Catastrophe models are designed to estimate the probability of loss, not to forecast future events



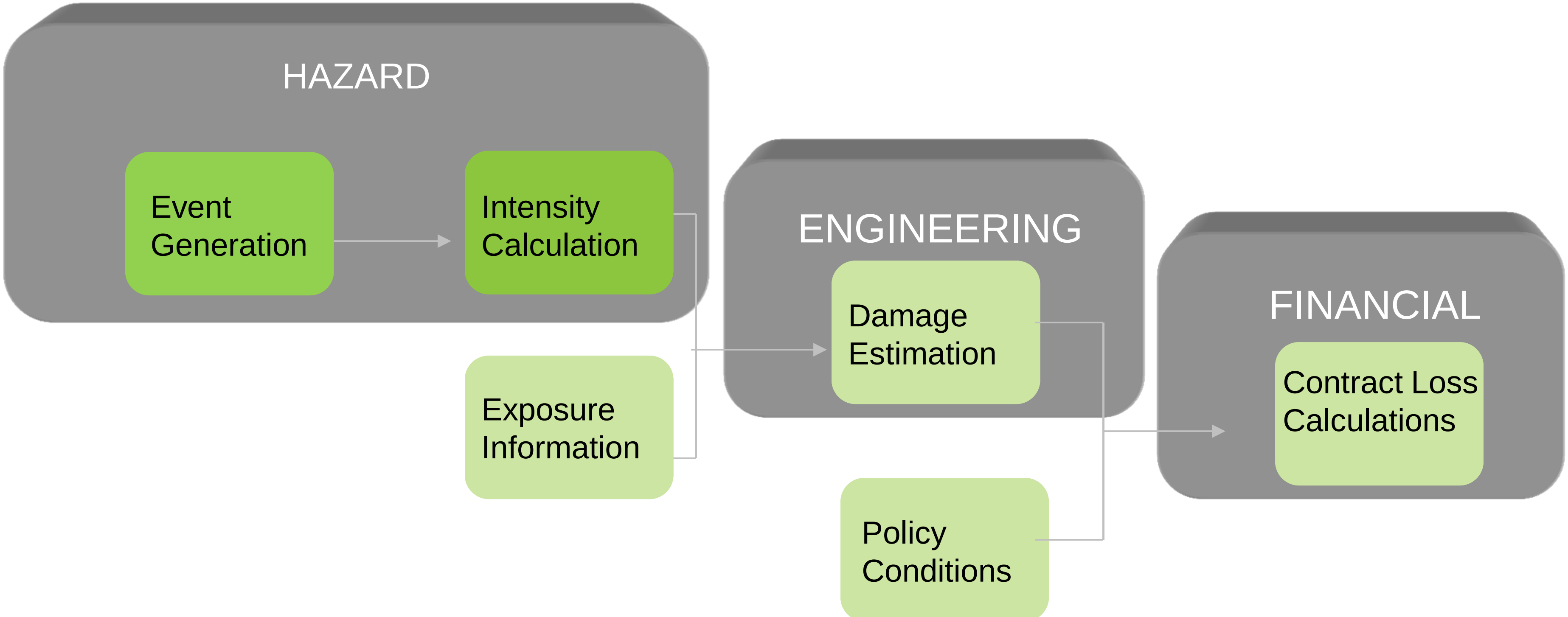
SOUTH ISLAND OF NEW ZEALAND

2011 02 21 23:51:43 UTC 43.60S 172.71E Depth: 5.0 km

Peak Ground Acceleration (m/s^2) with 10% Probability of Exceedance in 50 Years

Earthquake Hazard

Catastrophe Modeling Framework: Event Generation



HAZARD

Event Generation

Intensity Calculation

Exposure Information

ENGINEERING

Damage Estimation

Policy Conditions

FINANCIAL

Contract Loss Calculations

Where are future events likely to occur?

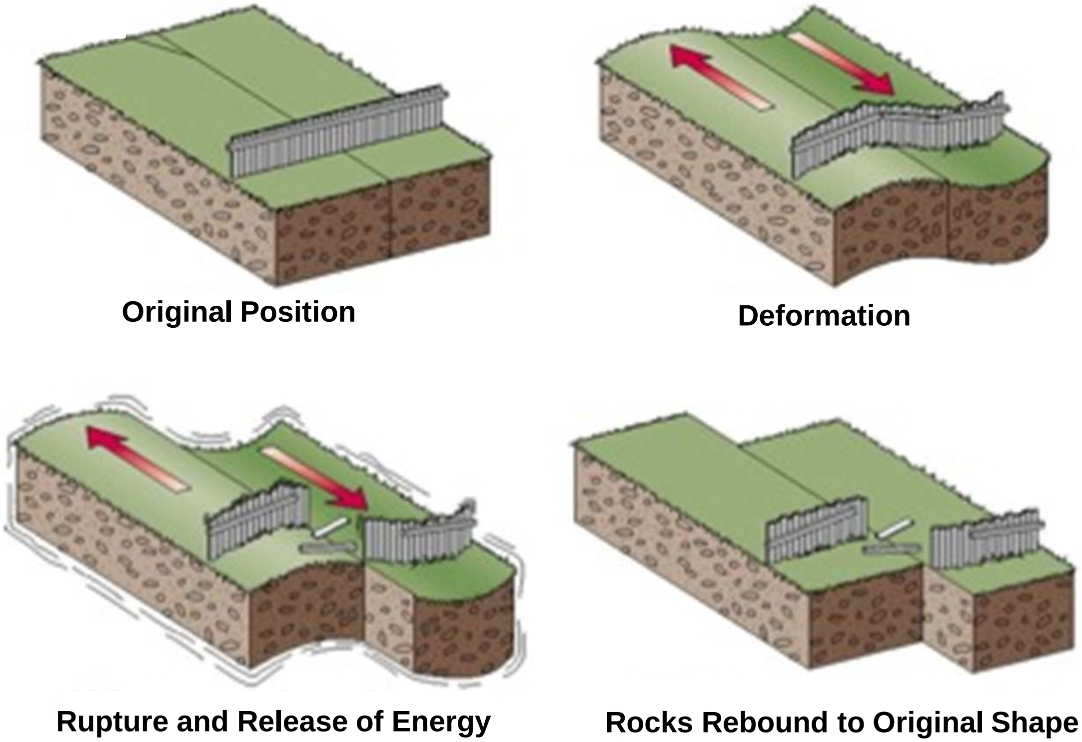
How intense are they likely to be?

How frequently are they likely to occur?

What Causes an Earthquake?

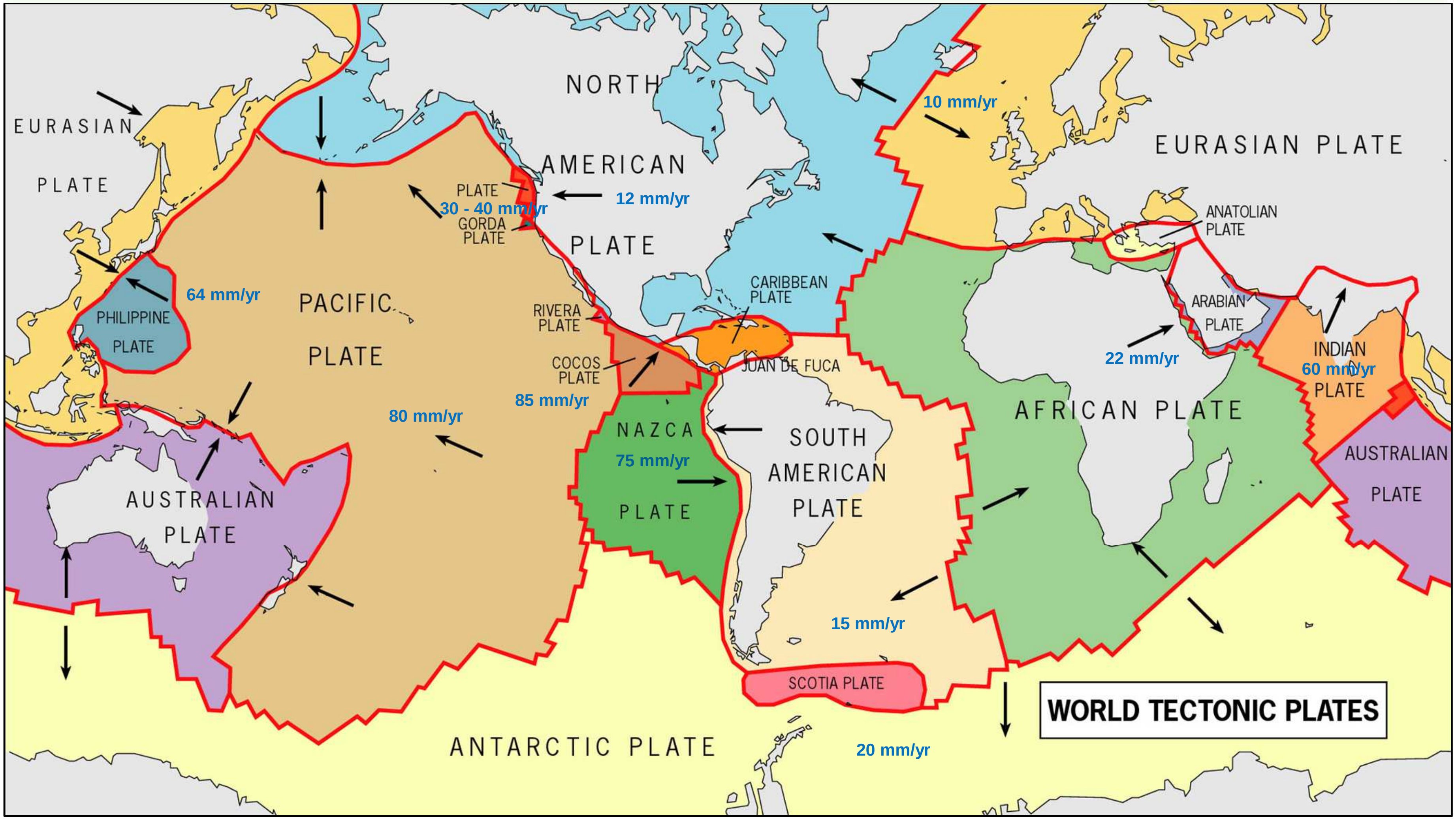
An earthquake is a sudden, rapid shaking of the Earth caused by the breaking and shifting of rock beneath the Earth's surface

Research conducted by Professor H.F. Reid in the aftermath of the 1906 San Francisco earthquake led him to postulate the **Elastic Rebound Theory (1910)**, which holds that the surface of the earth gradually distorts from the accumulating strain of relative ground motion until the strain is suddenly and violently released in the form of an earthquake.



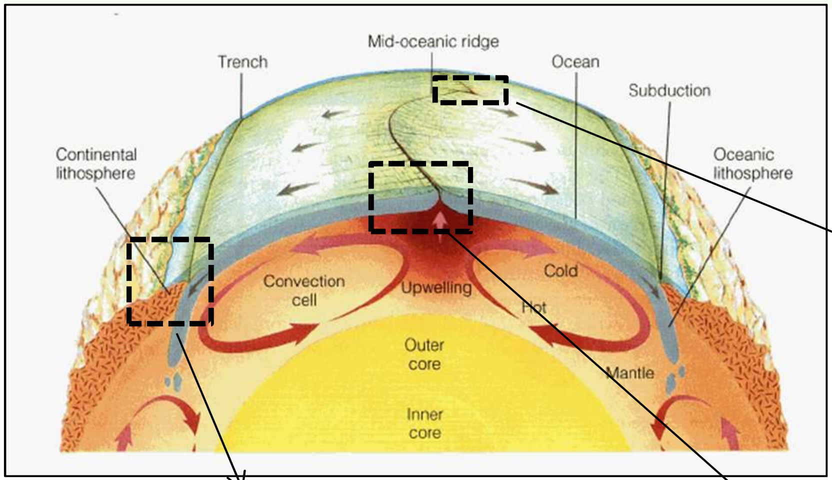
© 2001 Brooks/Cole - Thompson

Earthquakes Typically Occur Along Plate Boundaries Where Tectonic Plates Slide Past One Another

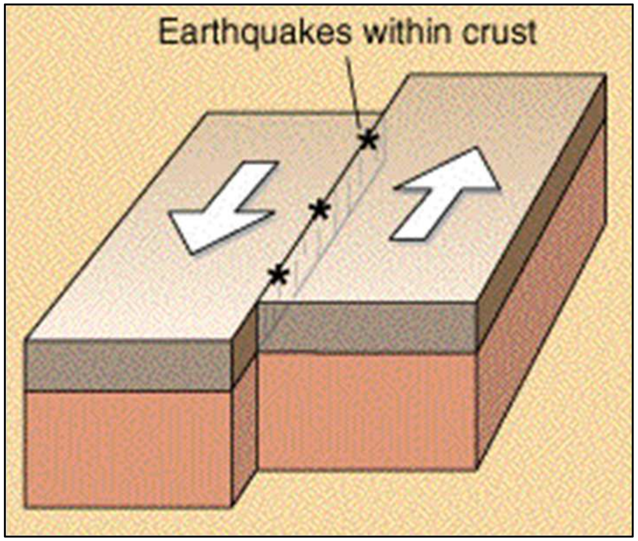


Source: *Environmental Physical Geology*

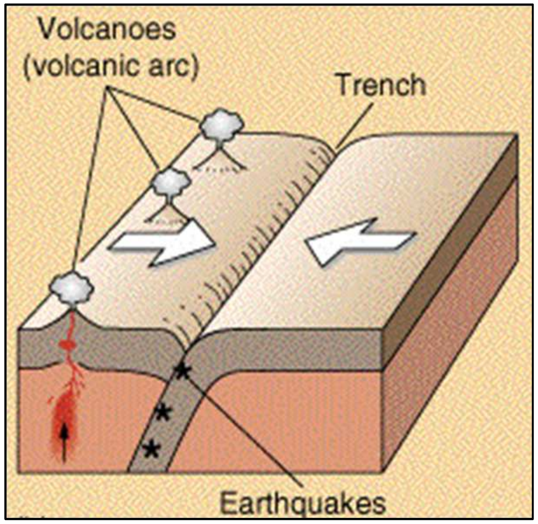
Plate Boundaries Are Classified By Relative Direction of Motion



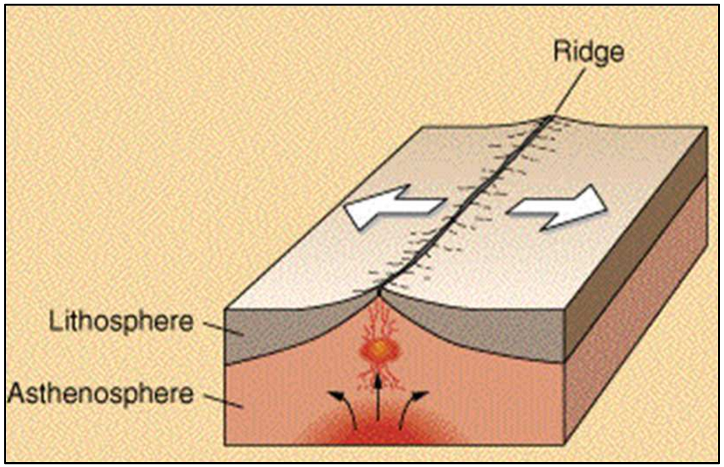
Transform Plate Boundary



Convergent Plate Boundary

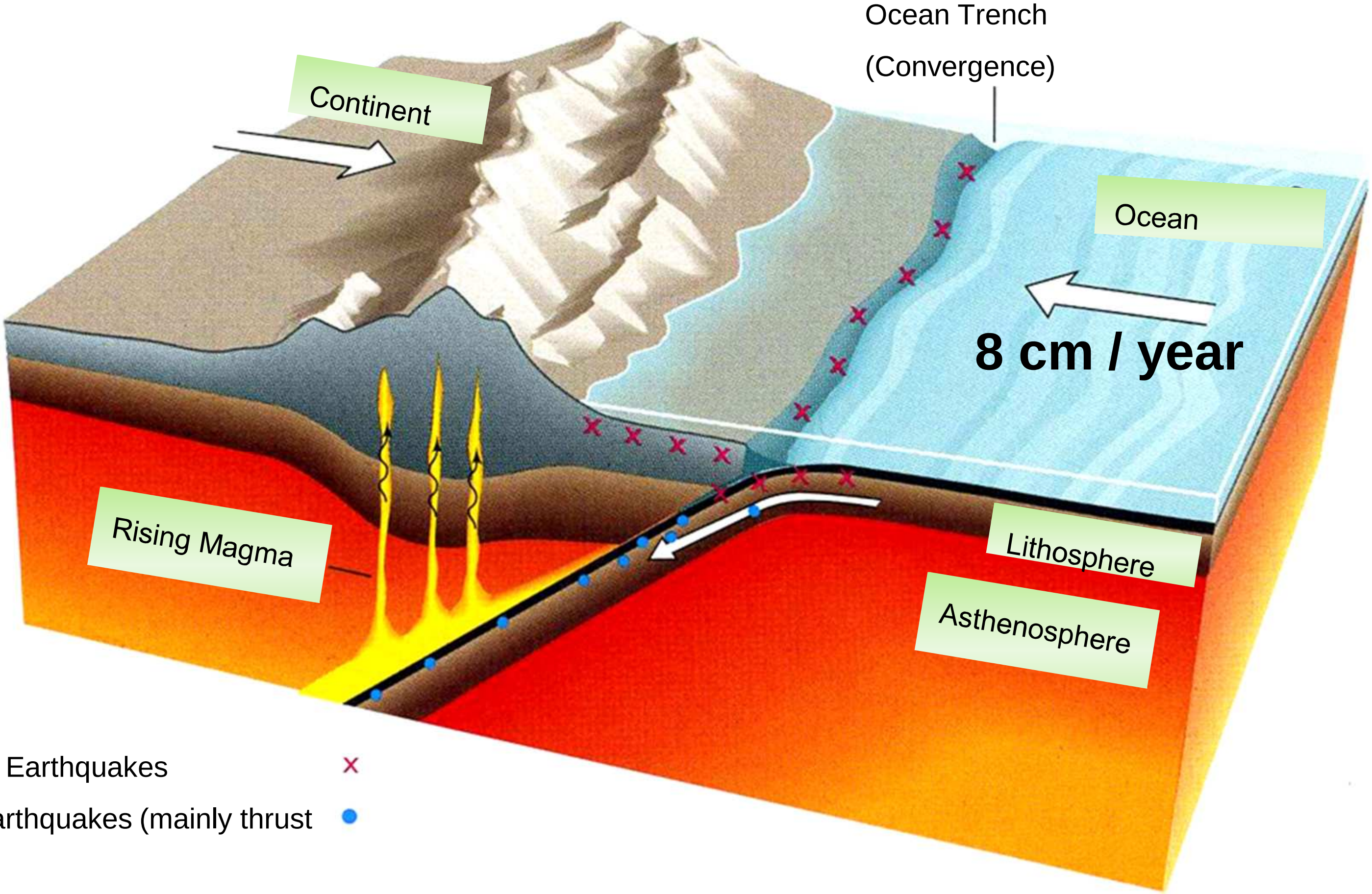


Divergent Plate Boundary



Source: *USGS Dynamic Earth*

Japan Is a Mega-Thrust Convergence Zone



Ocean Trench

(Convergence)

Continent

Ocean

8 cm / year

Rising Magma

Lithosphere

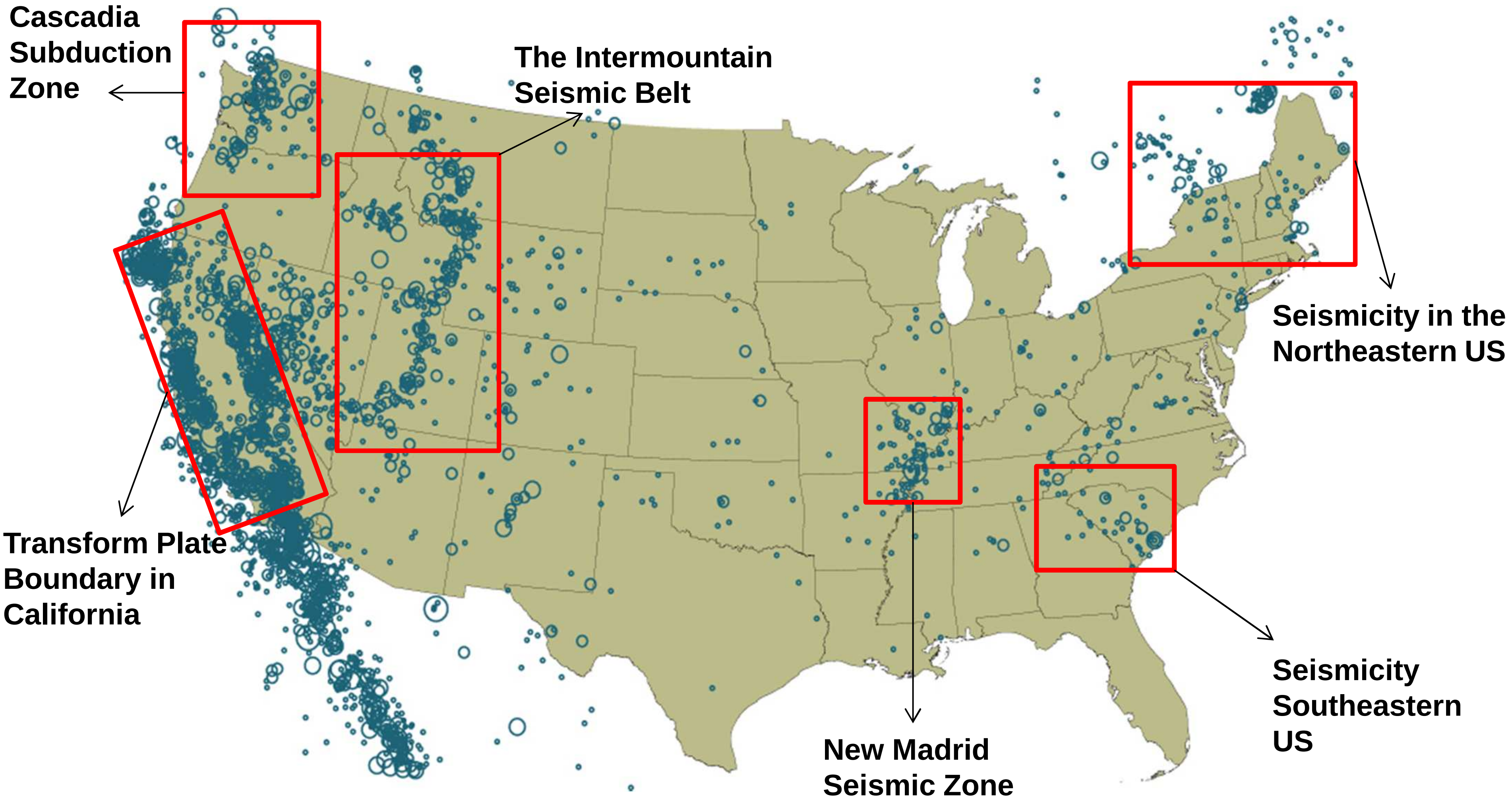
Asthenosphere

Shallow Earthquakes ×

Deep earthquakes (mainly thrust ●

faulting)

Seismic Hazard in the United States Is the Result of Several Tectonic Environments



Cascadia Subduction Zone

The Intermountain Seismic Belt

Seismicity in the Northeastern US

Transform Plate Boundary in California

New Madrid Seismic Zone

Seismicity Southeastern US

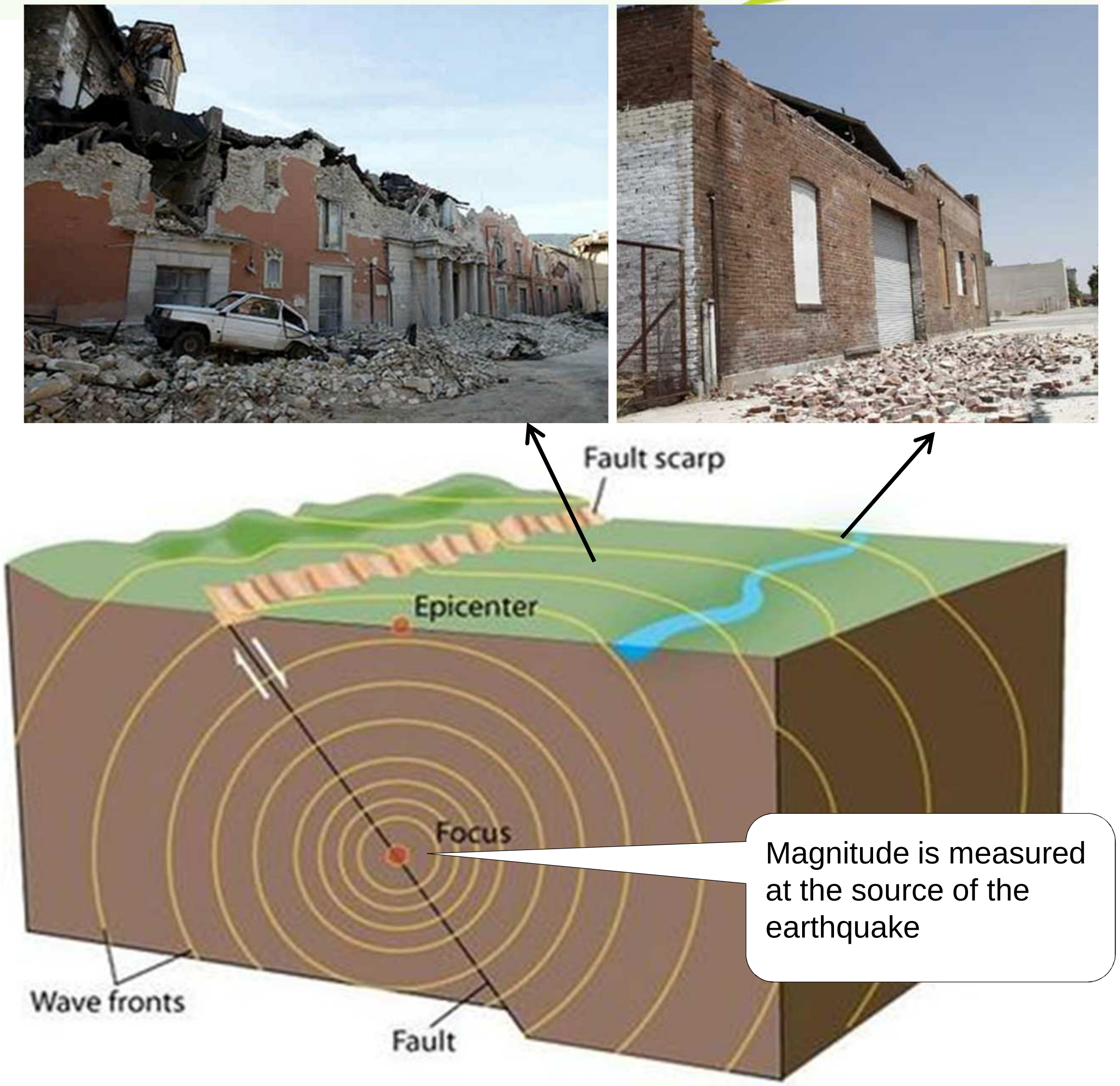
To Create a Simulated Earthquake Event, AIR Uses Several Physical Parameters

- Epicenter location
- Magnitude
- Focal depth
- Rupture length
- Rupture azimuth and dip angle
- Fault rupture mechanism

Measurement of an Earthquake: Intensity and Magnitude

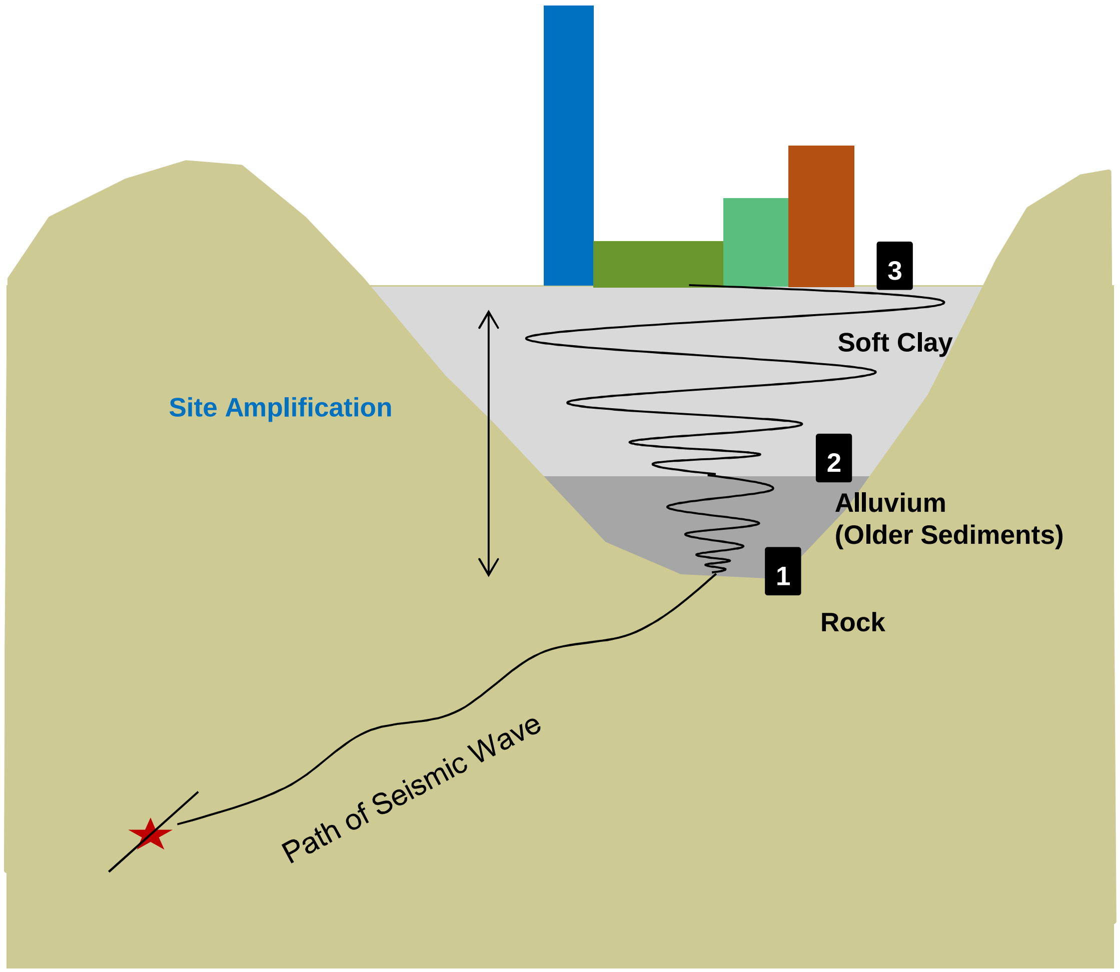
Magnitude: Magnitude refers to quantification of strain energy released during an individual earthquake event

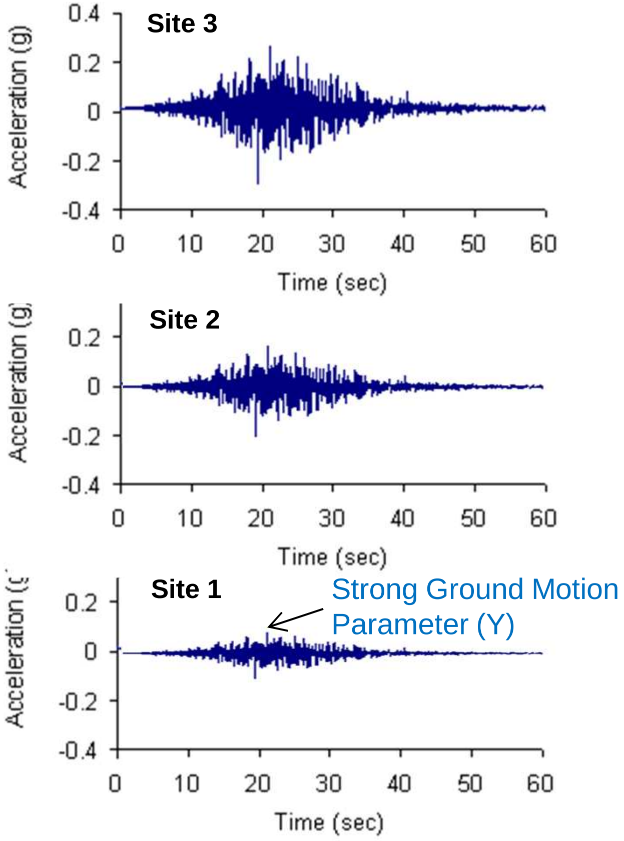
A magnitude 7.0 earthquake produces 32 times more energy than a magnitude 6.0 earthquake. The energy release best indicates the destructive power of an earthquake.



Magnitude is measured at the source of the earthquake

Seismic Site Amplification Shows Differences Between Soil and Rock Types





Strong Ground Motion Parameter (Y)

Earthquake Damage Is Caused By Different Perils


Collapsed Three Story School in Fukushima

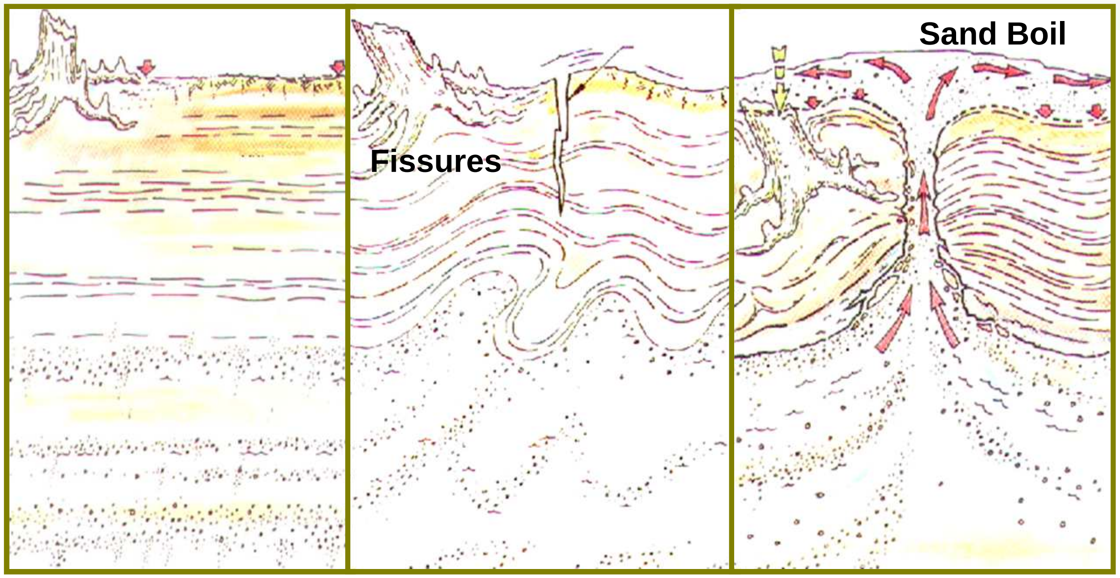
Shake


Liquefaction


Tsunami


Fire Following

Under Strong Ground Shaking Saturated Sandy Soils Experience Liquefaction and May Create Sand Boils



Before Earthquake

Strong shaking of the saturated sandy materials re-structures the sand particles and causes an increase in the pore water pressure

As the pore pressure becomes larger than the weight of the overburden materials, the soil liquefies and in some cases creates sand boils

Severity of Liquefaction Damage in Urban Cities

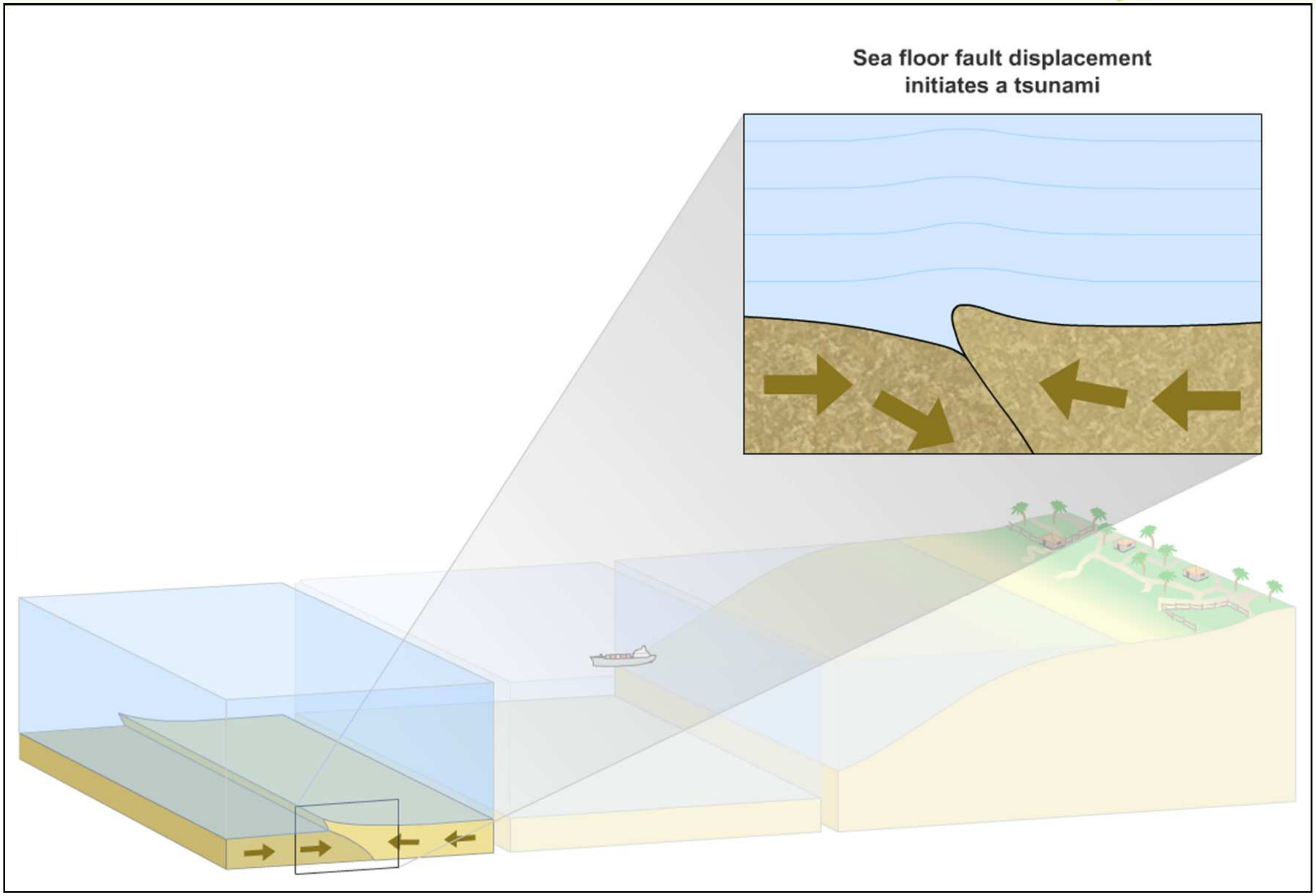
Niigata Japan, 1964
Following M7.4 Earthquake

Source: *National Geophysical Data Center*

Christchurch New Zealand, 2011

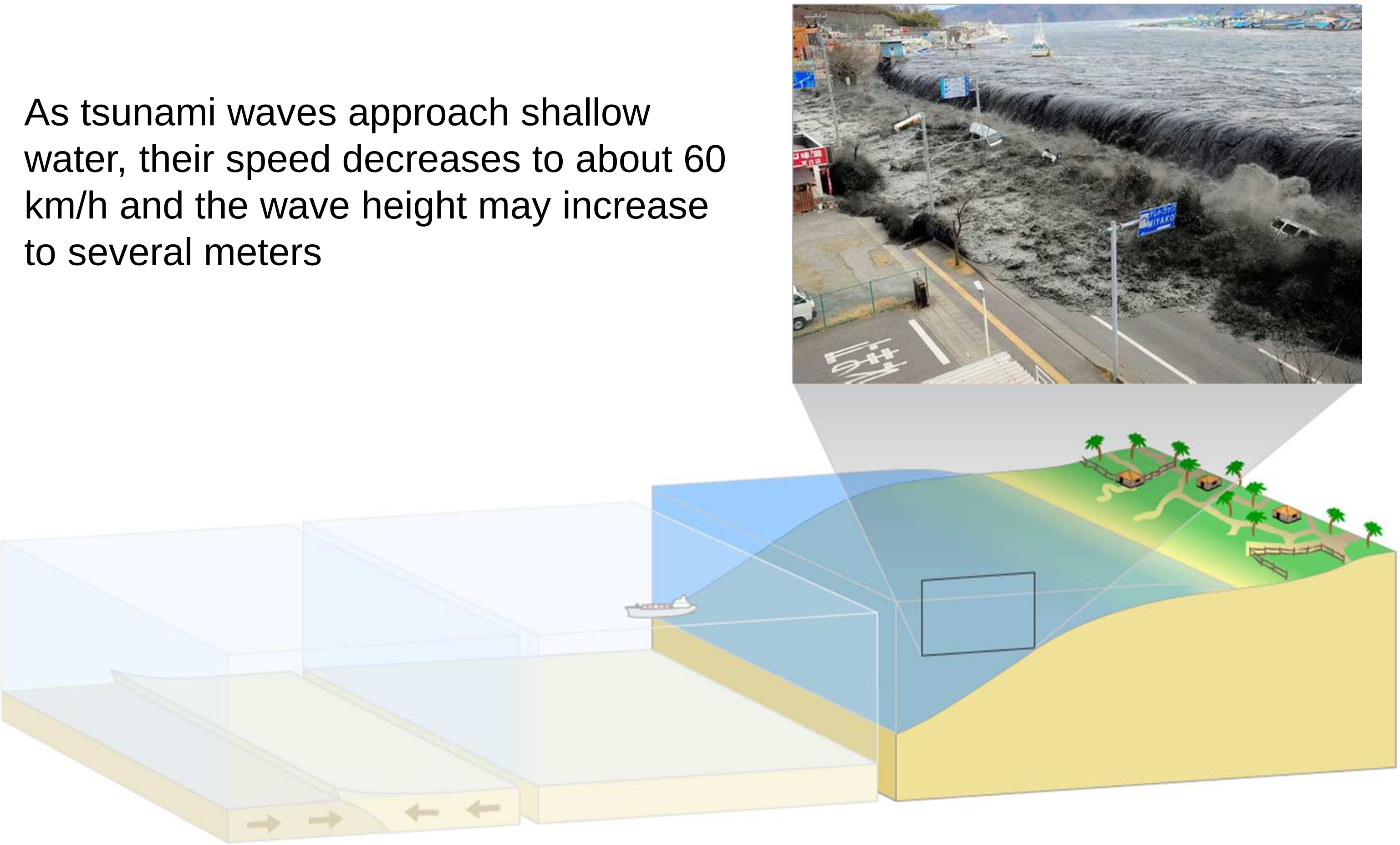
Source: *AIR Worldwide*

Seafloor Disturbances Resulting From Seismic Activity May Displace Water Causing a Tsunami



As Tsunamis Reach the Coast, Wave Height Increases Causing Severe Damage

As tsunami waves approach shallow water, their speed decreases to about 60 km/h and the wave height may increase to several meters



In shallow water, a tsunami's wave height increases.

Evidence of Tsunami Damage in the United States

The 1964 Alaska earthquake caused extensive damage in south-central Alaska and caused a massive tsunami that severely damaged several coastal towns

Tsunami damage along waterfront on Kodiak Island from 1964 M9.2 Alaska earthquake

Tsunami damage along Seward's waterfront from 1964 M9.2 Alaska earthquake

Earthquakes Can Ignite Fires Due to Electrical Systems Failures, Sparking, and Ignition of Leaking Natural Gas

- Multiple simultaneous ignitions may overwhelm fire department resources
- Ground shaking may damage the water supply lines limiting the ability of the fire departments to extinguish the fire


© Reuters

Fire Following an Earthquake May Occur if the Pipes or Wiring are Disturbed and Ignitions Evolve into Fires

San Francisco, 1906

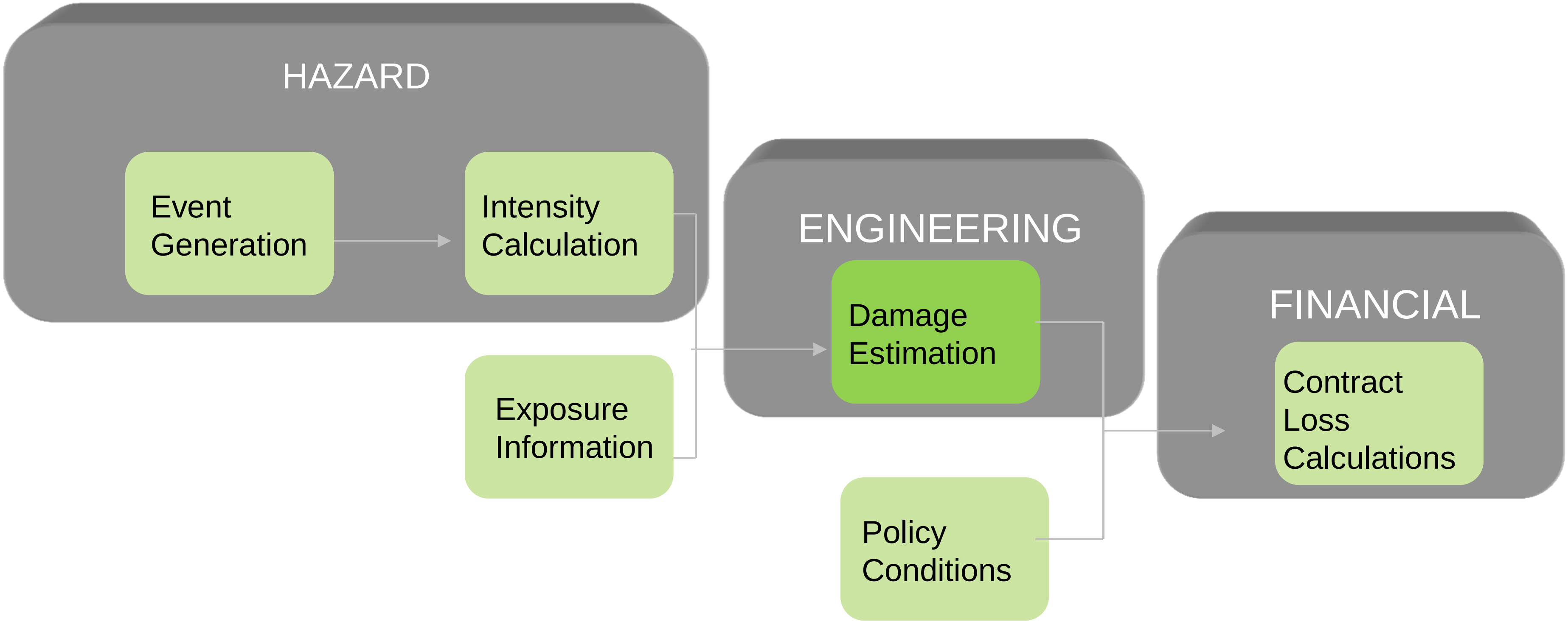
Northridge, 1994

AIR's U.S. Earthquake Data Sources Are Well Regarded and Reflect the Most Current Information Available

- AIR U.S. Earthquake Model data sources include
  - United States Geological Survey (USGS)
  - Working Group on California Earthquake Probabilities (WGCEP)
  - The National Geophysical Data Center (NGDC)
  - The Southern California Earthquake (SCEC)
  - Multidisciplinary Center for Earthquake Engineering Research (MCEER)
  - The California Department of Mines and Geology (CDMG)
  - The Seismological Society of America (SSA)
  - National Weather Service (NWS)
- AIR model has undergone a rigorous internal and external peer review process

Vulnerability

Catastrophe Modeling Framework: Damage Estimation



- What level of damage is experienced at each location?

Key Contributors to Earthquake Vulnerability

- Height
- Construction type
- Age
- Load resisting mechanisms
- Special cases

Building Behavior in an Earthquake Is Characterized By a Building's Mass and Stiffness

The response of a building to shaking is fundamentally determined by

- QUANTITY AND DISTRIBUTION OF MASS

  Tall Structures
  Often show a reduction of mass as height increases to stabilize the structure

- RESISTANT CAPABILITIES OR STIFFNESS

  Flexible: the structure deforms considerably under stress

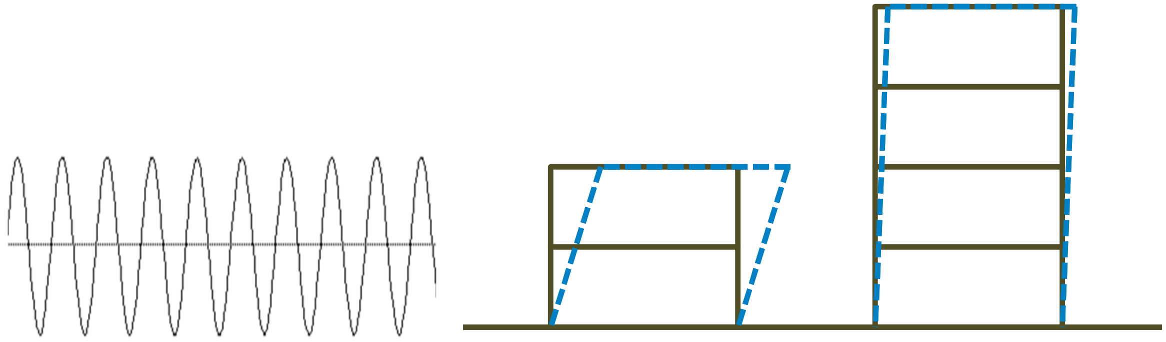
  Stiff: the structure deforms slightly under stress

Short and Tall Buildings Behave Differently to Ground Motion

Short Building
- ⬇ Less Mass
- ⬆ More Stiffness
- ⬇ Smaller Natural Period

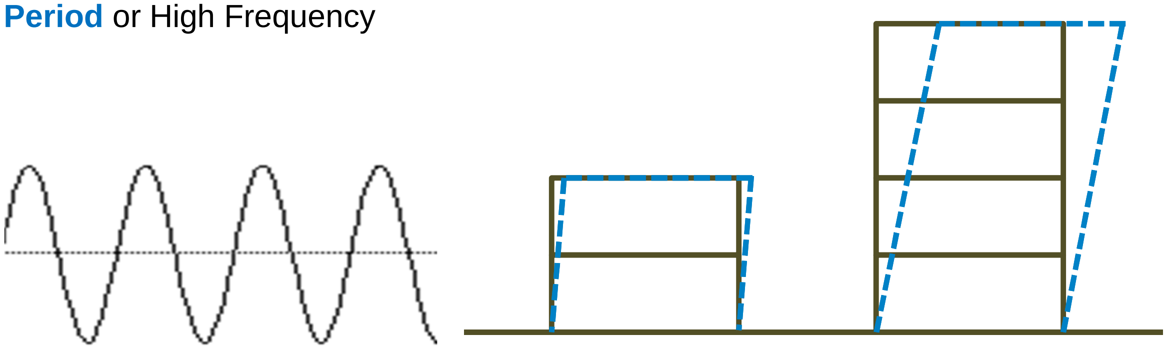
Tall Building
- ⬆ More Mass
- ⬇ Less Stiffness
- ⬆ Large Natural Period

$$\mathit{Natural\ Time\ Period} \propto \frac{\mathit{Mass}}{\mathit{Stiffness}}$$



Shorted Building which has a small Natural Period of Vibration Resonates to Small Period Ground Motion

Ground Motion with **Small Time Period** or High Frequency



Taller Building which has a longer Natural Period of Vibration Resonates to Long Period Ground Motion

Ground Motion with **Long Time Period** or Low Frequency

Seismic Design Code Evolution in the United States

1900 1925 1950 1975 2000

1906
San Francisco

1925
Santa Barbara

1933
Long Beach

1971
San Fernando

1994
Northridge

UBC 1927

First seismic design provision

UBC 1949

Introduced national seismic hazard map for the first time

UBC 1976

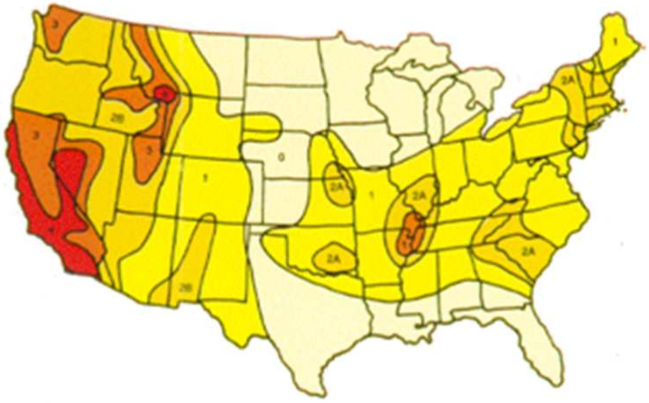
Included more stringent design requirements based on the work of SEAOC

IBC 2000

Used contours of design ground motion rather than a numbered zonation map

Performance-Based Design

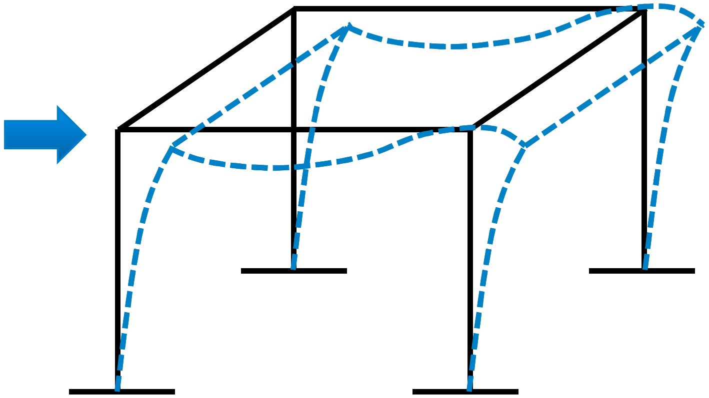
Define multiple target performance levels, which are expected not to be exceeded, when the building is subjected to earthquake of specified intensity



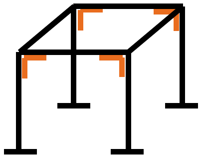
1991

2000

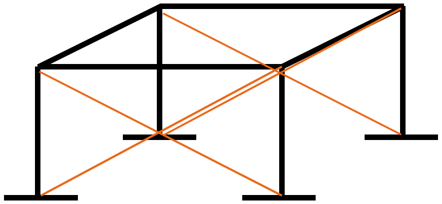
Proper Resisting Mechanisms Can Reduce Earthquake Risk



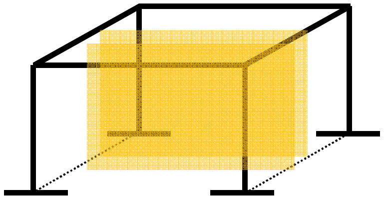
Moment Resisting Frames



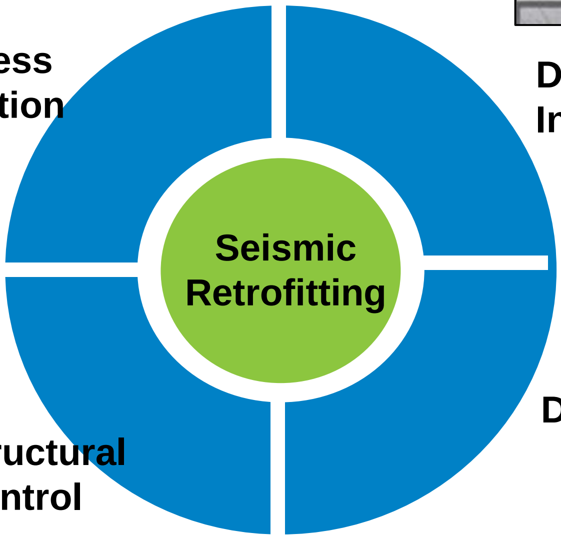
Braced Frames



Shear Walls

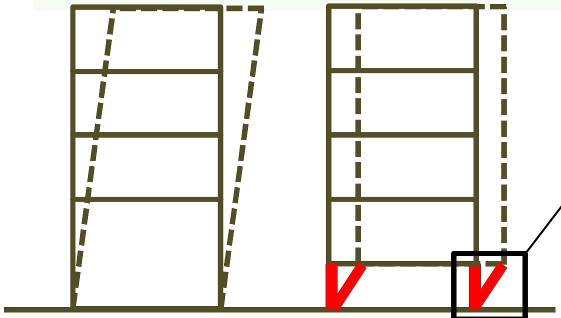


Earthquake Damage Mitigation Measures: Seismic Retrofitting of Buildings

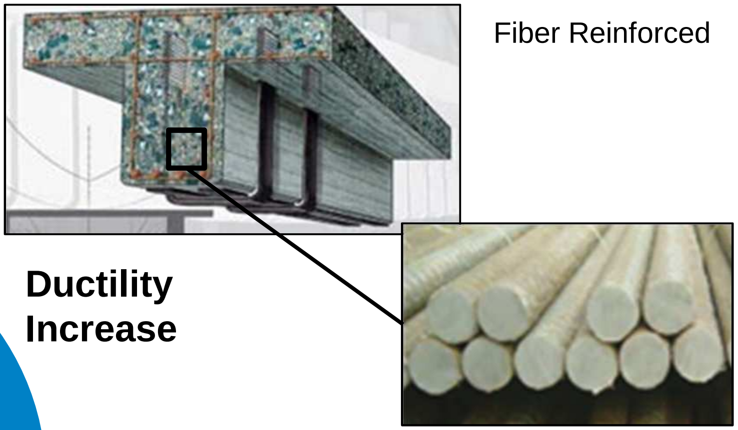


Seismic Retrofitting

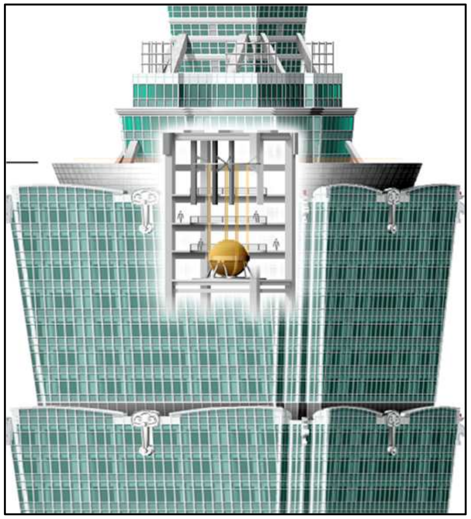
Stiffness Reduction



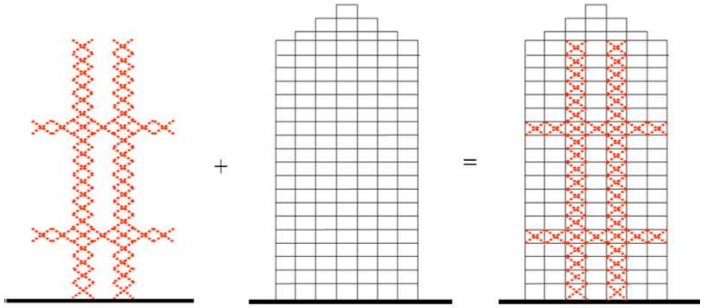
Ductility Increase



Structural Control



Damage Controlled Structures

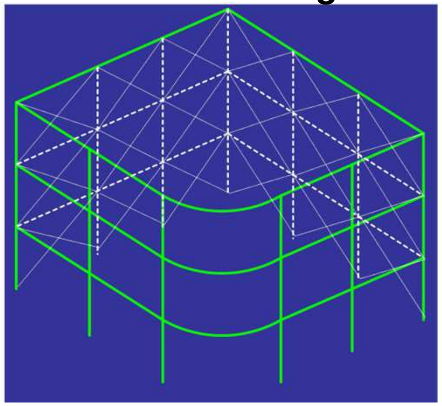


Structural Characteristics of a Building May Affect Seismic Response

Soft Story Effect

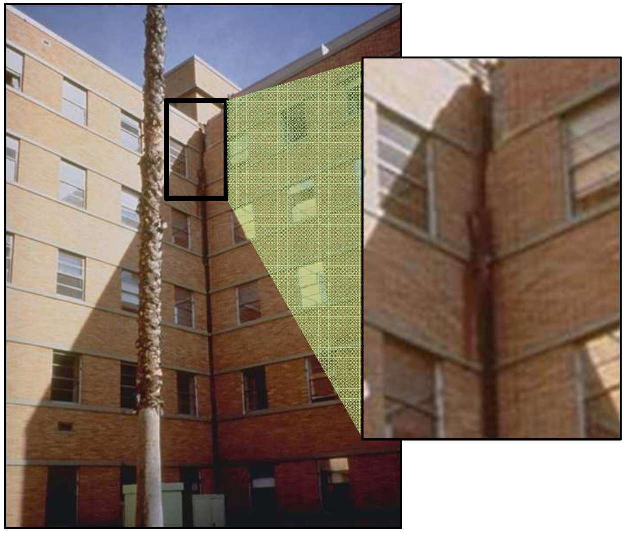
1971 M6.6 San Fernando Earthquake

Corner Buildings



1995 M7.4 Kobe Earthquake, Japan

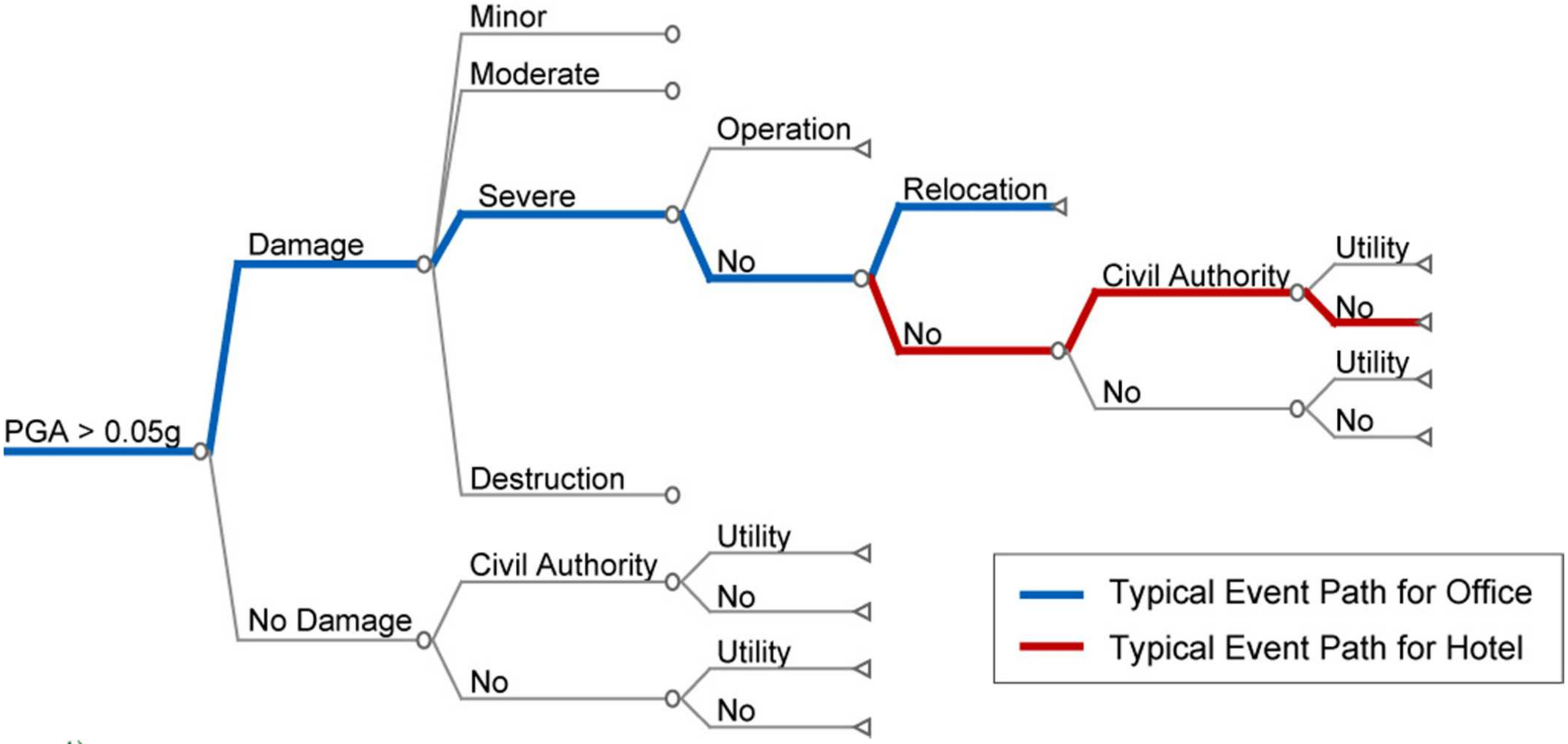
Pounding Effect



1994 M6.7 Northridge Earthquake

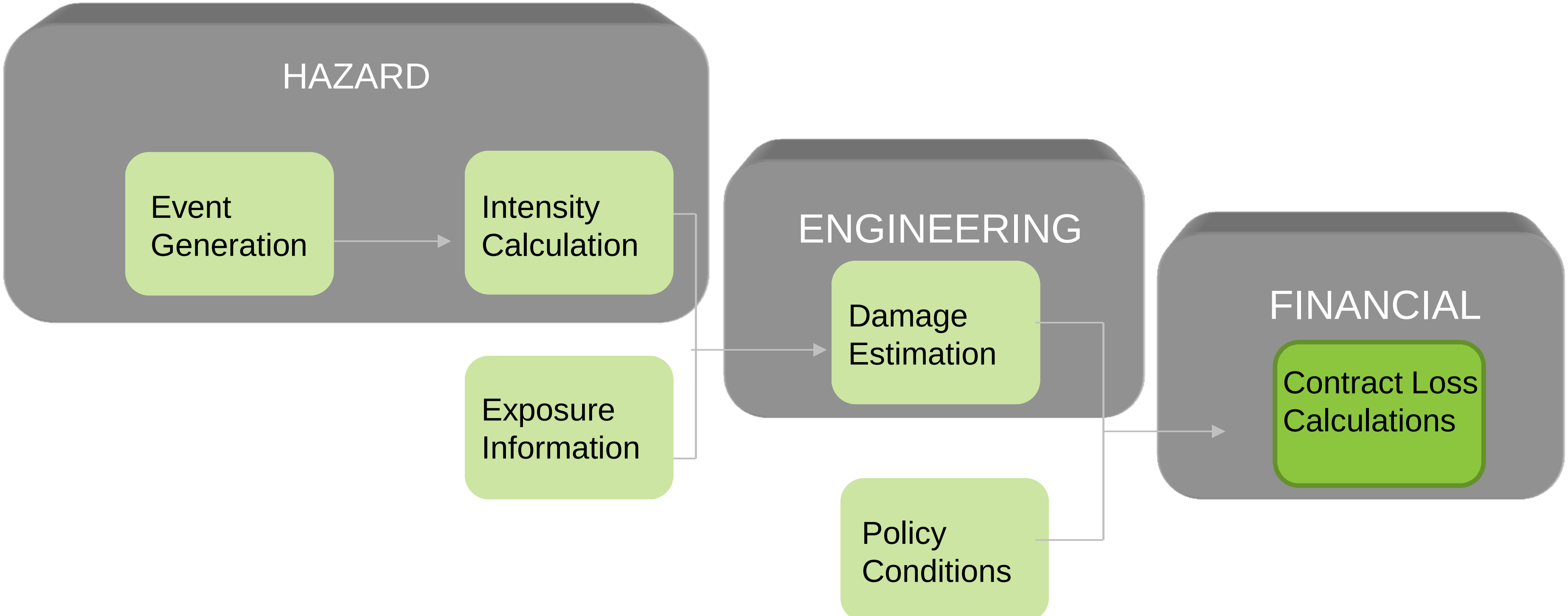
AIR's Model Uses an Event Tree Approach to Handle Business Interruption

- **Event tree approach**
- **Function of building damage and occupancy class**



Model Output and Application

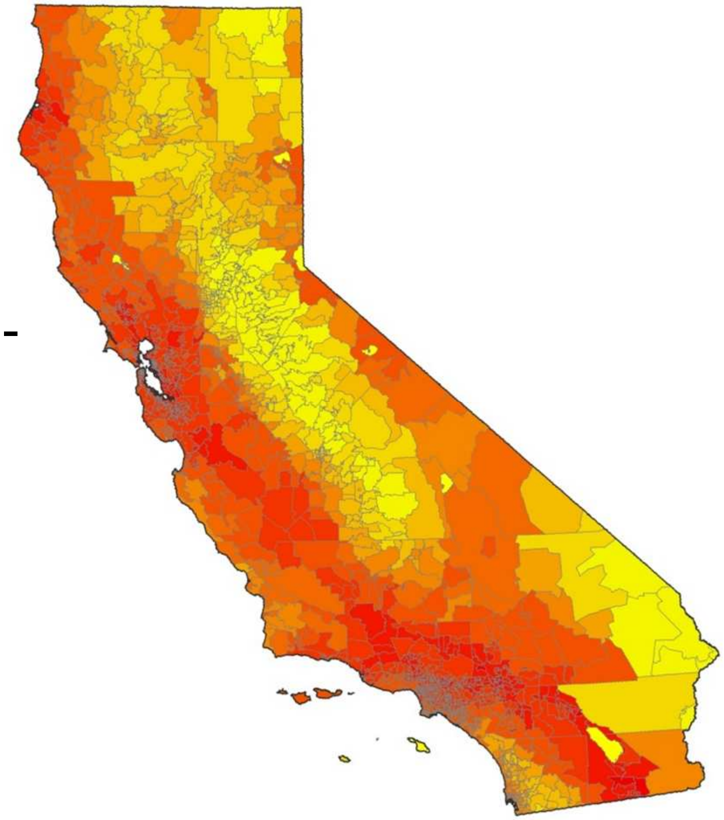
Catastrophe Modeling Framework



The financial module transforms raw damage estimates – the output of the hazard and engineering modules – into estimates of losses to contracts established to cover catastrophic events

Have You Accounted for All the Risk?

- If the exposure data is good, your loss distribution provides a robust starting point for catastrophe risk management
- Additional things to consider
  - Modeled peril versus non-modeled peril
  - Modeled loss component versus non-modeled loss component



Additional Sources of Loss from Earthquake to Consider

AIR Modeled Perils

Shake
Fire Following
Sprinkler Leakage
Liquefaction

AIR Modeled Coverage

Building
Appurtenant structures
Contents
Additional living expenses, BI

AIR Non-Modeled Perils

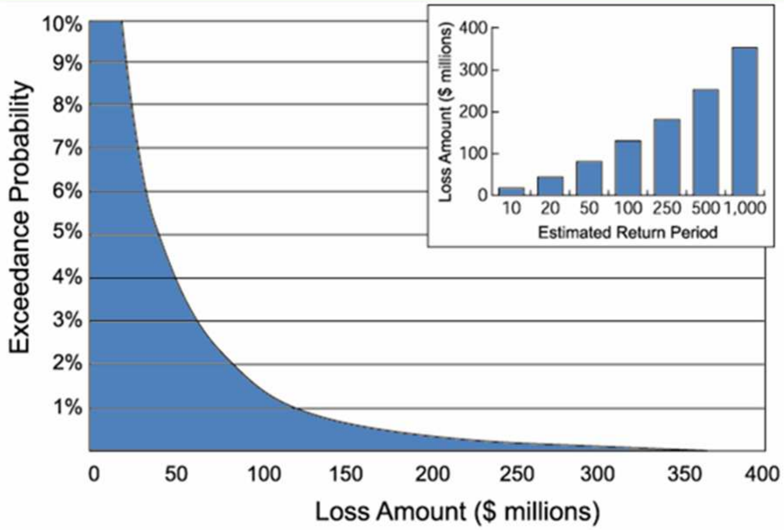
Landslides
Tsunamis
Loss from levee or dam failures
Fire following earthquake due to arson

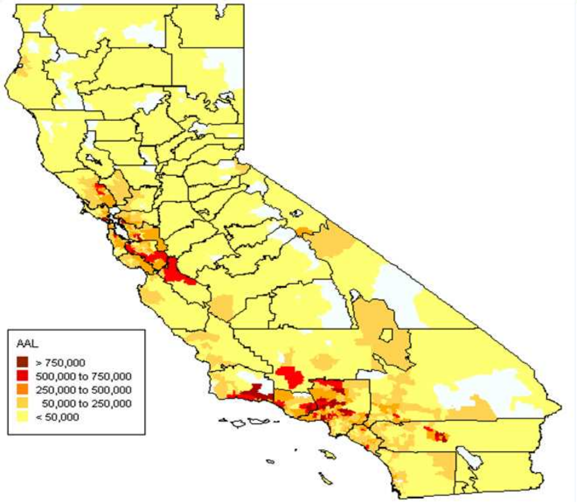
AIR Non-Modeled Loss Components

Loss adjustment expenses
Windpool / FAIR Plan assessments
Hazardous waste cleanup/debris removal
Infrastructure losses

- Review of experience from past events can provide guidance for factors to be used to adjust modeled loss distribution
- Dependent on unique nature of event

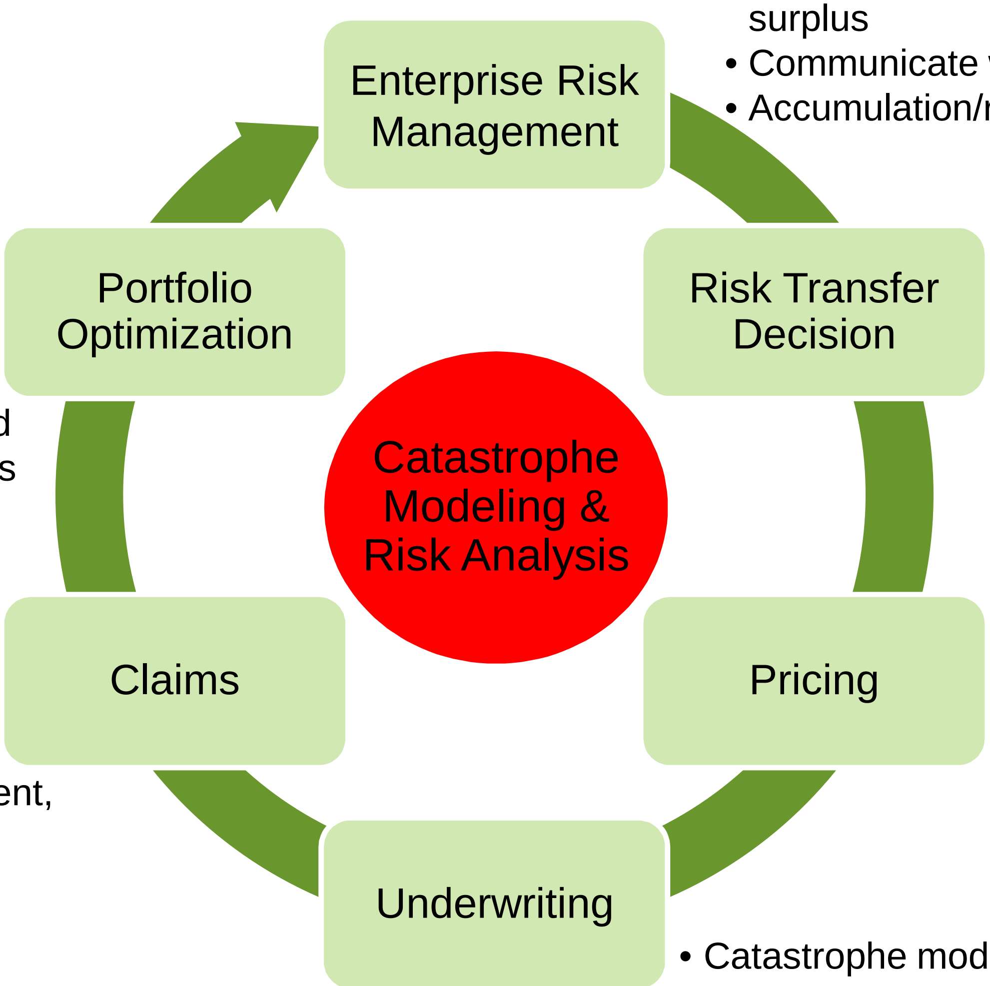
Catastrophe Models Provide a Wide Range of Outputs





Event	Year	Contract Loss	Event Info
270007942	2353	1,995,714,211	Class 3 Hurr TX GOM
270003822	1143	1,994,490,277	Class 3 Hurr FL GOM GA
110044047	6410	1,993,822,104	MW 7.4 EQ Los Angeles
270021674	6488	1,992,783,613	Class 3 Hurr GOM AL FL GA MS
270018191	5445	1,992,529,830	Class 3 Hurr MA RI ME NY CT
270021539	6447	1,992,239,441	Class 3 Hurr FL BF
110010511	1539	1,991,950,215	MW 6.6 EQ Los Angeles
270014761	4407	1,991,795,632	Class 2 Hurr TX GOM LA
270029332	8763	1,990,905,697	Class 3 Hurr GOM FL AL GA MS
110014872	2164	1,990,461,843	MW 6.5 EQ San Francisco
270006759	1983	1,989,857,449	Class 2 Hurr LA GOM MS AL
270023332	6984	1,989,268,193	Class 3 Hurr SC TN NC KY GA
270008182	2423	1,989,078,459	Class 2 Hurr NC SC VA

Insurers Use Catastrophe Models Across Multiple Functional Areas



- Manage the impact of catastrophe risk on surplus
- Communicate with ratings agencies
- Accumulation/risk-aggregation management

- Use models to evaluate reinsurance purchases or issuance of Cat Bond
- Streamline efficiency of communication with reinsurance intermediaries

- Use model outputs in rate filings and in pricing of individual policies or programs

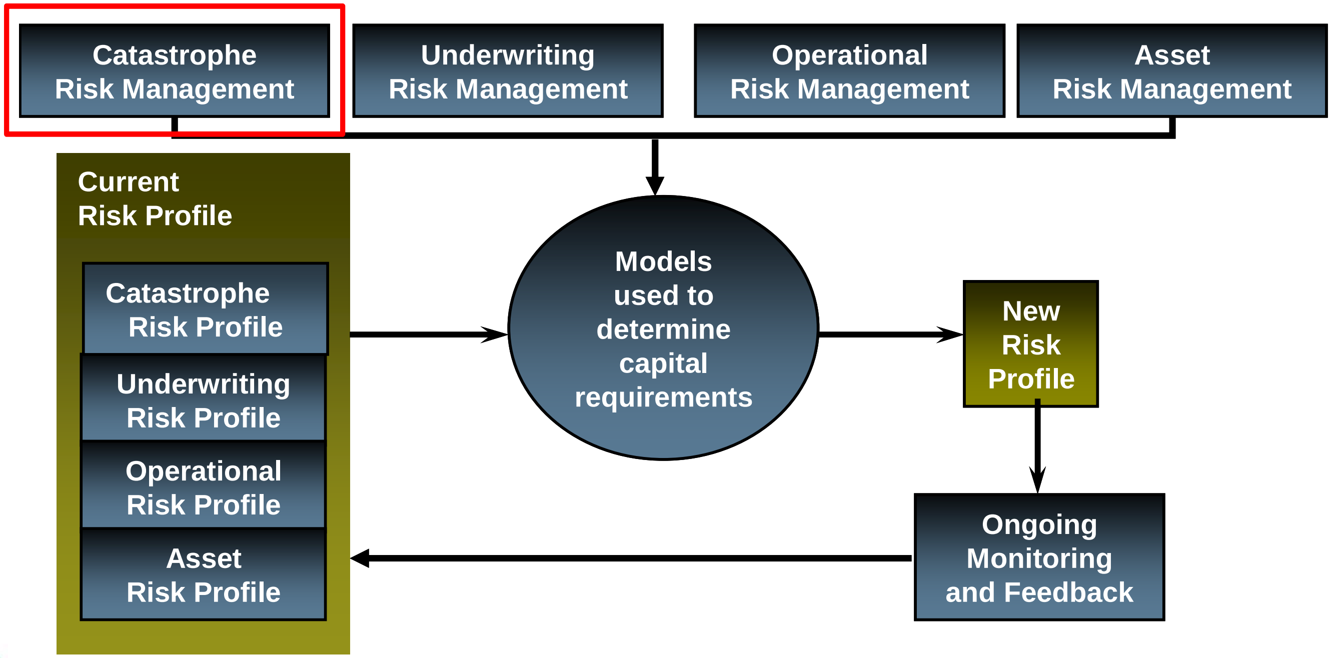
- Catastrophe model output used for risk selection and pricing at the point of sale

- Advance planning, resource deployment, post-event communications

- Identify areas to grow or retract based on model-based risk metrics
- Perform model-based analyses to understand and manage the drivers of catastrophe risk

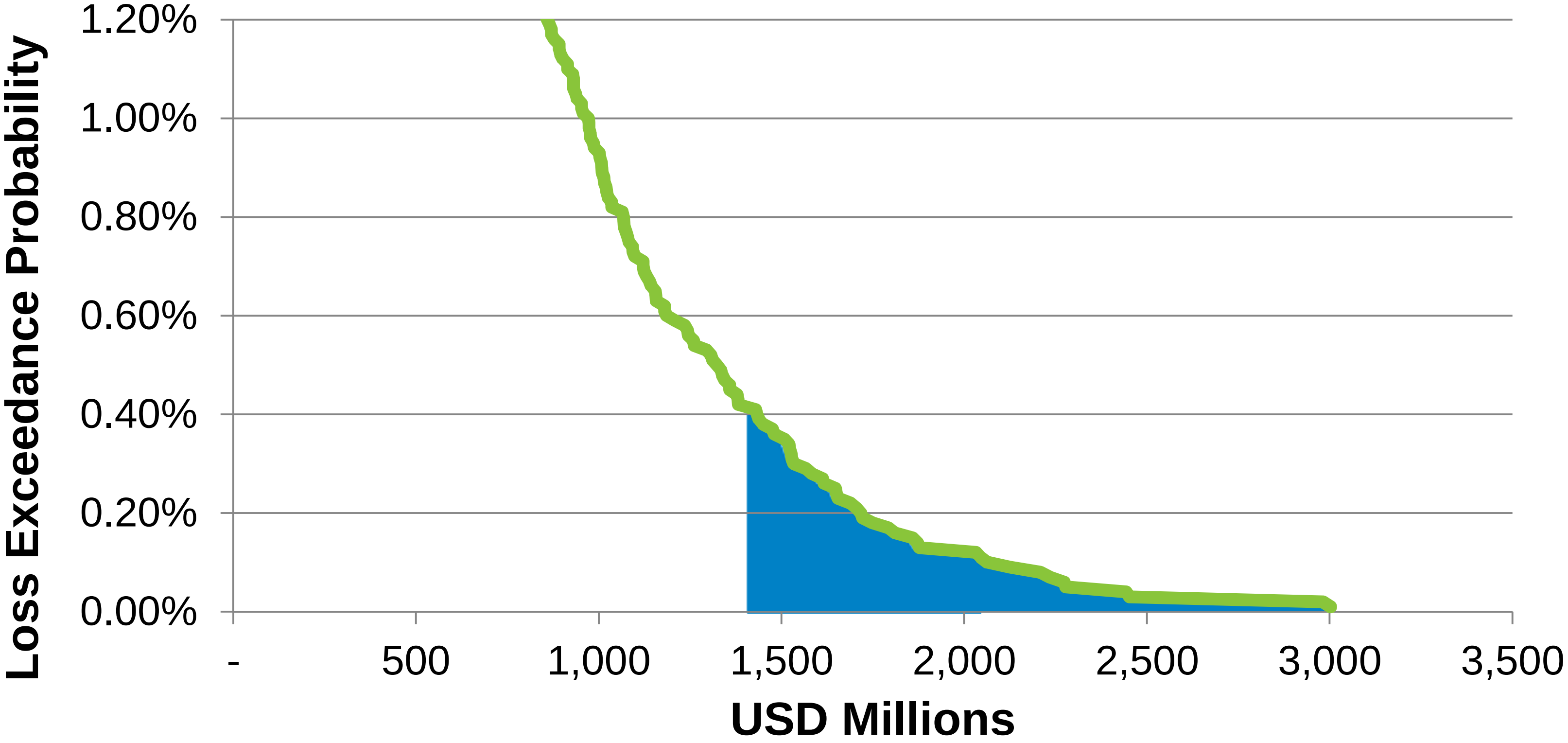
What is ERM and Why Does it Require Model Results?

- A framework for mapping (identifying), measuring, monitoring, and managing a wide variety of risks, both independently and in combination
  - Catastrophe risk is the greatest threat to solvency
  - Catastrophe risk also highly correlated to operational and asset disruptions



Portfolio Optimization Through Tail Value at Risk Management

- Tail value-at-risk (TVaR): average of all simulated event losses beyond specified probability, such as 1% or 0.4%

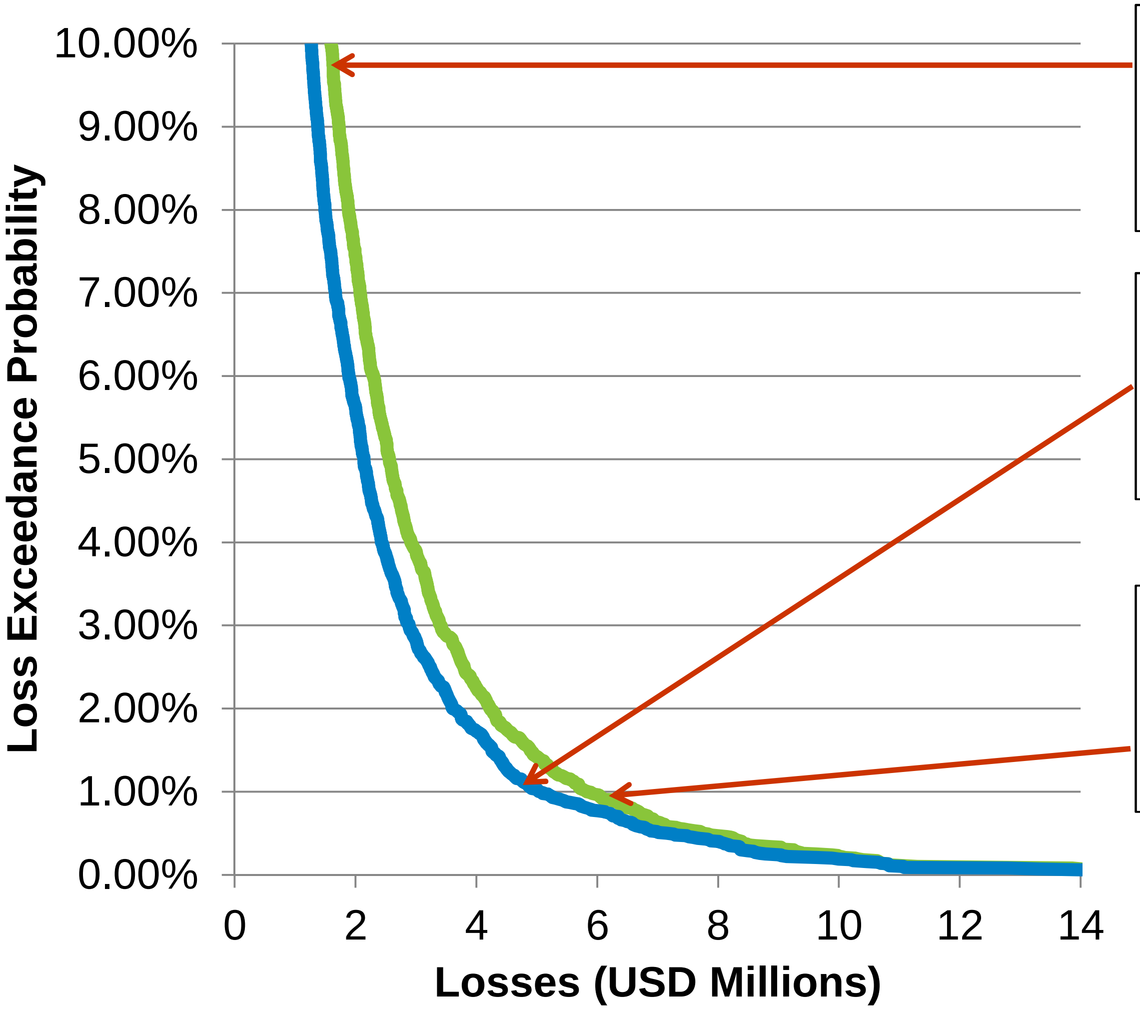


TVaR is a standard output of AIR software products

Catastrophe Risk Transfer Decisions Have Several Elements

- Main goal: modify EP curve net of transfer so that enterprise-wide risk appetite and tolerance goals are achieved
  - But trade-offs in ERM among catastrophe and other risks (credit, liquidity) may ensue
  - Traditional reinsurance most common mechanism, but new ways of risk transfer such as issuance of Cat Bond is gaining popularity
- Price per unit (rate on line) determined by supply and demand for capital
  - But often depends on "technical prices" derived using model results
- Quantity of transfer often directly determined by model results
  - Occurrence (XOL) retention, top limit, and coinsurance
  - Aggregate (XOL) retention and limit
  - Per-risk and facultative retentions and limits on large single risks
  - Participation in state funds determined indirectly by models

Software Users Analyze Occurrence and Aggregate EP Curves to Understand Risk Transfer Needs



Retentions also selected based on how often the enterprise can "take a hit" and for how much

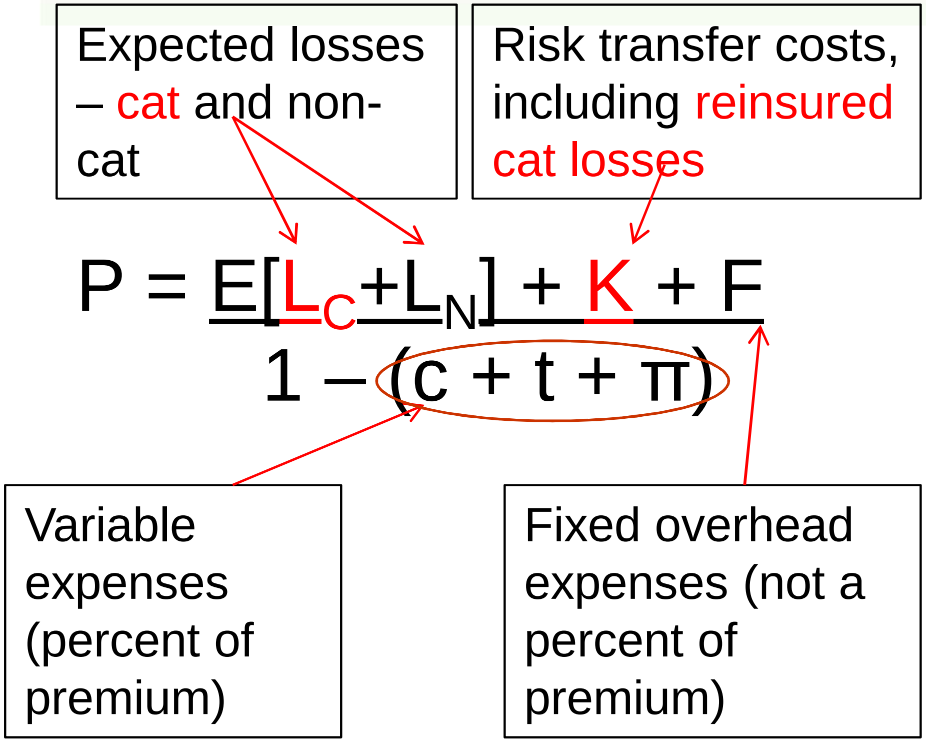
Coverage for severe events ("the big one") based on maximums at selected return periods

Reinstatement and drop-down provisions selected based on probability of multiple covered events

Direct Insurance Premiums Are Determined By Many Complex, Interdependent Base Rates and Differentials

- Base Rates
  - Set to provide sufficient overall revenue to insure entire portfolio
  - In regulated environments, include provisions for specific cost components
    - Normal losses (non-catastrophe)
    - Catastrophe retained losses
    - Catastrophe risk transfer (e.g. reinsurance) costs
    - Expenses, taxes and profit
- Rating Factors
  - Set to equitably distribute premiums among risks of different loss potential
    - Geographic location (territory, building code zone)
    - Property attributes (construction, occupancy, mitigation features)
    - Coverage modifiers (deductibles, coinsurance)
    - Marketing preferences (multi-policy discount)

Typical Rating Algorithm and Base Premium Formula – Modeled Losses Enter in Several Places



Expected losses – cat and non-cat

Risk transfer costs, including reinsured cat losses

$$P = \frac{E[L_C + L_N] + K + F}{1 - (c + t + \pi)}$$

Variable expenses (percent of premium)

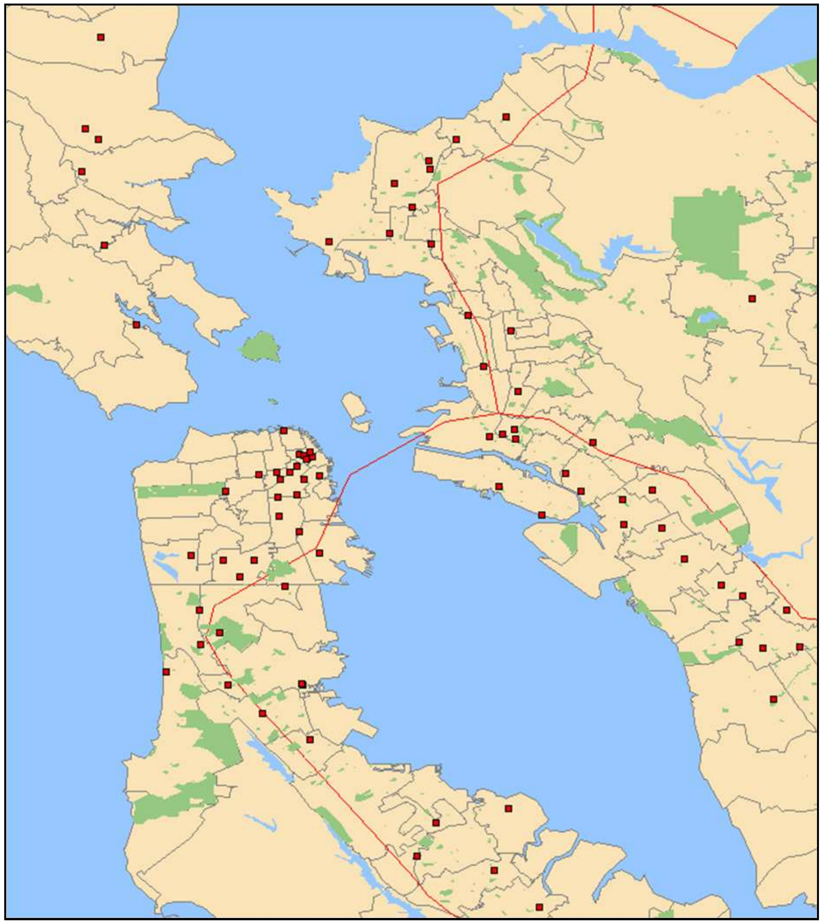
Fixed overhead expenses (not a percent of premium)

Then: Base Premium [**P**]
x Construction Type factor
x Territory factor
x Amount of Insurance factor
x Deductible factor
x Mitigation discount
x Building Code Zone discount
x Multi-Policy discount
\+ Policy Fees
= Final Premium

- Allocation of base premiums (via rating factors) should be based on relative loss potential – including catastrophe losses from models
- Relative loss potential should be measured using both expected losses and a measure of risk (volatility)

The Role of Models in the Underwriting Workflow

- **Risk Selection**
  - Quickly assess whether new policies meet underwriting guidelines
  - Manage catastrophe risk on the ‘front-end’ before a policy goes on the books, not just at the portfolio level
- **Loss Analysis:** Produce potential loss result and EP curve for your location which will guide you through the underwriting process, help you set coverage terms and pricing



Summary

- Catastrophe modeling provides a better estimate of potential insurable losses than traditional techniques based solely on historical claims
- AIR's modeling processes for earthquakes incorporate the latest science, engineering, and actuarial knowledge to estimate the probability of catastrophe losses
- To best understand risk, actuaries must fully understand model assumptions and limitations
- Catastrophe modeling is widely used in the insurance industry

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