NAT-2

EARTHQUAKES: MODELING AND MANAGEMENT OF THE SHAKE, RATTLE AND ROLL

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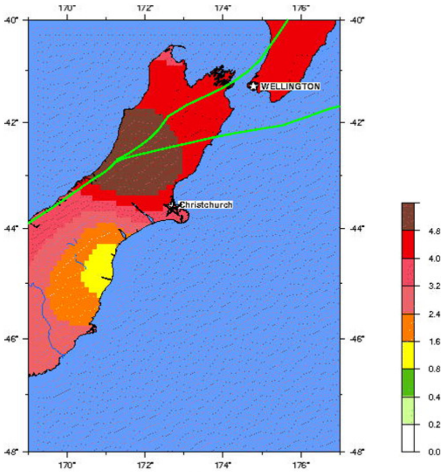
Agenda

- How earthquakes are modeled
- Accounting for building vulnerability
- Catastrophe risk management
- Managing earthquake risk using models
- Managing earthquake risk with mapping

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

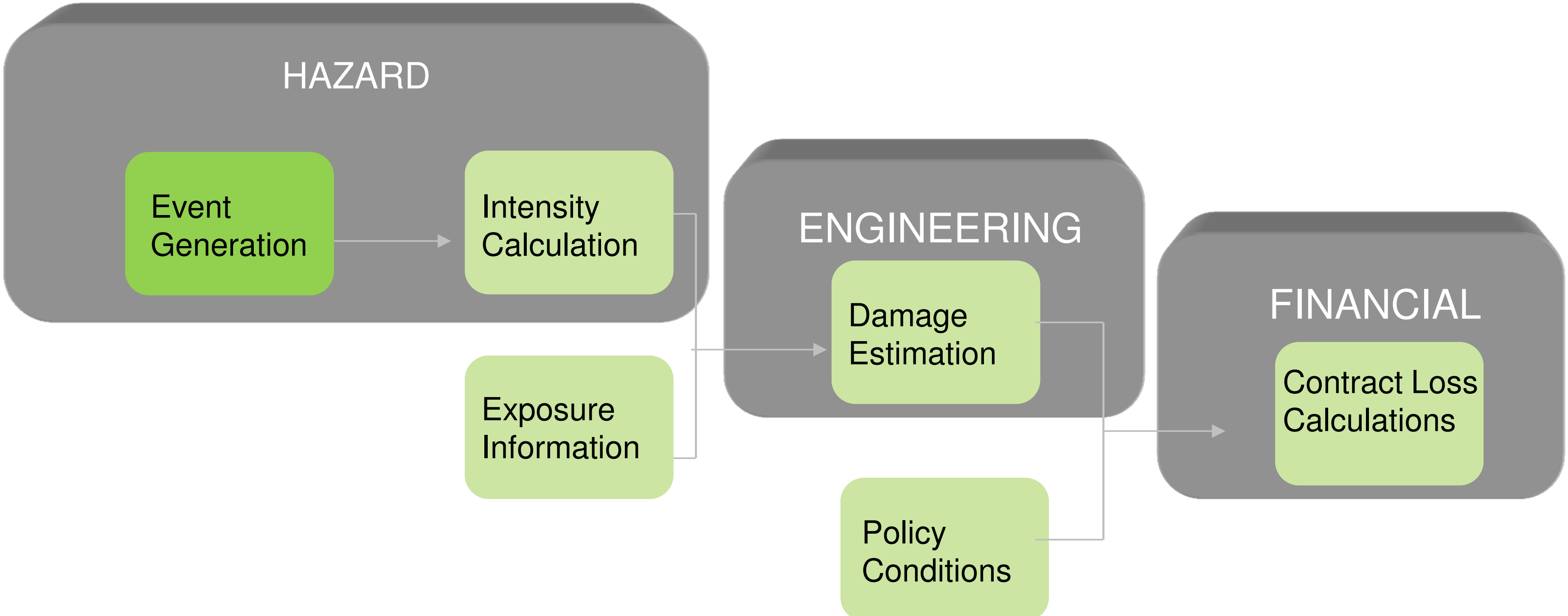


SOUTH ISLAND OF NEW ZEALAND

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

Catastrophe Modeling Framework: Event Generation



Where are future events likely to occur?

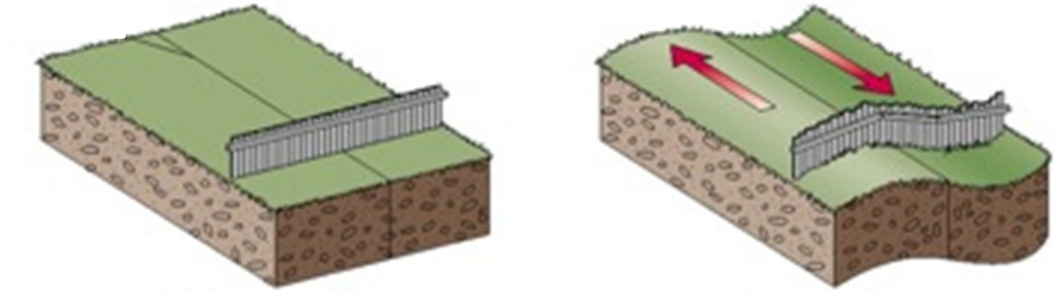
How intense are they likely to be?

How frequently are they likely to occur?

What Causes an Earthquake?

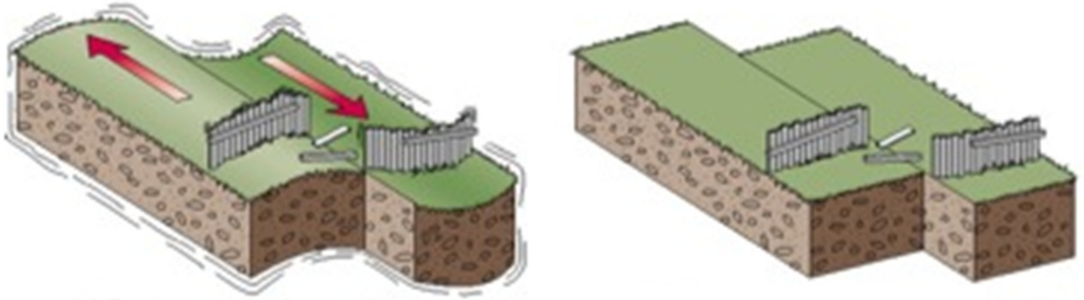
An earthquake is a sudden, rapid shaking of the Earth caused by the breaking and shifting of rock beneath the Earth's surface

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.



Original Position

Deformation



Rupture and Release of Energy

Rocks Rebound to Original Shape

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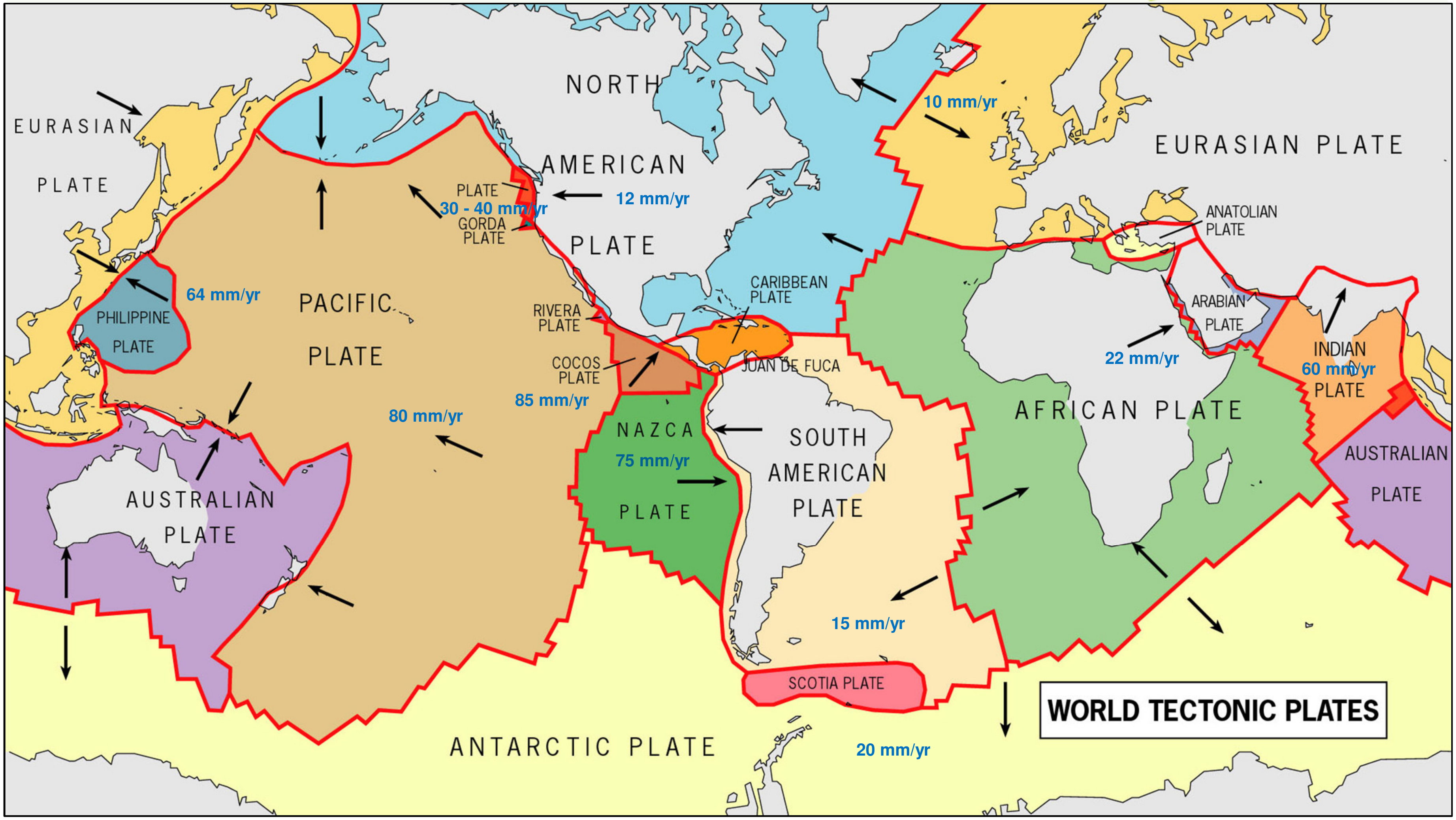
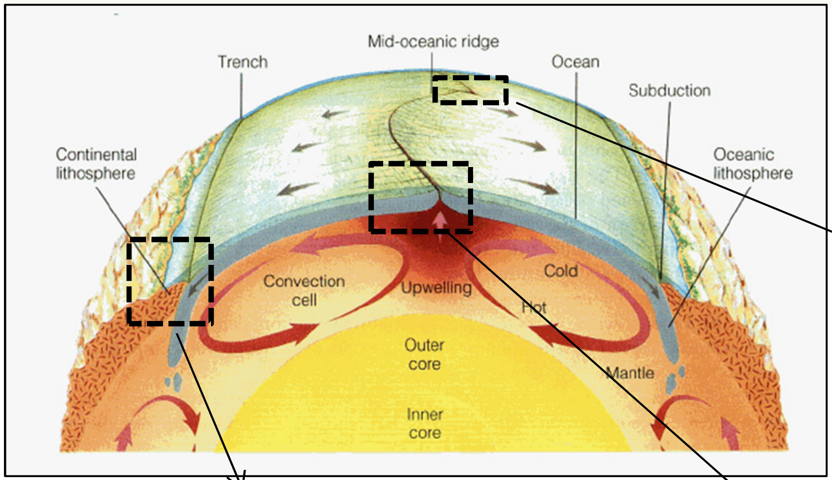
Earthquakes Typically Occur Along Plate Boundaries Where Tectonic Plates Slide Past One Another

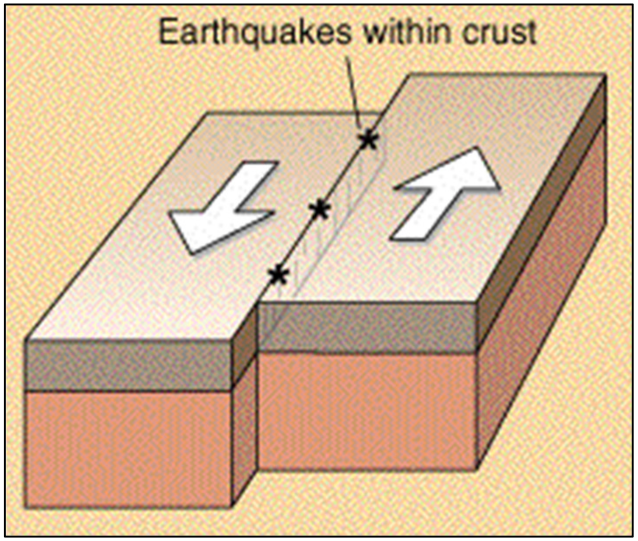


Source: *Environmental Physical Geology*

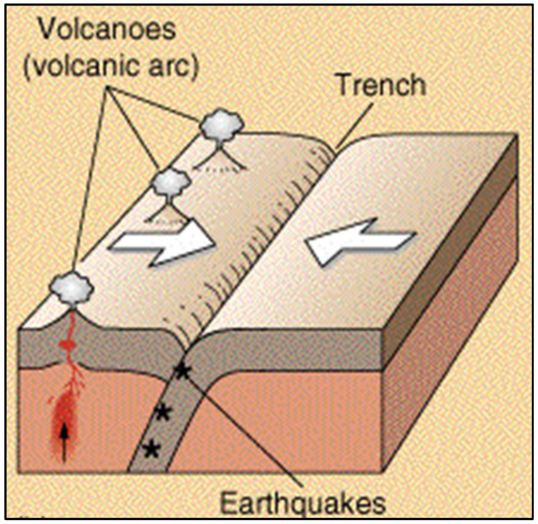
Plate Boundaries Are Classified By Relative Direction of Motion



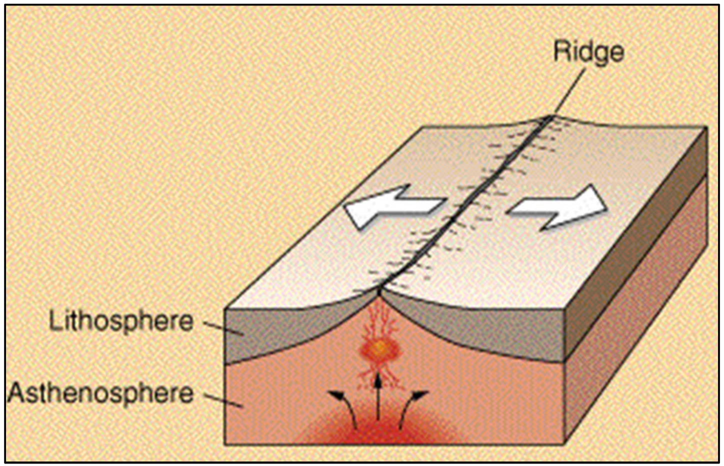
Transform Plate Boundary



Convergent Plate Boundary

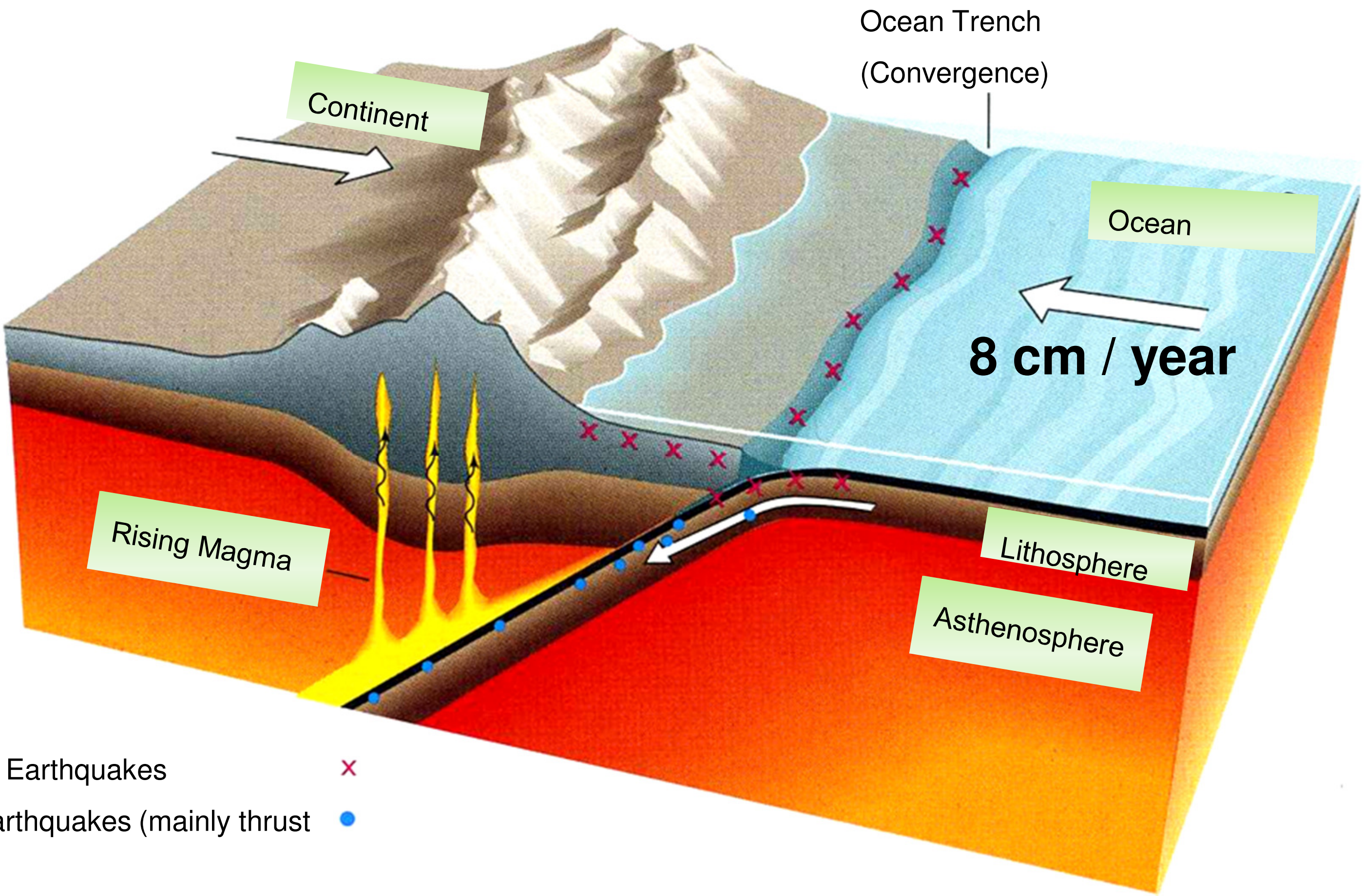


Divergent Plate Boundary



Source: *USGS Dynamic Earth*

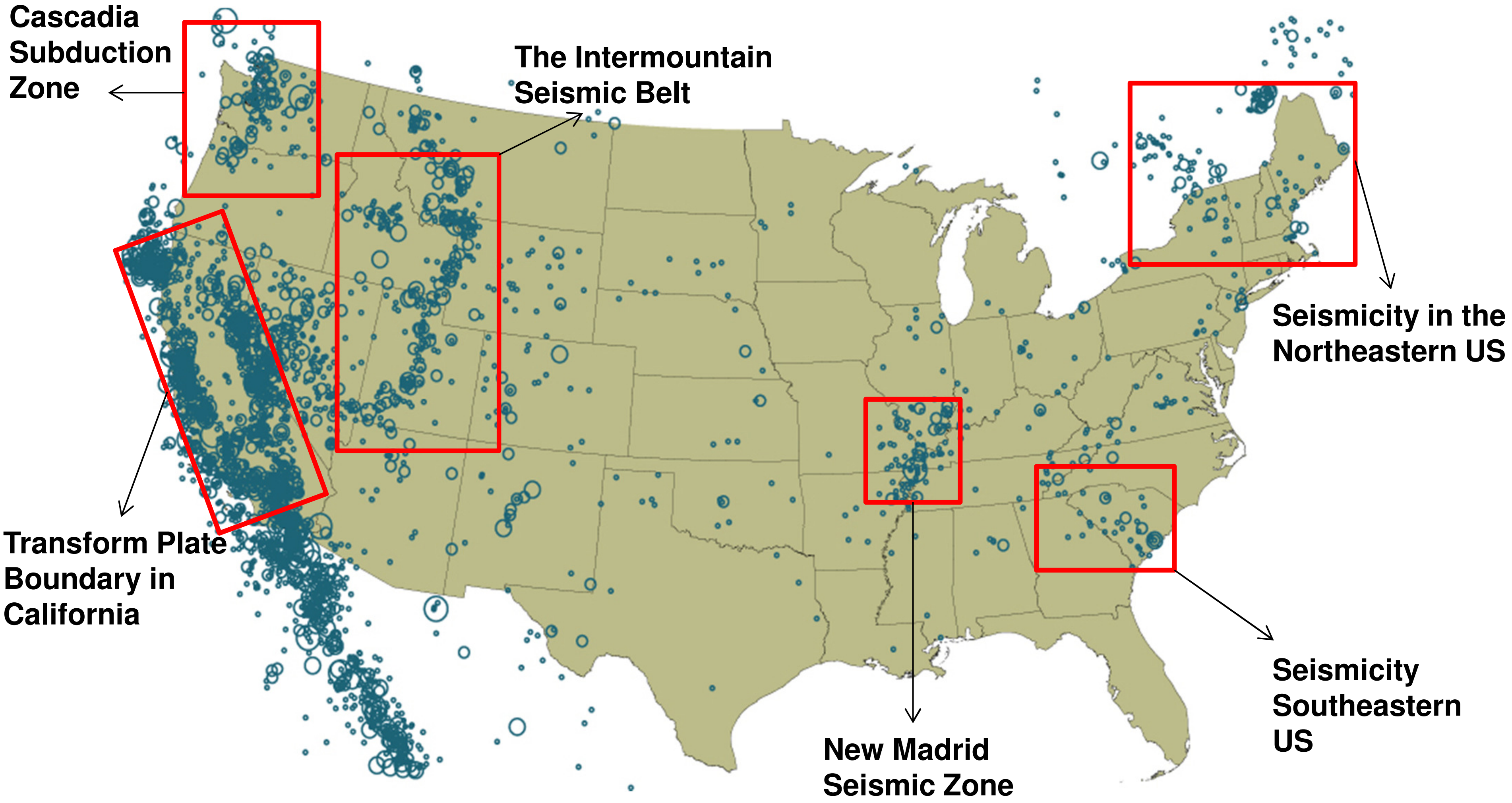
Japan Is a Mega-Thrust Convergence Zone



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

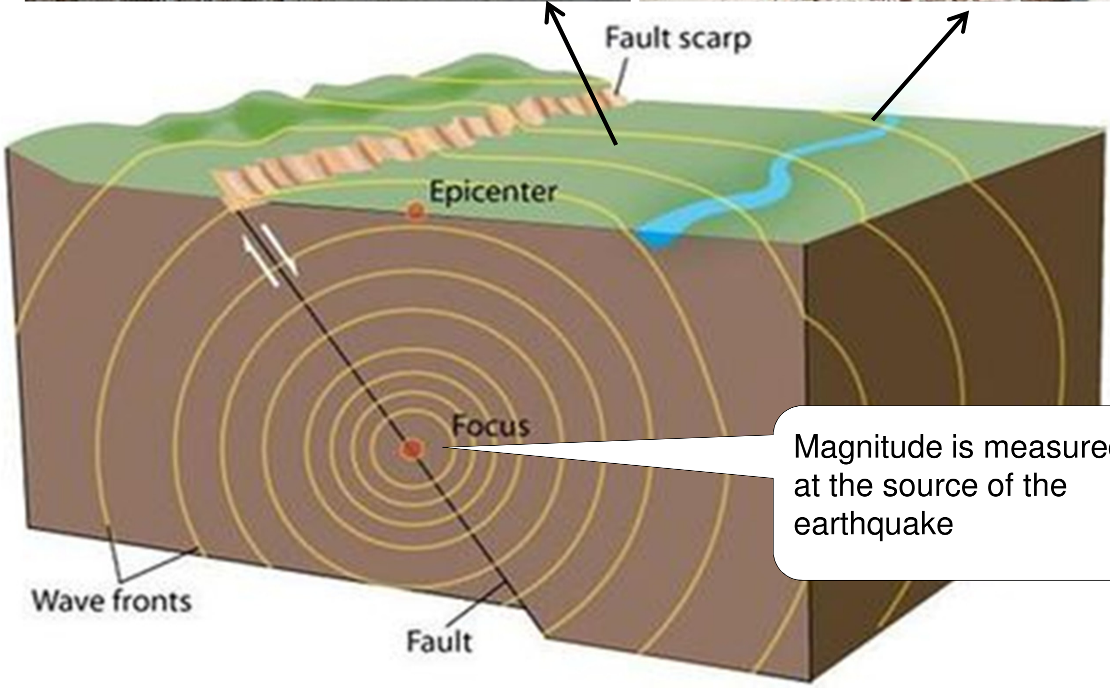
To Create a Simulated Earthquake Event, AIR Uses Several Physical Parameters

- 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

Earthquake – Modeled and Non-Modeled Perils

Modeled Perils

- Shake
- Fire Following
- Sprinkler Leakage
- Liquefaction

Modeled Coverages

- *Coverage A* - Dwelling
- *Coverage B* - Other Structures
- *Coverage C* – Contents / Personal Property
- *Coverage D* – Additional Living Expense / Business Interruption

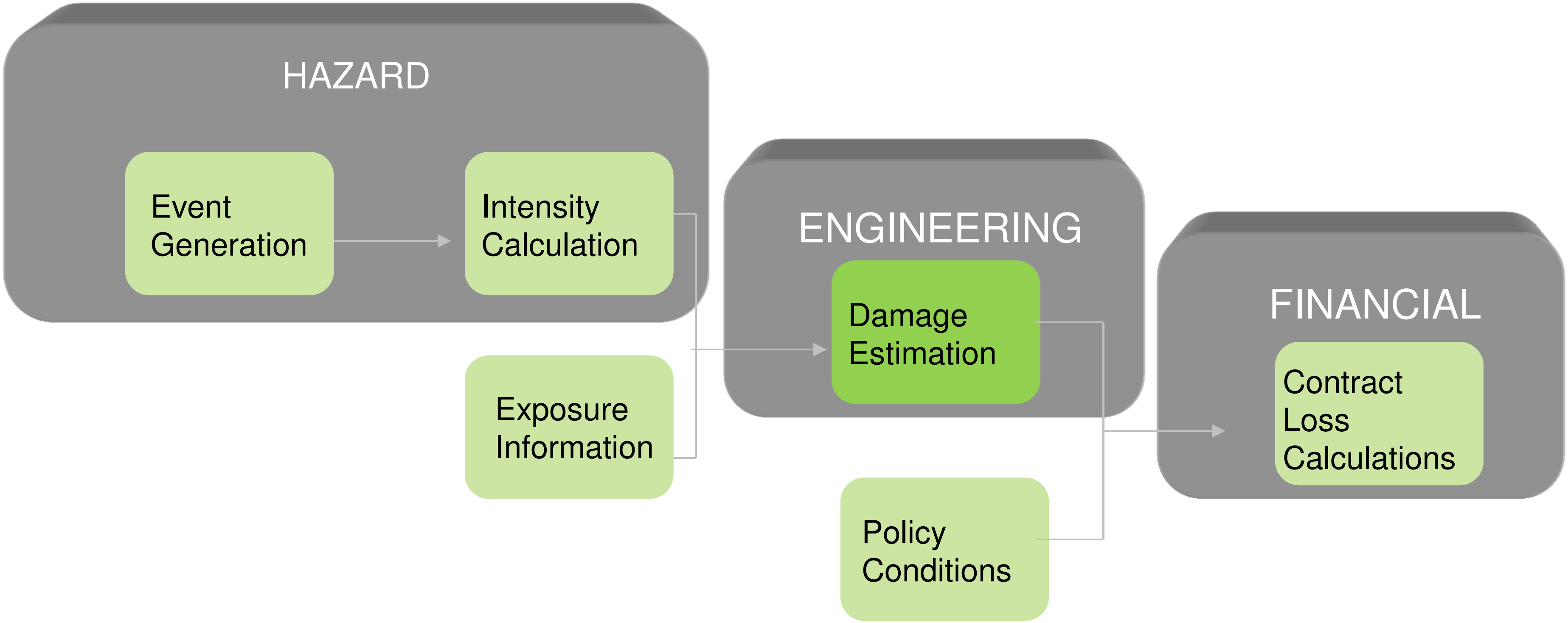
Non Modeled Perils

- Landslide
- Loss from Levee or Dam Failures
- Fire Loss Following EQ due to Arson
- Tsunami

Non Modeled Loss Components

- Loss Adjustment Expenses
- Debris Removal
- Hazardous Waste Removal
- Loss inflation due to political pressure

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

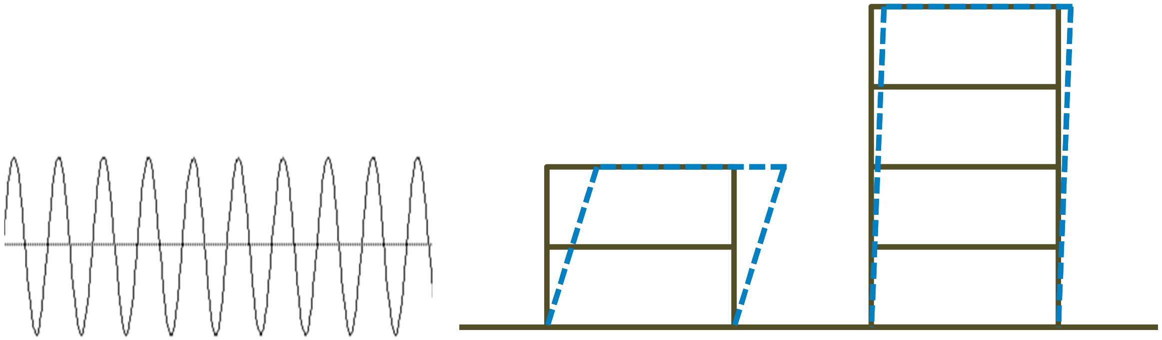
  Stiff: the structure deforms slightly under stress

Short and Tall Buildings Behave Differently to Ground Motion

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

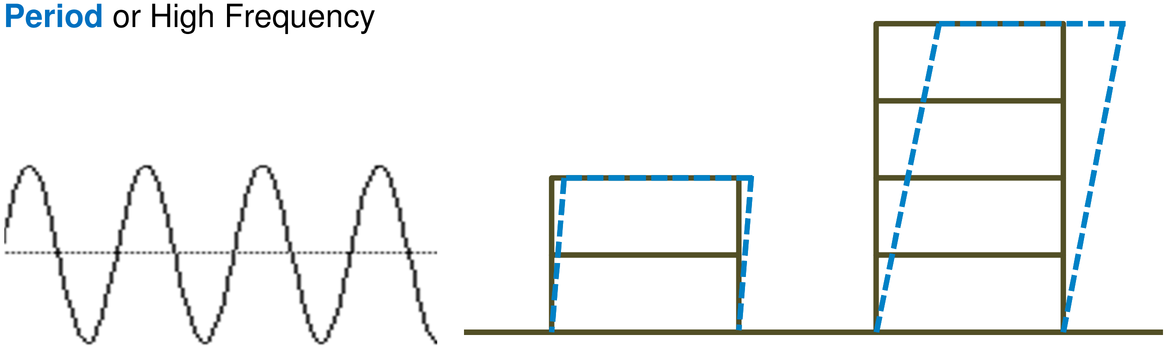
Tall Building
- ⬆ More Mass
- ⬇ Less Stiffness
- ⬆ Large Natural Period

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



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

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

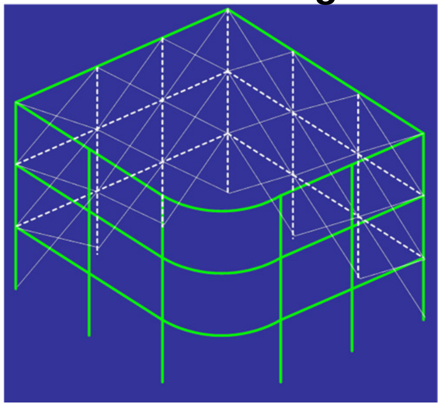


Ground Motion with **Long Time Period** or Low Frequency

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

Structural Characteristics of a Building May Affect Seismic Response

Corner Buildings

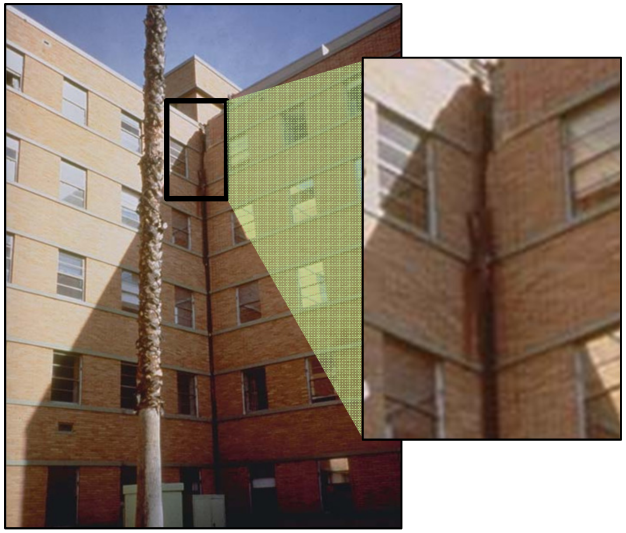


1995 M7.4 Kobe Earthquake, Japan

Soft Story Effect

1971 M6.6 San Fernando Earthquake

Pounding Effect

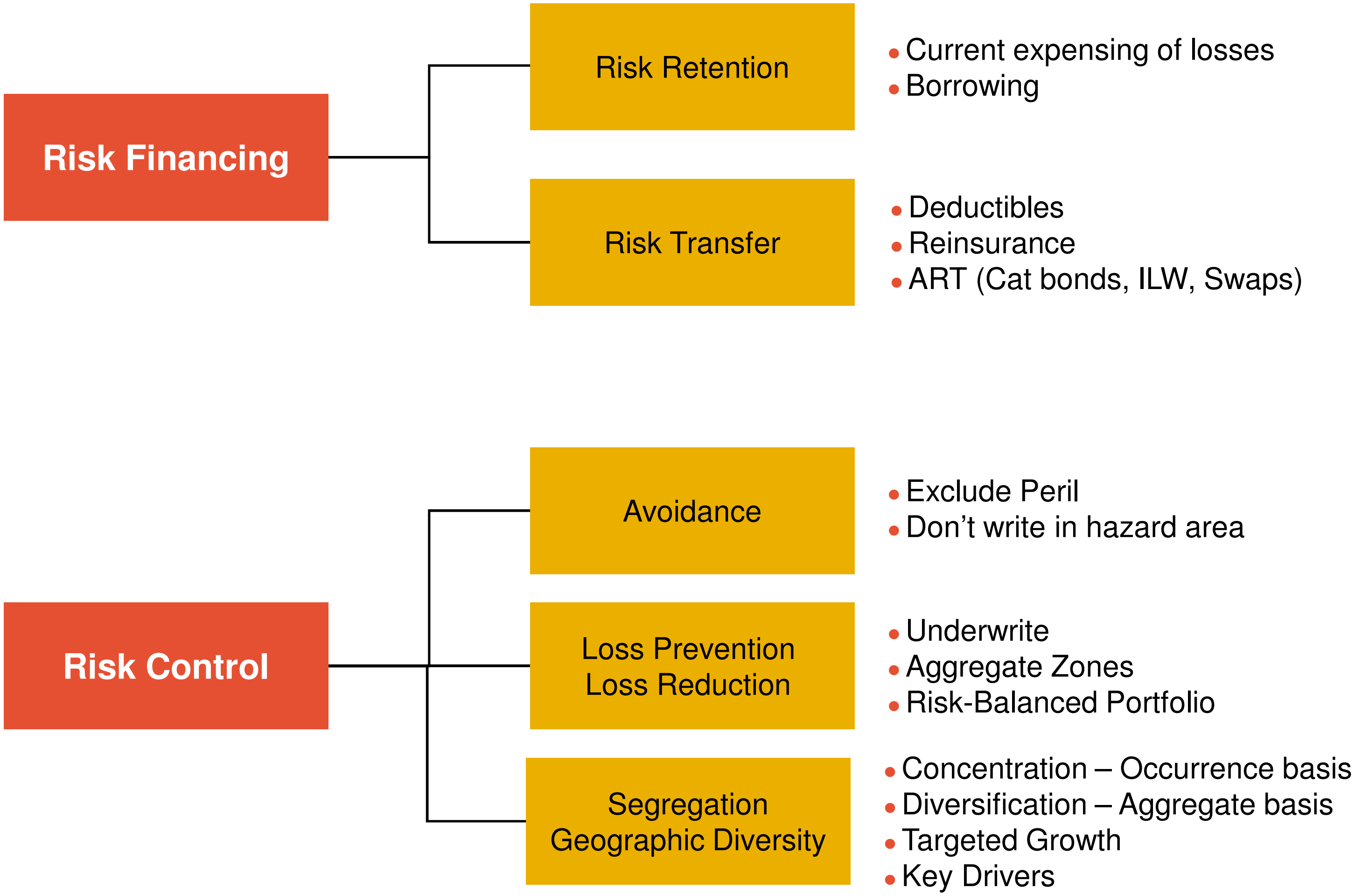


1994 M6.7 Northridge Earthquake

Catastrophe Risk Management

TOWERS WATSON

Risk Management 101



Risk Financing

Risk Retention

- Current expensing of losses
- Borrowing

Risk Transfer

- Deductibles
- Reinsurance
- ART (Cat bonds, ILW, Swaps)

Risk Control

Avoidance

- Exclude Peril
- Don’t write in hazard area

Loss Prevention
Loss Reduction

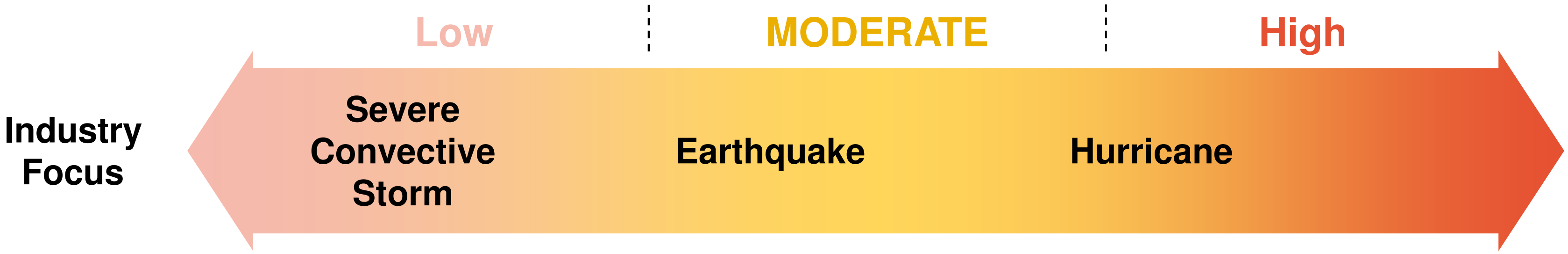
- Underwrite
- Aggregate Zones
- Risk-Balanced Portfolio

Segregation
Geographic Diversity

- Concentration – Occurrence basis
- Diversification – Aggregate basis
- Targeted Growth
- Key Drivers

How Earthquake Fits In

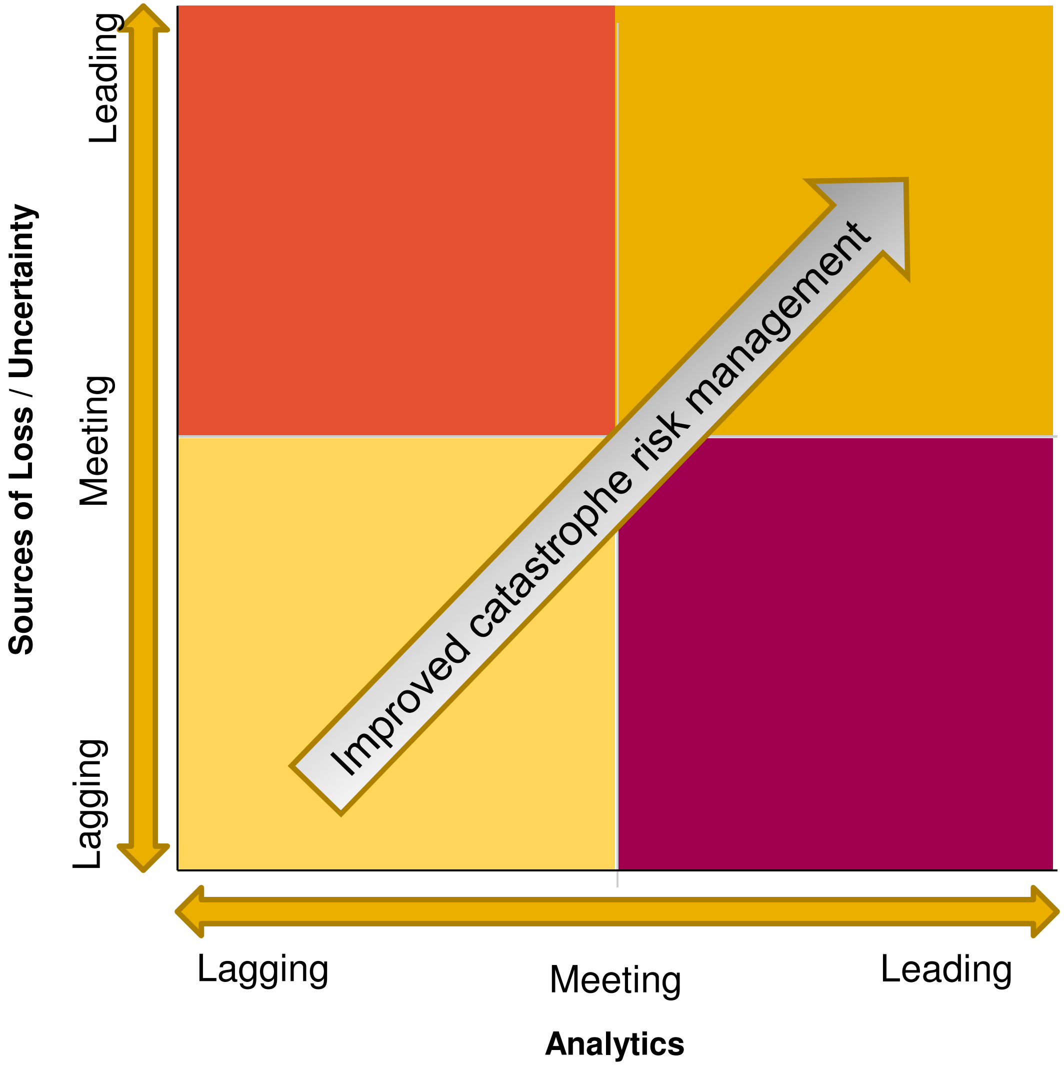
Peril Comparison



- Least focus	- Focus of initial models	- Highest Focus
- Not generally a threat to exceeding reinsurance limits - Despite high frequency, outbreak nature makes it difficult to evaluate	- Low frequency, and lack of major US event has lead to second-tier status - Low take-up rates influence attention, but fire following could become a major issue	- Recent activity provides large amount of claims data - Reasonable historical record

Cat Risk Management - Overview

- Sources
  - Loss
    - Modeled Perils
    - Non-modeled losses
    - Non-modeled Perils
  - Uncertainty
    - Data quality
    - Model inaccuracies
- Analytics
  - Models
    - Full range of output
    - Multiple viewpoints
  - Mapping
    - Spatial analysis
  - Implementation
    - Strategic / tactical



Source - Data Quality

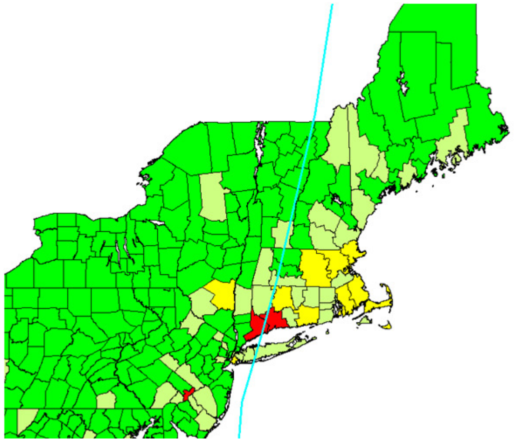
Characteristic	Information	AAL	% Change
Zip	32901	220.96	—
Street Address	621 Burr Street, Melbourne, FL	232.52	5.2%
Parcel	28.069065 -80.609726	240.83	3.6%
Occupancy	Single Family	222.34	-7.7%
Construction	Wood Frame	245.99	10.6%
# Stories	1	235.89	-4.1%
Year Built	1987	282.04	19.6%
Area	1440	317.43	12.5%
Secondary	Gable roof, unknown pitch	354.36	11.6%
Overall		**354.36**	**60.4%**

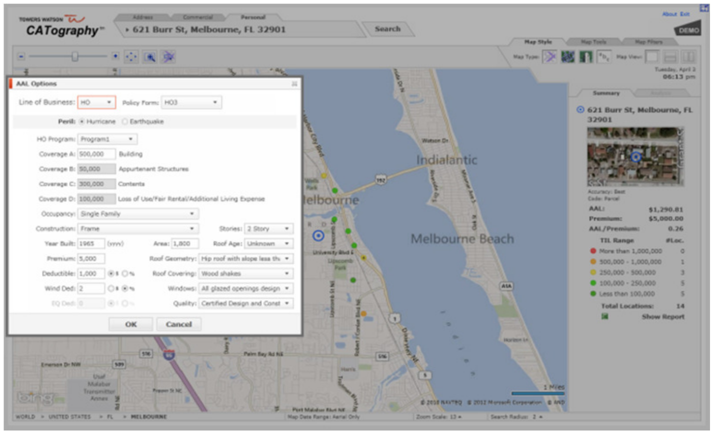
Homeowners
HO-3

Coverage A:	60,000
Coverage B:	6,000
Coverage C:	30,000
Coverage D:	12,000

Analytics - Model Output

- Deterministic loss estimates
  - Realistic disaster scenarios (RDS)
- Probabilistic loss estimates
  - Occurrence / aggregate exceeding probability (OEP / AEP)
  - TVaR / XSAAL
  - Marginal impact
- Results by portfolio / region / location
  - Key drivers of loss
  - Location level analysis





621 Burr St, Melbourne, FL 32901

Tuesday, April 3
06:13 pm

AAL Options

Line of Business: HO
Policy Form: HO3
Peril: ● Hurricane ○ Earthquake
HO Program: Program1
Coverage A: 500,000 Building
Coverage B: 50,000 Appurtenant Structures
Coverage C: 300,000 Contents
Coverage D: 100,000 Loss of Use/Fair Rental/Additional Living Expense
Occupancy: Single Family
Construction: Frame
Stories: 2 Story
Year Built: 1965 (yyyy)
Area: 1,800
Roof Age: Unknown
Premium: 5,000
Roof Geometry: Hip roof with slope less th
Deductible: 1,000 ● $ ○ %
Roof Covering: Wood shakes
Wind Ded: 2 ○ $ ● %
Windows: All glazed openings design
EQ Ded: 0 ● $ ○ %
Quality: Certified Design and Const

621 Burr St, Melbourne, FL 32901
Accuracy: Best
Code: Parcel

AAL:	$1,290.81
Premium:	$5,000.00
AAL/Premium:	0.26
TIL Range	#Loc.
🔴 More than 1,000,000	0
🟠 500,000 - 1,000,000	1
🟡 250,000 - 500,000	3
🟢 100,000 - 250,000	5
🟢 Less than 100,000	5
Total Locations:	14

Show Report

Analytics – Multiple Viewpoints

- Medium term / Long term / Warm SST / Standard Catalog
  - Recognizes current environment vs. Science not understood enough to be predictive

- Blending models
  - Stabilizes results vs. Creates new model that isn't directly based on research
  - Standardizes multiple viewpoints of risk vs. incorporates wrong answer

- Recent releases have led more companies to adopt this approach

Models - Occurrence View vs. Aggregate View

- Most of traditional cat risk management has been focused on the occurrence exceeding probability analysis
  - Reinsurance structure – purchase to 1 in X year loss level

- Recent activity has changed the focus toward the aggregate exceeding probability
  - Impact on balance sheet from multiple events
    - Severe convective storm losses
    - 2004 / 2005 hurricane seasons

- Earthquake cat risk management general focuses on occurrence exceeding probabilities since frequency is low
  - However, historic events like the recent New Zealand earthquakes and the New Madrid earthquakes in the early 1800s raise questions on clustering

Implementations - Strategic vs. Tactical

- Catastrophe risk management should focus on analyses that create strategic direction as well as guidelines that support tactical decisions

- Earthquake risk management
  - Strategic plans focus on controlling aggregate exposures within specific seismic zones and developing growth plans and non-renewal efforts
  - Tactical tools assist underwriters in evaluating new and renewal risks by evaluating hazard levels
    - Modeling the average annual loss
    - Overview of hazard including risk indexes and soil information

Implementations - Risk Aggregate Zones

- Control overall loss levels for single event by controlling total insured values in each zone for each peril
  - OEP curve
  - Need to define zones such that any loss in that zone does not exceed loss thresholds

- Earthquake aggregate zones may focus on seismic zones
  - Southern CA, Northern CA, Pacific Northwest, New Madrid
  - Actual implementations will vary by company based on risk appetite

Implementations - Risk-Balanced Portfolio

- Manages overall portfolio so that all catastrophes in given time period will not impact company over a threshold
  - AEP curve

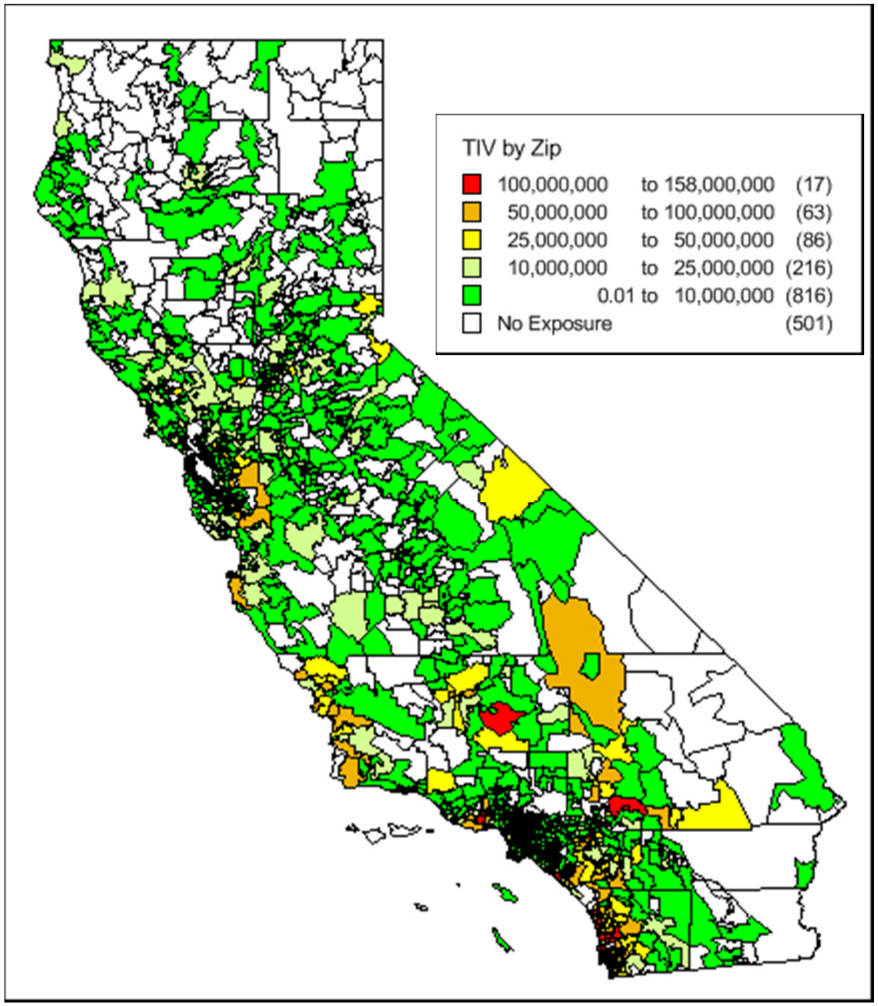
- Looks to efficiently use capital by avoiding concentrations
  - Identifying key drivers
  - Targeted growth

Potential Impact from Risk-Balancing Portfolio

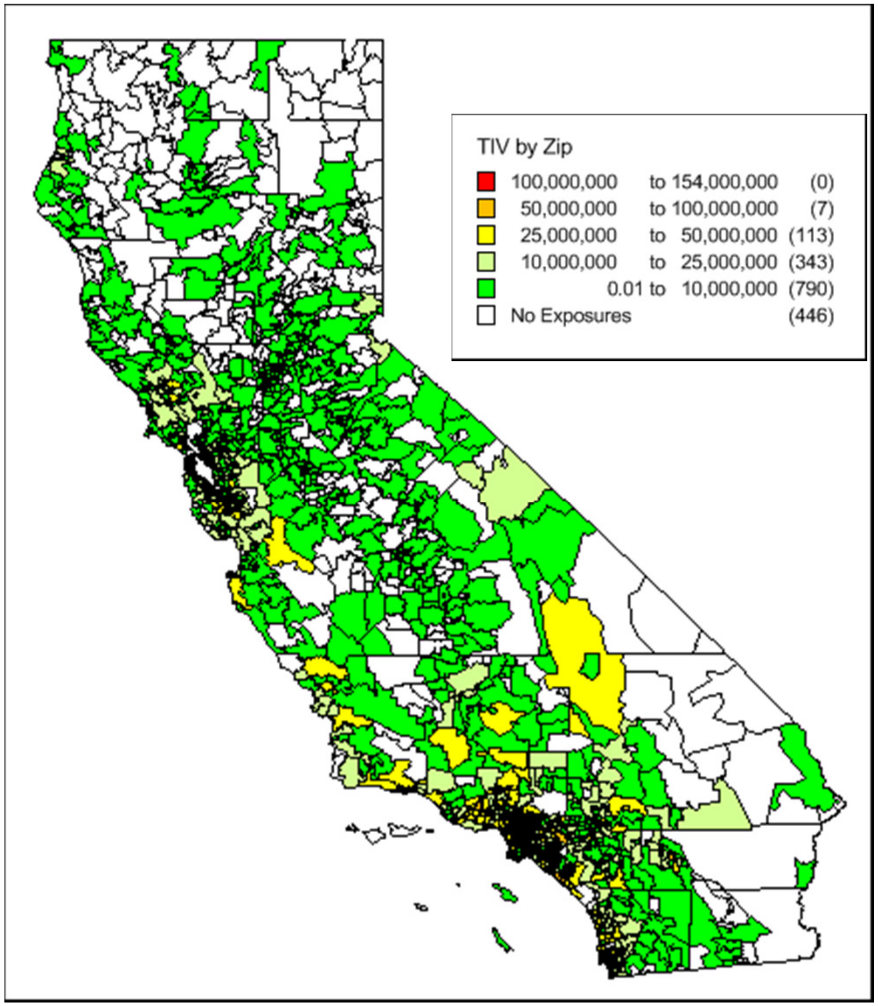
	Current Process		Risk-Balanced		% Change	
Return Period	Ground-up	Gross	Ground-up	Gross	Ground-up	Gross
10	43,876,468	14,904,180	35,313,144	10,182,542	-20%	-32%
20	103,515,562	43,517,921	73,733,314	26,748,875	-29%	-39%
50	219,854,703	108,584,478	138,887,732	59,920,594	-37%	-45%
100	325,384,468	177,414,010	198,654,305	94,019,126	-39%	-47%
250	461,131,530	274,719,592	292,670,256	153,143,929	-37%	-44%
500	567,474,232	352,550,184	374,637,322	208,614,522	-34%	-41%
1,000	686,997,292	440,047,558	463,999,033	271,550,197	-32%	-38%
AAL	19,383,390	8,681,896	14,078,673	5,230,033	-27%	-40%
StDec	66,849,274	37,846,014	44,779,635	22,809,266	-33%	-40%
Policy Count		19,299		25,140		30%
Total TIV		12,644,349,045		16,447,015,381		30%
Average Coverage A		448,754		448,754		0%
Average TIV		655,182		654,205		0%
Total Premium		19,900,063		19,900,063		0%
1:250 PML/Premium		13.80		7.70		-44%
1:100 PML/Premium		8.92		4.72		-47%
AAL/Premium		0.44		0.26		-40%

Risk-Balanced Portfolio

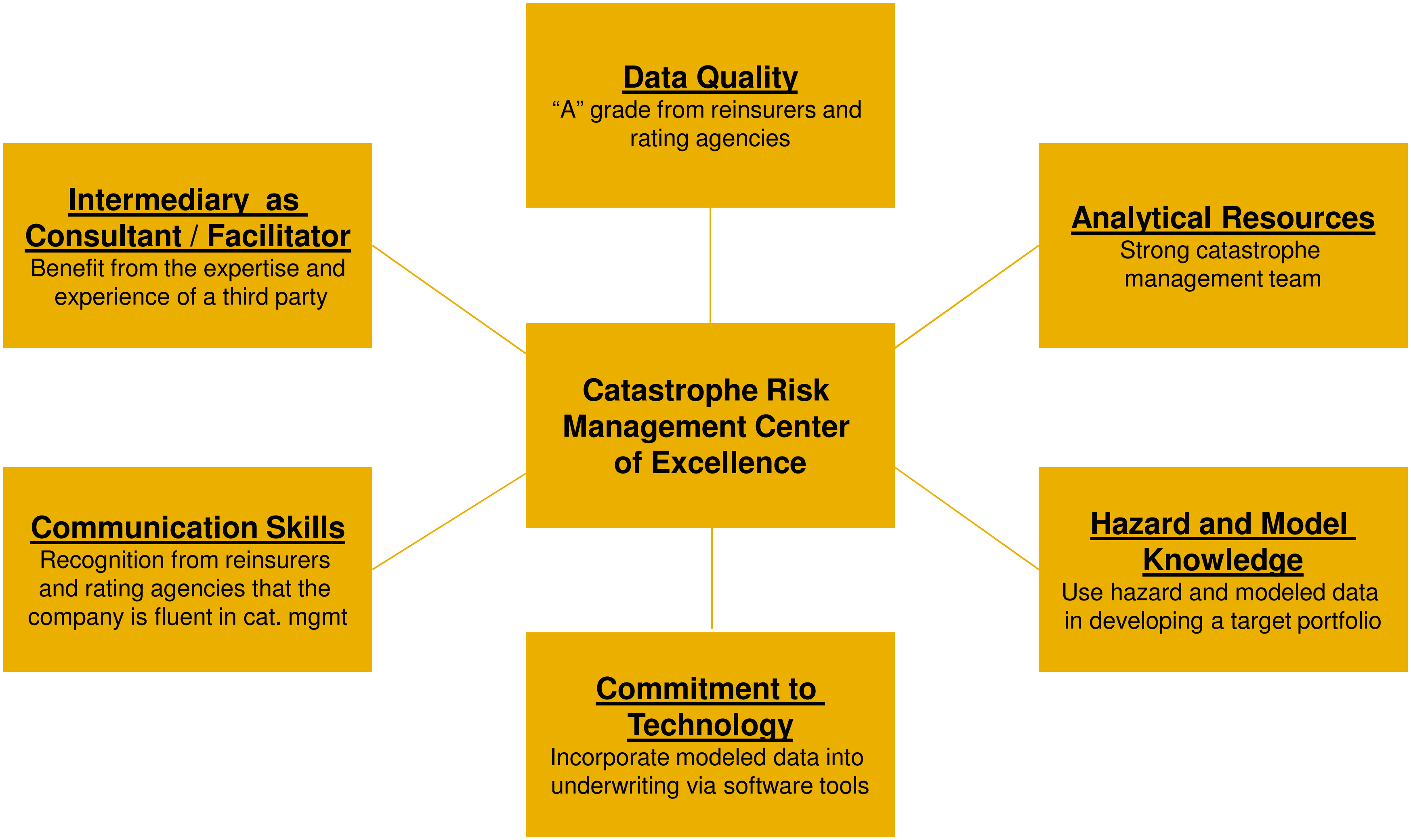
Baseline



Risk-Balanced



Catastrophe Risk Management – Center of Excellence



Catastrophe Risk Management Center of Excellence

Data Quality
"A" grade from reinsurers and rating agencies

Intermediary as Consultant / Facilitator
Benefit from the expertise and experience of a third party

Analytical Resources
Strong catastrophe management team

Communication Skills
Recognition from reinsurers and rating agencies that the company is fluent in cat. mgmt

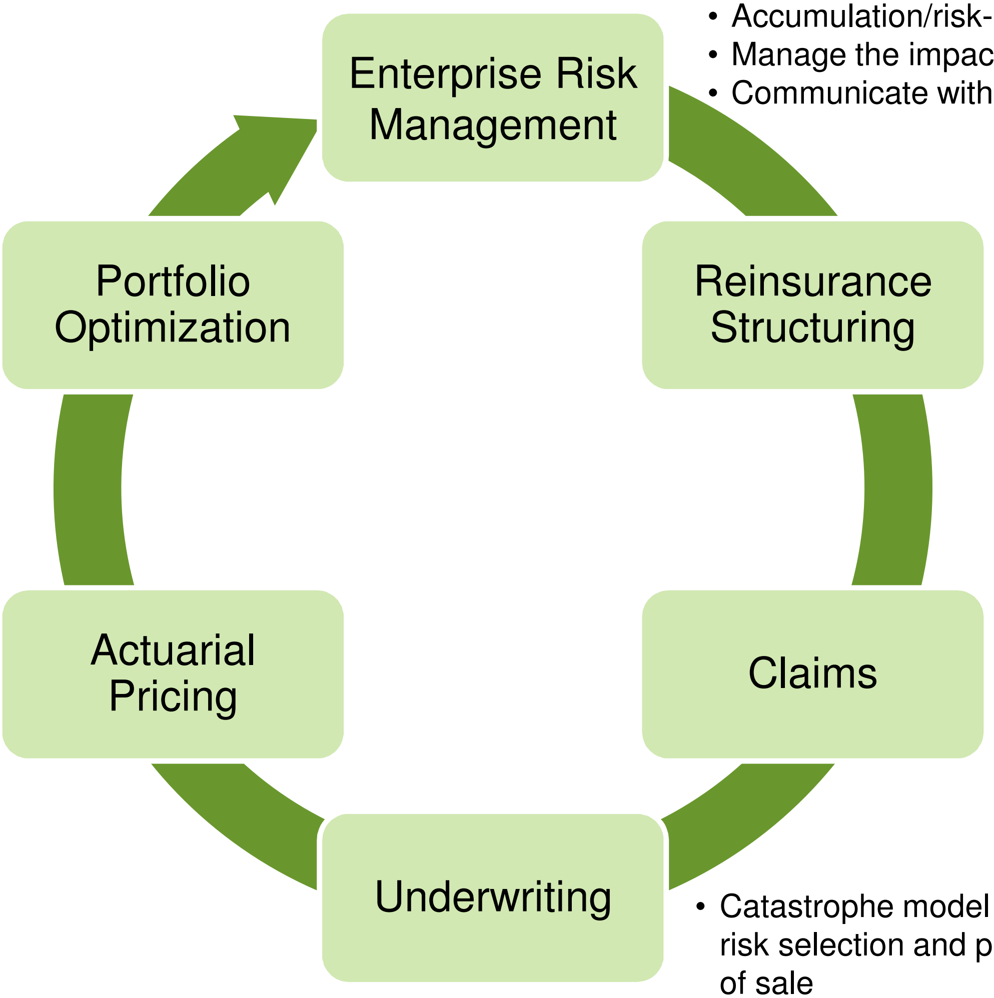
Hazard and Model Knowledge
Use hazard and modeled data in developing a target portfolio

Commitment to Technology
Incorporate modeled data into underwriting via software tools

Managing Earthquake Risk with Catastrophe Models

AIR

Application of Catastrophe Models to Primary Insurance Companies



Enterprise Risk Management

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

Reinsurance Structuring

- Use models to structure reinsurance treaties
- Use models to evaluate reinsurance purchases

Claims

- Advance planning, resource deployment, post-event communications

Underwriting

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

Actuarial Pricing

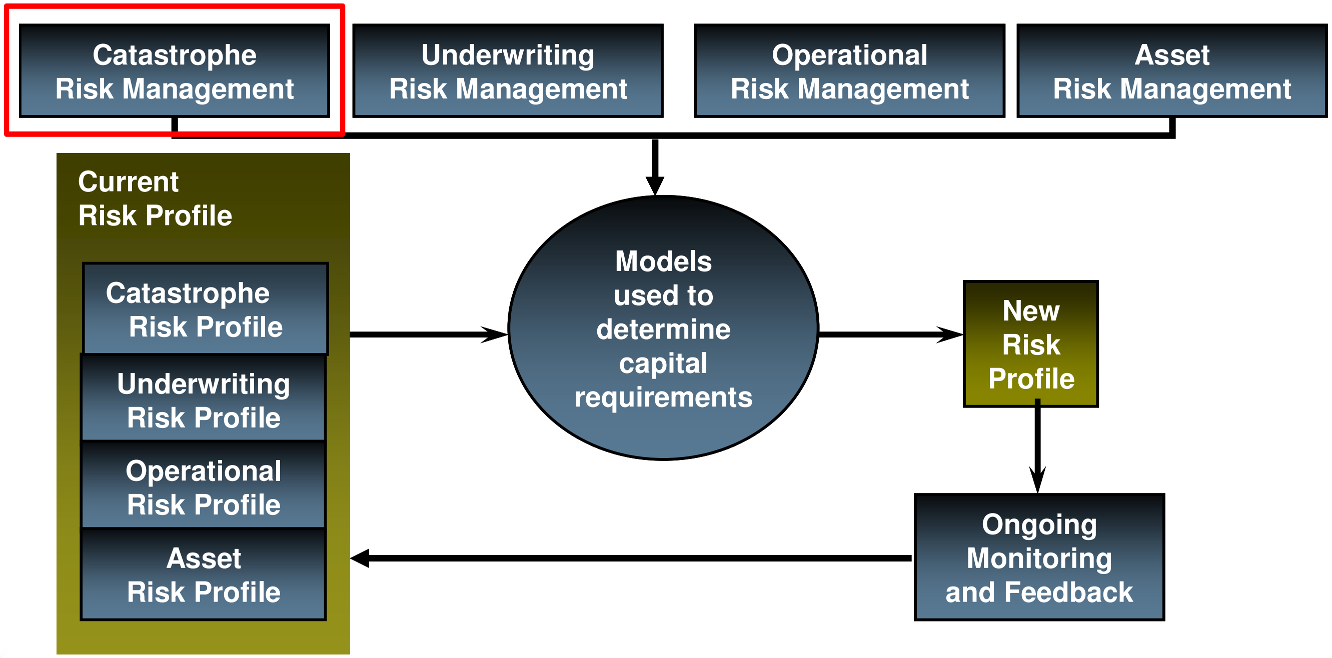
- Use model outputs in rate filings and in pricing of individual policies or programs

Portfolio Optimization

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

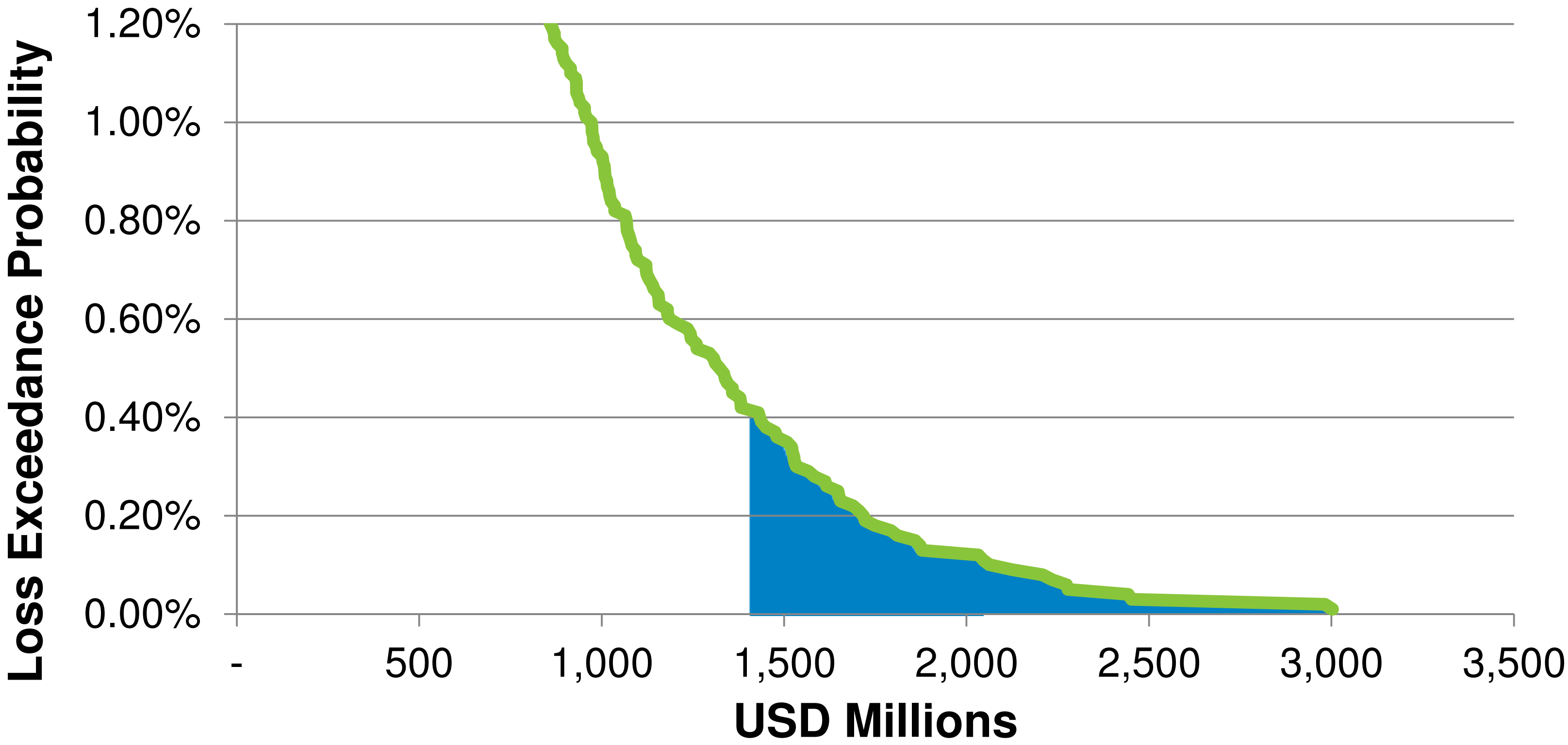
What is ERM and Why Does it Require Model Results?

- 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%

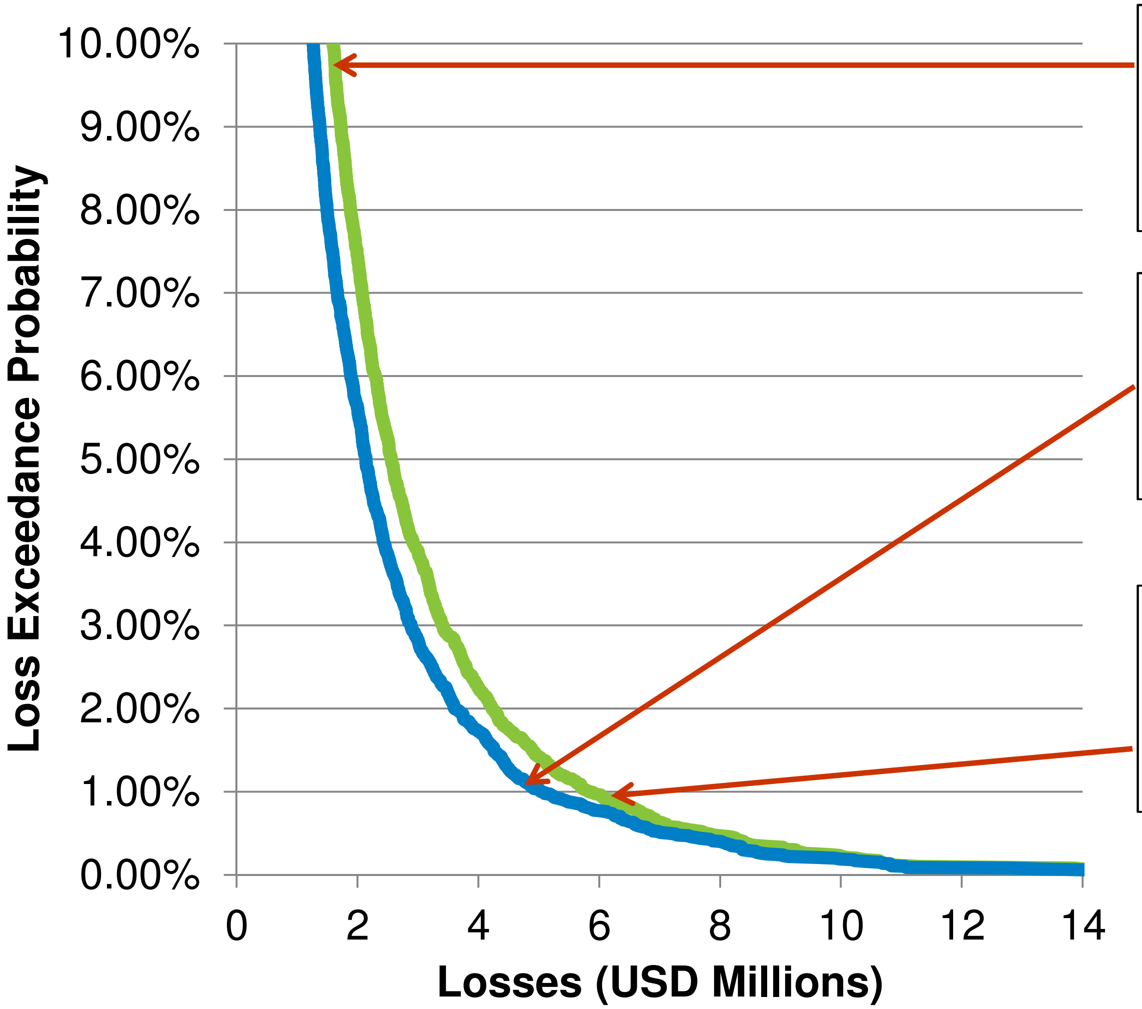


TVaR is a standard output of AIR software products

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

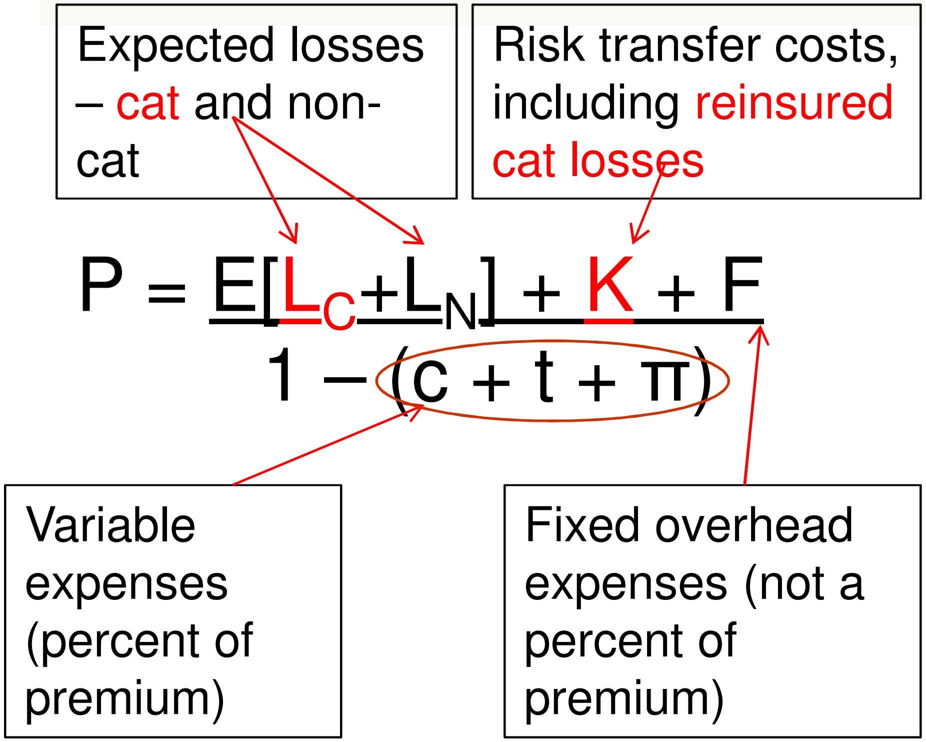
Coverage for severe events ("the big one") based on maximums at selected return periods

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)

Managing Capacity: 'Last Seat on an Airplane' Philosophy

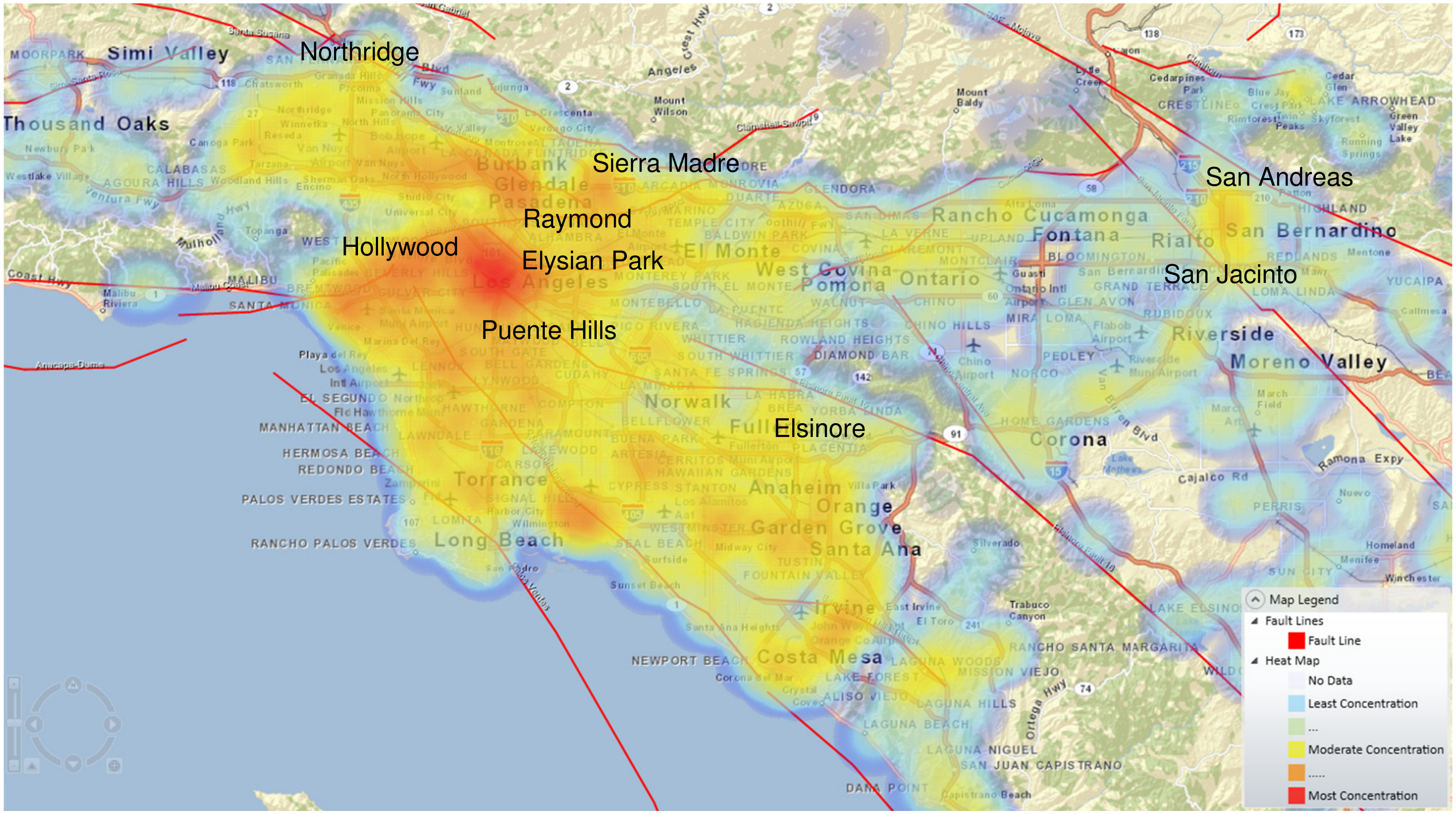
- The last seat booked on a full airplane is the most expensive
- Why not use the same thought for the last dollar of capacity on a fault?
  - Non-admitted business
  - Changing rating / Underwriting guidelines as capacity "fills up"
  - Re-underwriting / rating ENTIRE book over the annual cycle to meet the increasing / decreasing demand as influenced by corporate appetite

Catastrophe Models Enable Fault Management to Help Control Overall Risk

Loss	Event	Magnitude	Fault
2,707,351,345	110007291	6.8	Northridge_
2,684,925,863	110025255	6.9	Northridge_
2,623,156,259	110029266	6.6	Hollywood_
2,577,932,456	110053211	6.4	Puente_Hills_(SantFe_Springs)_
2,552,324,744	110052744	6.4	Elysian_Park_(Upper)_
2,510,187,818	110001664	6.9	Elsinore:_W_
2,506,411,662	110022190	6.5	Raymond_
2,454,086,323	110067140	6.6	SantMonicalt_1_
2,434,921,378	110023131	7.0	SierrMadre_
2,409,796,978	110006646	7.3	Palos_Verdes_
2,403,899,137	110043451	7.8	San_Jacinto:_SBV+SJV+A+C_
2,331,331,353	110040102	7.8	San_Jacinto:_SBV+SJV+A+C_
2,313,906,245	110019304	6.9	Elysian_Park_(Upper)_
2,265,782,580	110050341	7.0	SantMonicConnected_alt_2_
2,245,010,275	110014048	6.6	Raymond_
2,236,160,405	110033423	8.0	S._San_Andreas:_PK+CH+CC+BB+NM+SM_
2,227,982,958	110058573	7.9	S._San_Andreas:_SM+NSB+SSB+BG+CO_
2,225,690,300	110020629	6.7	Northridge_
2,197,063,955	110061608	7.9	S._San_Andreas:_SM+NSB+SSB+BG_
2,143,565,649	110018063	6.9	Puente_Hills_(LA)_
2,077,950,438	110064170	6.6	Puente_Hills_(Coyote_Hills)_
1,937,860,691	110040428	6.9	SierrMadre_Connected_

250yr event

AIR's NGP Provides Spatial Analytics Exposure Heat Maps to Enable Better Exposure Concentration Management



Managing Earthquake Risk with Mapping

TOWERS WATSON

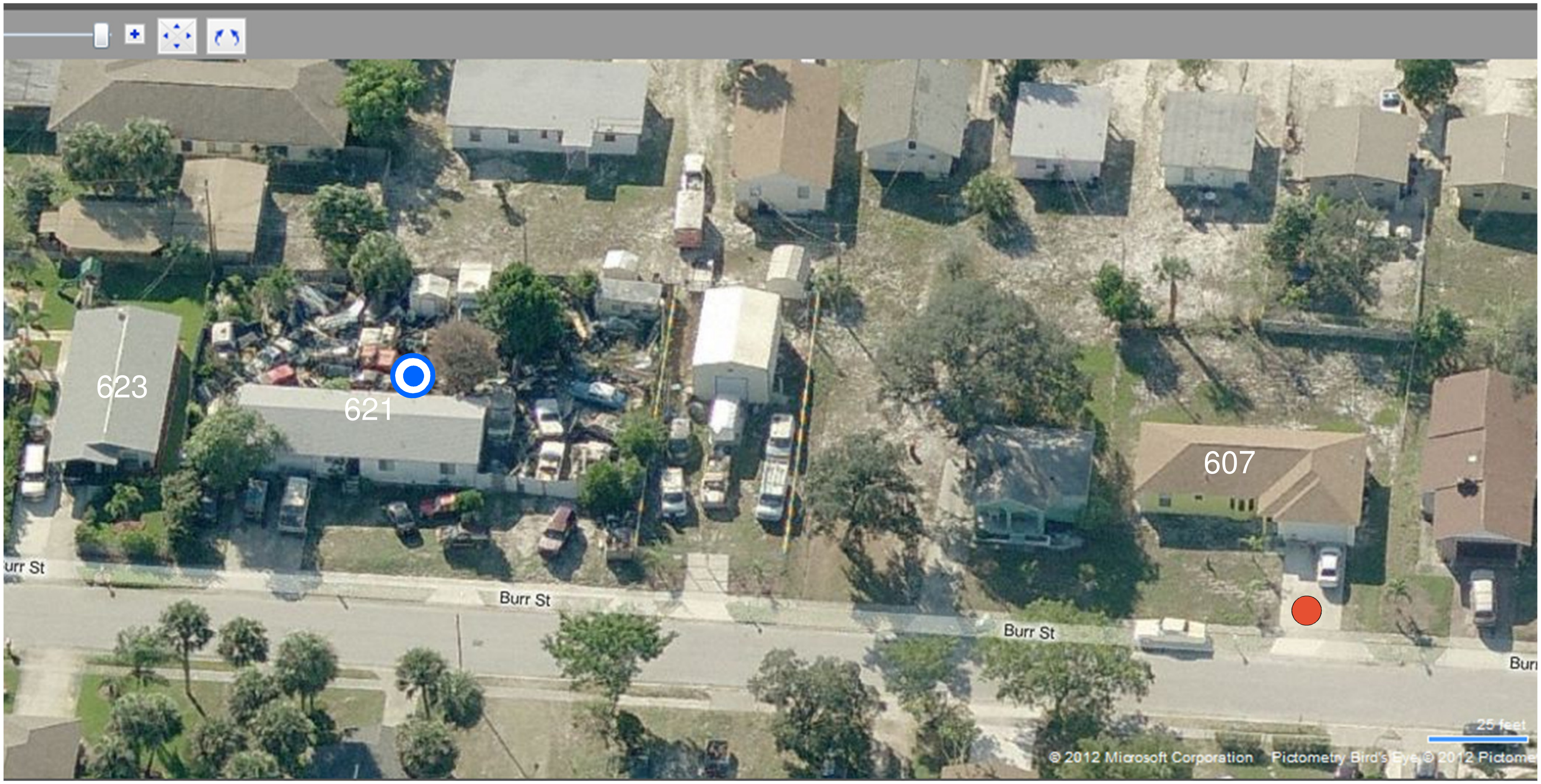
Catastrophe Risk Management - Mapping

- Mapping is a key element of catastrophe risk management
  - Catastrophes have a fundamental spatial component
  - Mapping software provides the fundamental capabilities to visualize exposure concentrations

- Advances in technology have raised awareness and brought significant improvements in capabilities in recent years
  - Microsoft Bing / Google Maps / Google Earth
  - Satellite / aerial / street imagery
  - Parcel-level geocoding

Parcel Level vs. Street Interpolated Geocoding

621 Burr St., Melbourne, FL 32901



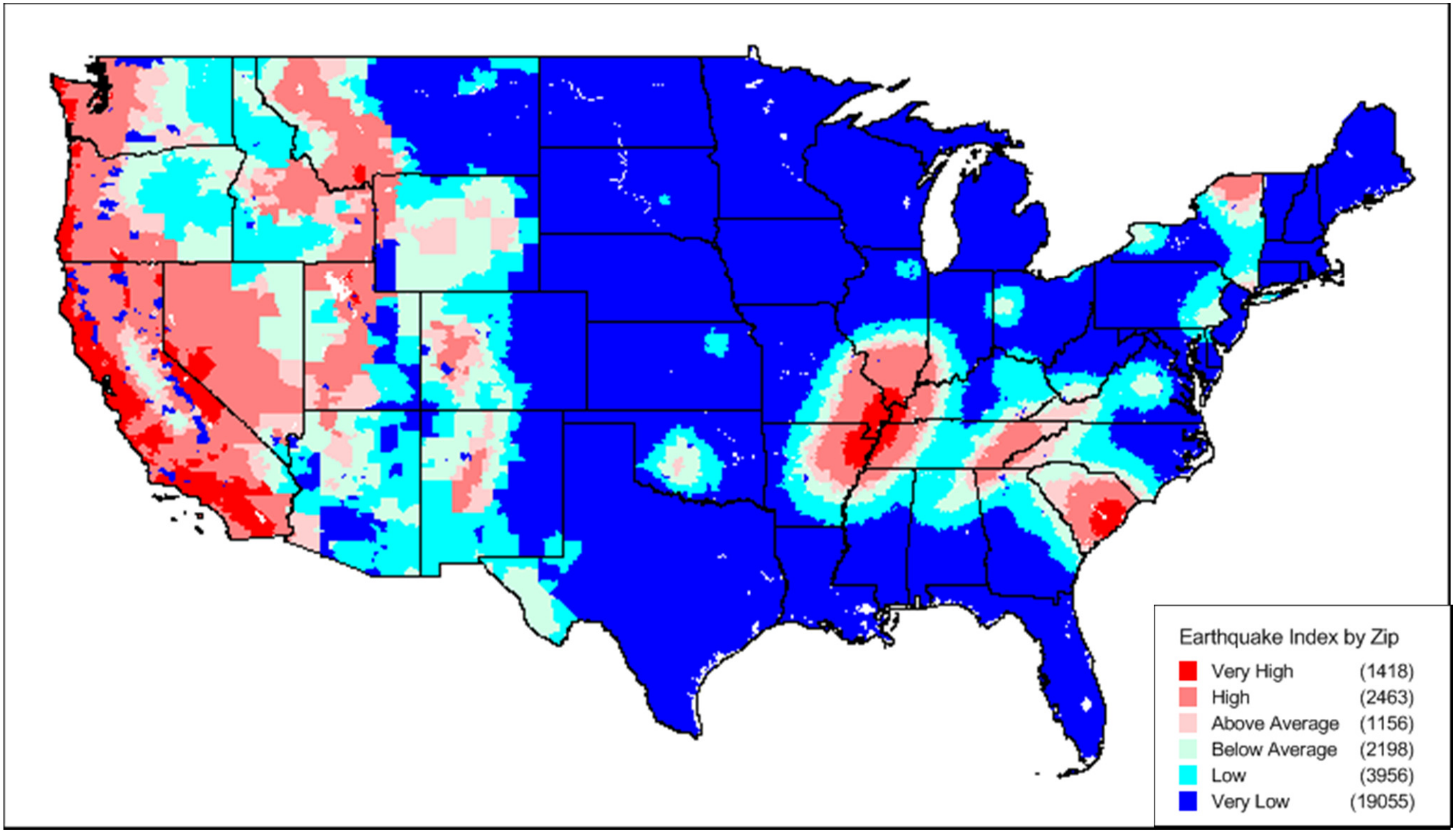
◉ Parcel   ● Interpolated

Portfolio vs. Location - Mapping

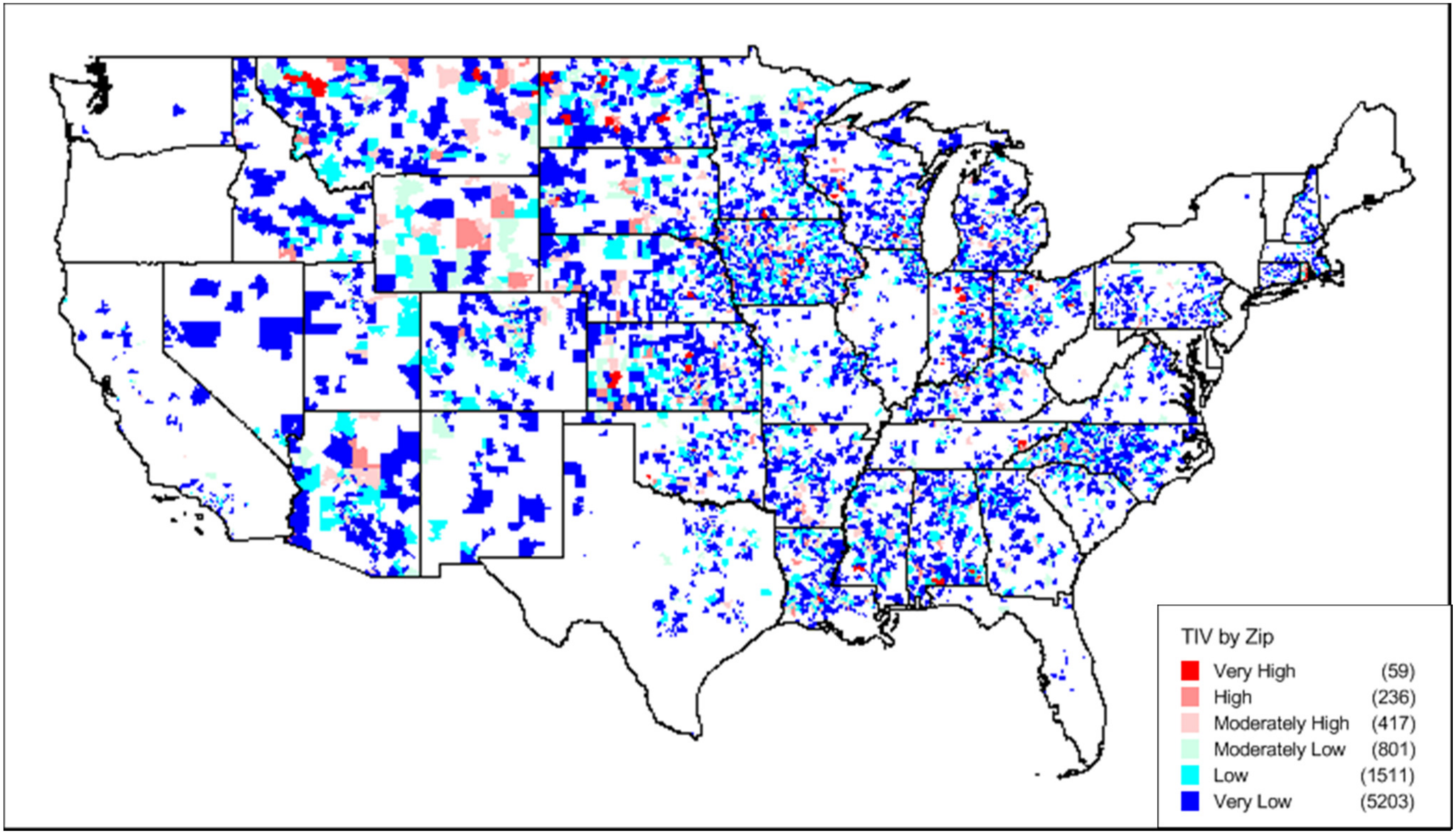
- Portfolio
  - Review concentrations
  - Review hazards
  - Review territories

- Location
  - Individual risk underwriting
    - Hazard
    - AAL / other loss metrics

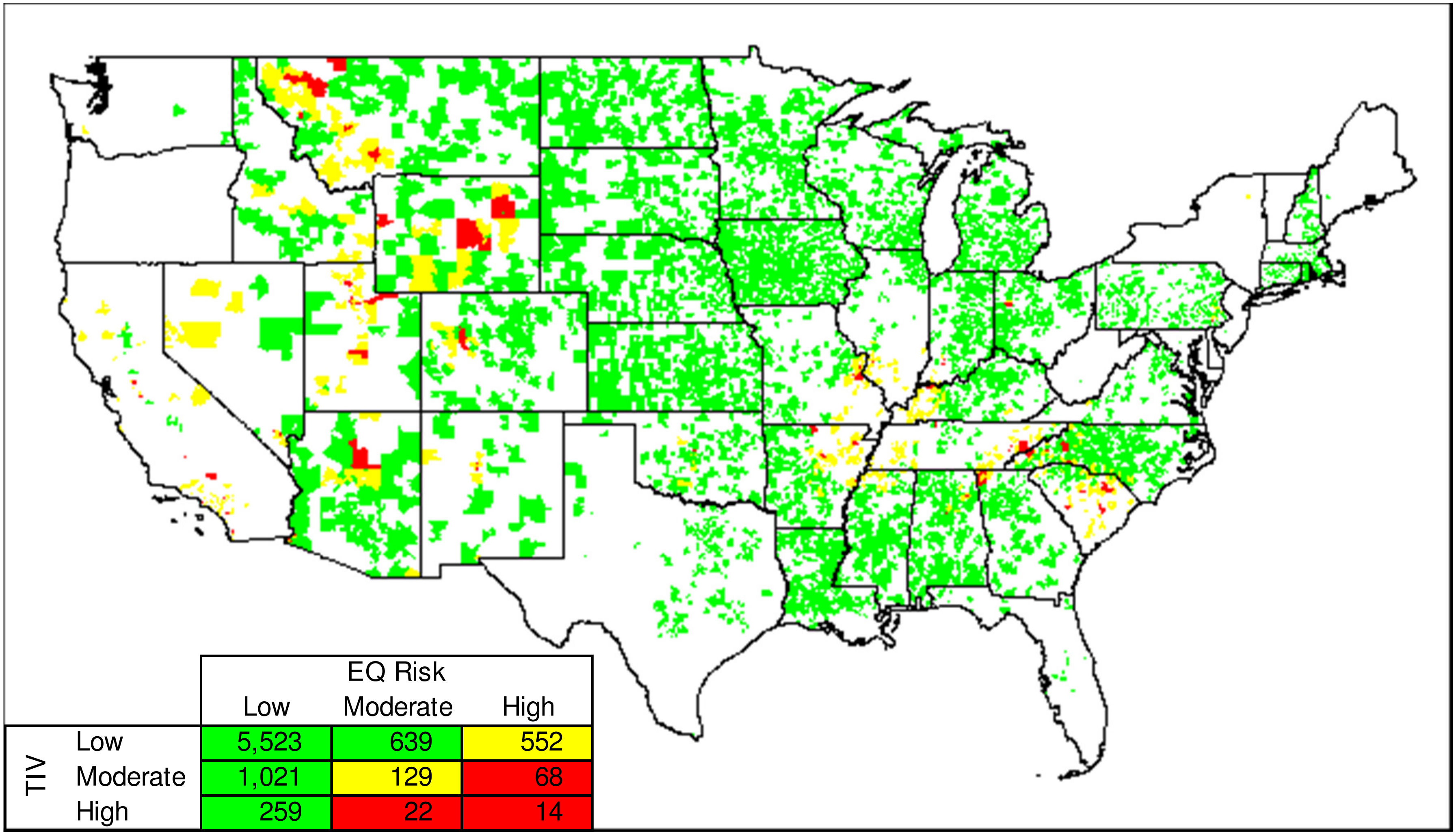
Portfolio Review - Map of Earthquake Hazard



Portfolio Review - Map of Exposure

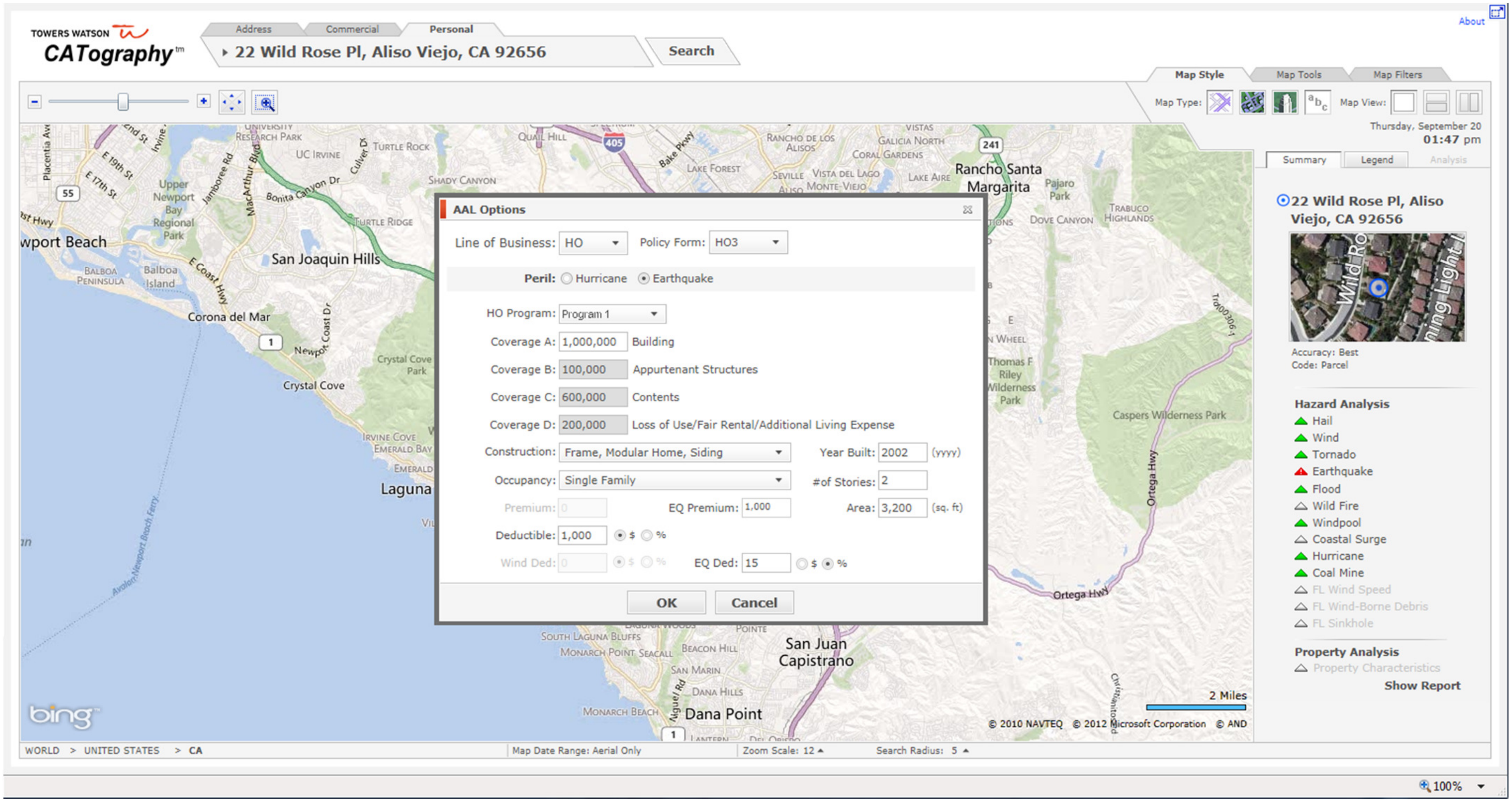


Portfolio Review - Map of Hazard and Exposure Overlaid



		EQ Risk		
		Low	Moderate	High
TIV	Low	🟩 5,523	🟩 639	🟨 552
	Moderate	🟩 1,021	🟨 129	🟥 68
	High	🟩 259	🟥 22	🟥 14

Location Underwriting



▸ 22 Wild Rose Pl, Aliso Viejo, CA 92656

AAL Options

Line of Business: HO

Policy Form: HO3

Peril: ○ Hurricane ● Earthquake

HO Program: Program 1

Coverage A: 1,000,000 Building

Coverage B: 100,000 Appurtenant Structures

Coverage C: 600,000 Contents

Coverage D: 200,000 Loss of Use/Fair Rental/Additional Living Expense

Construction: Frame, Modular Home, Siding

Year Built: 2002 (yyyy)

Occupancy: Single Family

#of Stories: 2

Premium: 0

EQ Premium: 1,000

Area: 3,200 (sq. ft)

Deductible: 1,000 ● $ ○ %

Wind Ded: 0 ● $ ○ %

EQ Ded: 15 ○ $ ● %

OK Cancel

Thursday, September 20
01:47 pm

22 Wild Rose Pl, Aliso Viejo, CA 92656

Accuracy: Best
Code: Parcel

Hazard Analysis

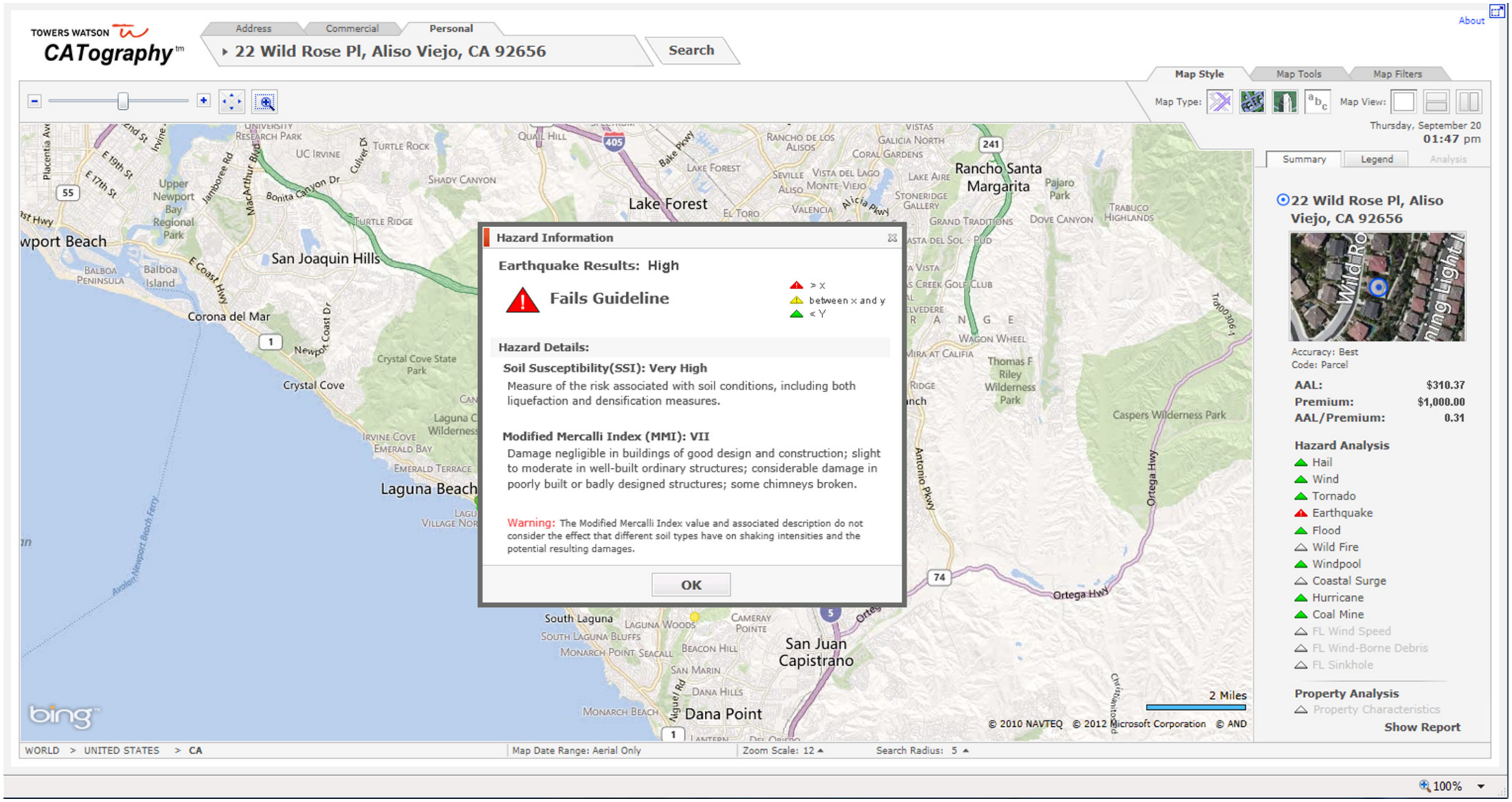
- Hail
- Wind
- Tornado
- Earthquake
- Flood
- Wild Fire
- Windpool
- Coastal Surge
- Hurricane
- Coal Mine
- FL Wind Speed
- FL Wind-Borne Debris
- FL Sinkhole

Property Analysis

- Property Characteristics

Show Report

Location Underwriting – Evaluating Hazard



22 Wild Rose Pl, Aliso Viejo, CA 92656

Thursday, September 20
01:47 pm

Hazard Information

Earthquake Results: High

Fails Guideline

- 🟥 > X
- 🟨 between x and y
- 🟩 < Y

Hazard Details:

Soil Susceptibility(SSI): Very High

Measure of the risk associated with soil conditions, including both liquefaction and densification measures.

Modified Mercalli Index (MMI): VII

Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.

Warning: The Modified Mercalli Index value and associated description do not consider the effect that different soil types have on shaking intensities and the potential resulting damages.

OK

22 Wild Rose Pl, Aliso Viejo, CA 92656

Accuracy: Best
Code: Parcel

AAL:	$310.37
Premium:	$1,000.00
AAL/Premium:	0.31

Hazard Analysis

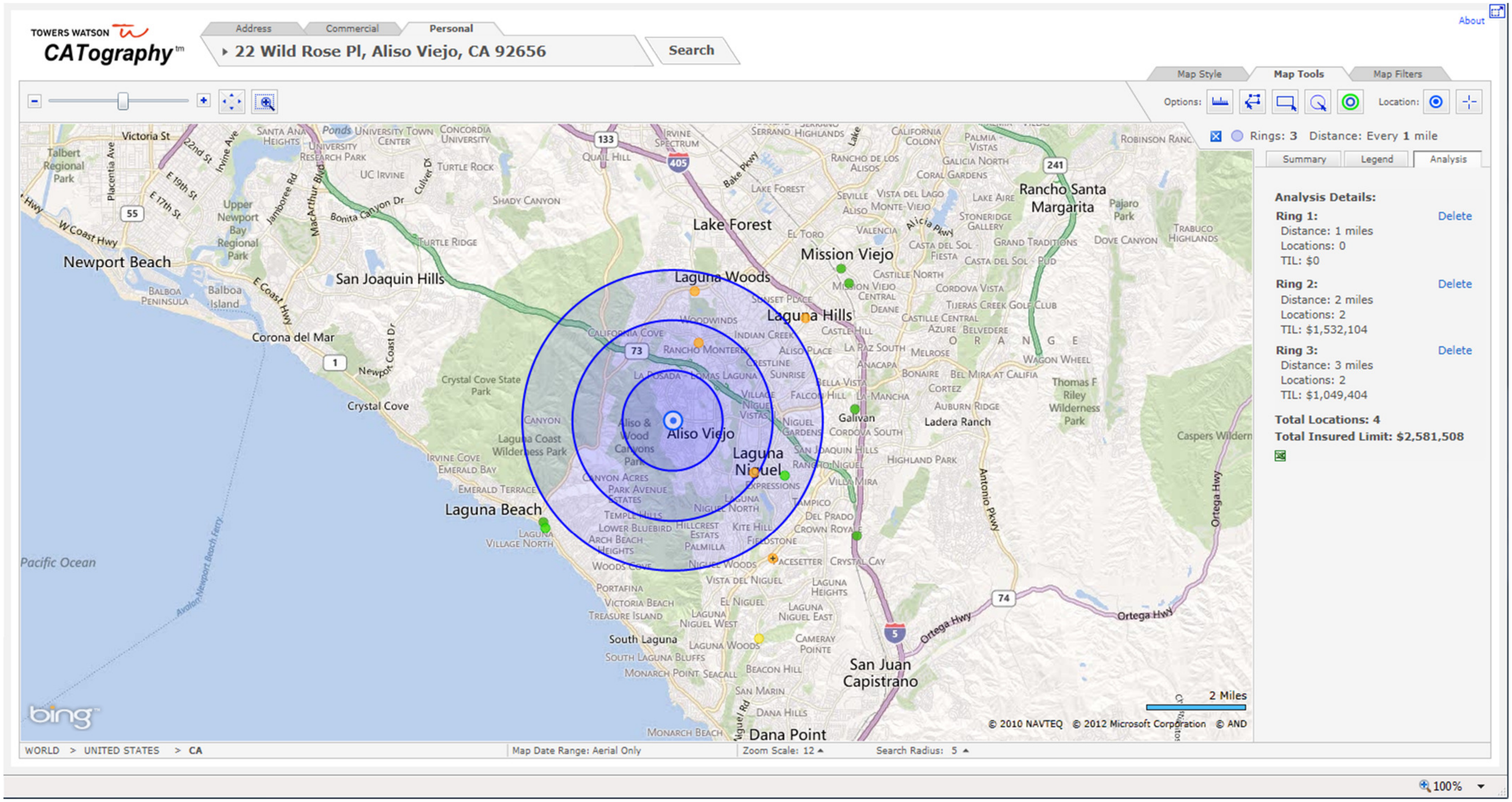
- 🟩 Hail
- 🟩 Wind
- 🟩 Tornado
- 🟥 Earthquake
- 🟩 Flood
- △ Wild Fire
- 🟩 Windpool
- △ Coastal Surge
- 🟩 Hurricane
- 🟩 Coal Mine
- △ FL Wind Speed
- △ FL Wind-Borne Debris
- △ FL Sinkhole

Property Analysis

- △ Property Characteristics

Show Report

Location Underwriting – Evaluating Concentration



22 Wild Rose Pl, Aliso Viejo, CA 92656

Rings: 3 Distance: Every 1 mile

Analysis Details:

Ring 1: Delete
Distance: 1 miles
Locations: 0
TIL: $0

Ring 2: Delete
Distance: 2 miles
Locations: 2
TIL: $1,532,104

Ring 3: Delete
Distance: 3 miles
Locations: 2
TIL: $1,049,404

Total Locations: 4
Total Insured Limit: $2,581,508

WORLD > UNITED STATES > CA
Map Date Range: Aerial Only
Zoom Scale: 12
Search Radius: 5


Thank you!