Extreme Events:
Those of Most Concern & How to Model

Aon Re Services

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AON

Contents

Section 1

Natural Catastrophe Modeling

Property Casualty Natural Catastrophe Modeling

- Hurricane and earthquake models entered mainstream after hurricane Andrew (1992) and Northridge earthquake (1994)
- Models now well developed and incorporated into business practices
- Commercial vendors: RMS, AIR, EQECat, Aon Impact Forecasting
- Model performance in 2004-05 storms often less than exemplary, but “the best available information”
- Model output relied upon by reinsurers to price catastrophe coverage
- Model output integrated into rating agency evaluation of capital adequacy
  - A.M. Best uses greater of 100 year hurricane and 250 year earthquake
  - S&P uses 250 year annual aggregate loss
  - Other stress tests apply

What is a Probable Maximal Loss (PML)?

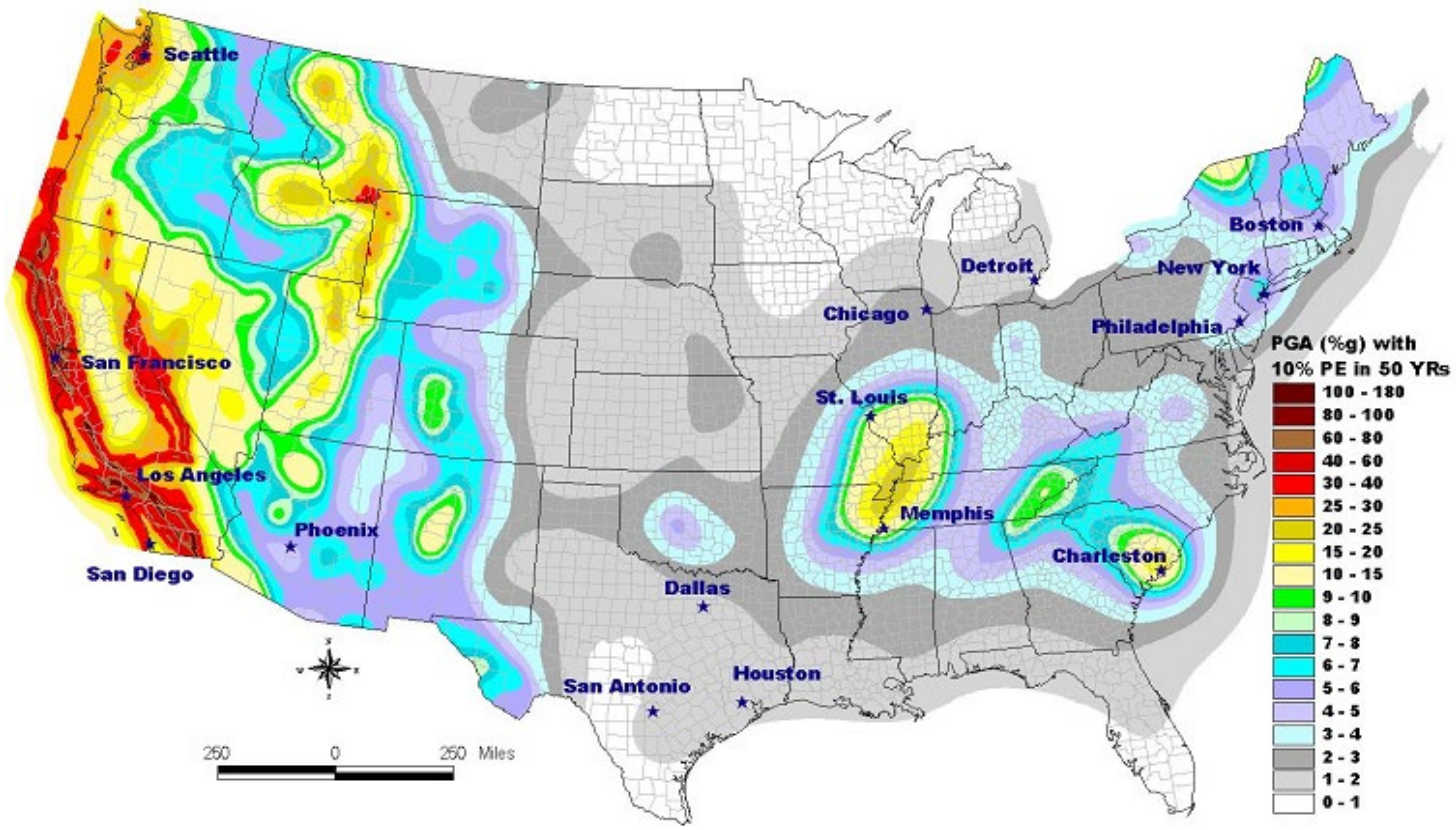
- Catastrophe models typically produce compound Poisson output: event, event frequency, event size
- Occurrence Probable Maximal Loss
  - There is a 1% chance of a loss from a single event greater than the 100 year PML loss occurring each year
  - There is a 0.4% chance of a loss from a single event greater than the 250 year PML loss occurring each year
- Aggregate Probable Maximal Loss
  - Percentile points off the aggregate loss distribution
- PMLs are routinely used to manage property/casualty catastrophe exposure

Calculation of Occurrence PMLs

Event	Frequency	Cumulative Frequency	Return Period (Years)	Event Size $M
1	0.001	0.001	916.3	81,864.2
2	0.002	0.003	384.8	47,743.3
3	0.002	0.004	239.9	34,918.1
4	0.002	0.006	171.8	27,732.3
5	0.001	0.007	144.6	24,536.3
6	0.002	0.009	113.1	20,513.6
7	0.002	0.011	92.8	17,688.2
8	0.002	0.013	79.5	15,710.5
9	0.002	0.014	70.1	14,244.2
10	0.002	0.016	62.4	12,992.4
…	…	…	…	…
998	0.001	2.101	0.5	2,316.0
999	0.002	2.103	0.5	2,050.4
1000	0.001	2.104	0.5	1,781.5

100 Year PML between $17.7B and $20.5B

US Earthquake Hazard Intensity



Contours show 90th Percentile of 50 year Peak Ground Acceleration

Earthquake Model Results
Hypothetical Earthquake PMLs

Return Period	Life Cover ($)	Disability Cover ($)	Potential Total ($)
1,000	91,556,693	101,111,428	192,668,121
500	50,749,894	49,985,492	100,735,386
250	26,617,542	22,642,175	49,259,717
100	9,761,728	6,811,162	16,572,890
50	3,996,670	2,290,467	6,287,137
20	1,089,075	397,282	1,486,357
10	363,071	69,920	432,991
Annual Average	**678,813**	**613,830**	**1,292,643**

Event	Death Cost ($)	Injury Cost ($)	Total Cost ($)
Ft Tejon (1857)	80,402	2,954,406	3,034,808
San Francisco (1906)	4,428,980	104,590,761	109,019,741
San Fernando (1971)	708,587	2,194,622	2,903,209
Loma Prieta (1989)	17,009	1,494,621	1,511,630
Northridge (1994)	107,431	4,078,499	4,185,930

- Modeling life coverage with property based techniques: how do you translate building damage into loss of life
  - Building occupied? Building collapse? Timing? Death or Injury?

Section 2

Terrorism Modeling Methodology

Terrorism Modeling

- Discuss design and implementation of terrorism extreme event modeling

- Terrorism modeling useful for
  - Company solvency, exposure management and underwriting guidelines
  - TRIA – Congress considering adding coverage for group life
  - Rating agency evaluations

- A.M. Best Property & Casualty, Supplemental Stress Test
  - BCAR includes terrorism stress test, event selected as the greater of:
    - Modeled loss from 5-Ton truck bomb occurrence or
    - 50% of exposure in the company's highest concentration location

- Indications that life & health companies will be held to similar standards
  - A.M. Best Supplemental Rating questionnaire asks about terrorism concentrations, $ and life exposures, and details of catastrophic reinsurance
  - S&P enhanced capital model: "credit for catastrophic reinsurance, assuming no significant risks are excluded will be permitted up to 20% of the base charge [for mortality risk]"

Terrorism Modeling

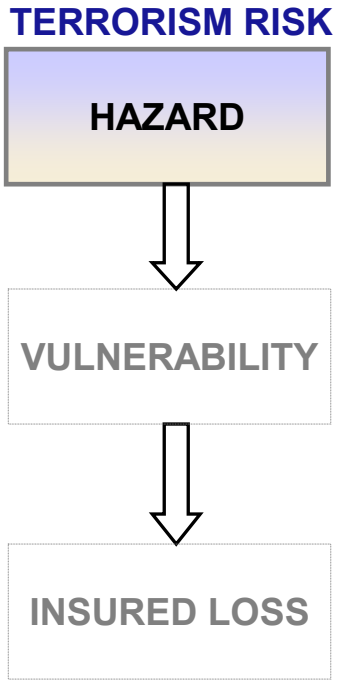
- Challenges
  - Where might future terrorist attacks occur?
  - The relative likelihood of an attack on different targets?
  - Frequency of terrorist attacks?
  - For each possible scenario, what is the insured loss?

- What we can do
  - Database of potential targets
  - Relative probabilities through client input
  - Range of annual frequencies
    - E.G. 1 in 5 years, 1 in 2 years, 1 per year…
  - Given an attack on a specific target, insured loss can be calculated (scientific and engineering knowledge)

- Aon Re developed the first terrorism model, shortly after 9/11
  - Maintained by Impact Forecasting (IF)
  - No “black-box”, clients are able to modify relative event probabilities
  - Model provides exposure concentration and PML analyses

Components of a Terrorism Model

- Hazard
  - Location of an attack
  - Type of attack
    - Truck bomb, airplane crash, nuclear, chemical, radiological, biological
  - Event database contains 24 attack modes at 7,827 targets
    - Total of 187,848 events



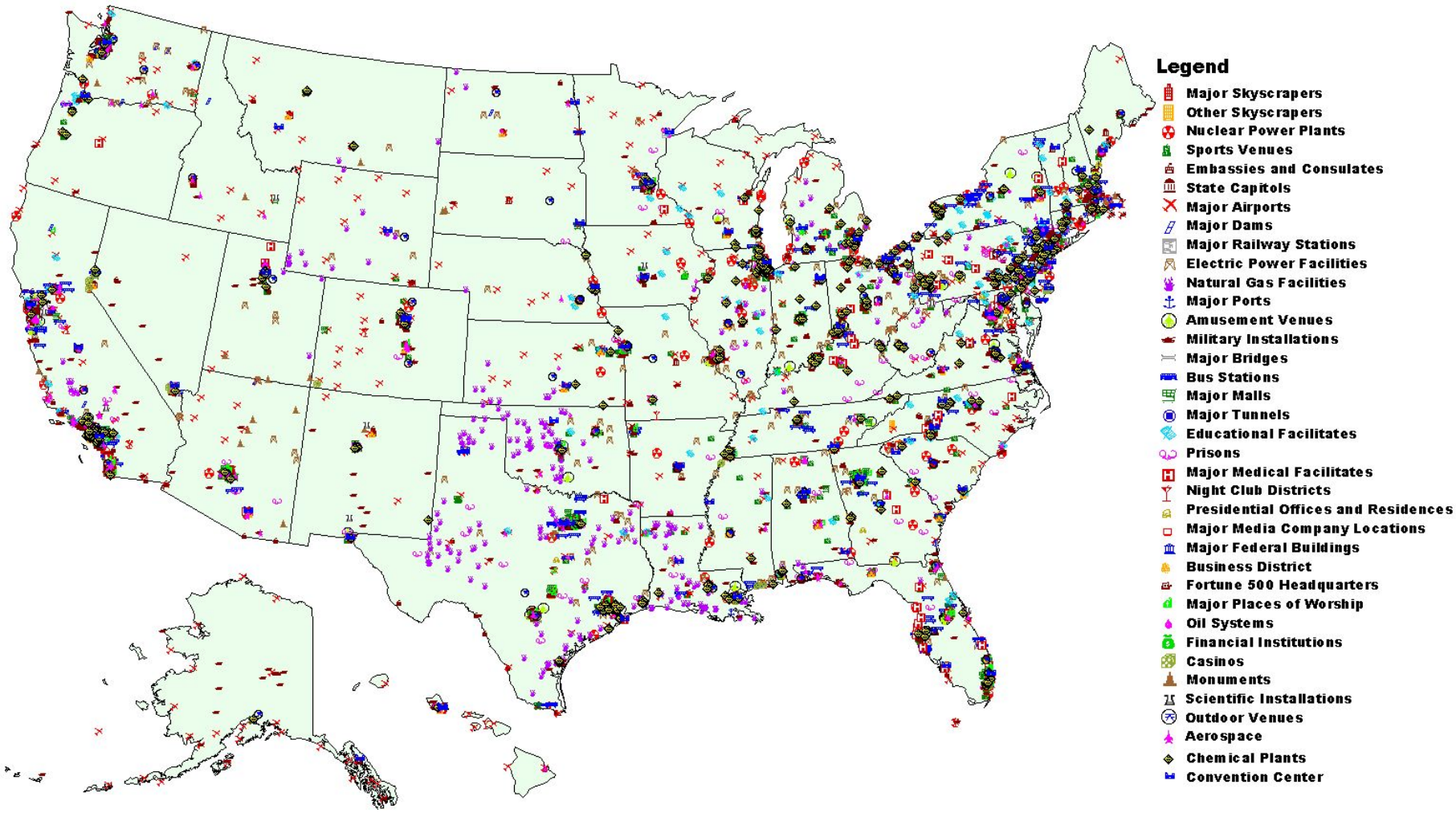
Aon United States Terrorism Risk Database v. 3.4

- Compiled from various sources including:
  - Federal Emergency Management Agency (FEMA)
  - Environmental Research institute (ESRI)
  - Review of government and commercial publications
  - Media releases
  - Site-specific damage functions for Oil Systems and Chemical Plants were created based on the explosive and toxic severities, and amounts of chemicals at each plant. This data was researched from the Environmental Protection Agency (EPA), and the resulting damage functions were validated against the ALOHA Energy Department software.
- Data was carefully reviewed and distilled for high risk targets that have either a symbolic value or have potential to cause large economic of life loss if attacked
- Database contains 7,827 such targets, classified into 37 categories.

Aon Terrorism Risk Database Version 3.4

Number	Target	Count
1	Major Skyscrapers (Top 100)	100
2	Other Skyscrapers (101-500)	400
3	Nuclear Power Plants	75
4	Sports Venues	393
5	Embassy and Consulates	1,377
6	State Capitols	50
7	Major Airports	429
8	Major Dams	10
9	Major Railway Stations	21
10	Electric Power Facilities	247
11	Natural Gas Facilities	243
12	Major Ports	47
13	Amusement Venues	74
14	Military Installations	445
15	Major Bridges	10
16	Bus Stations	252
17	Major Malls	250
18	Major Tunnels	9
19	Educational Facilities	203
20	Prisons	102
21	Major Medical Facilities	198
22	Nightclub Districts	527
23	Presidential Offices and	6
24	Major Media Company Locations	43
25	Major Federal Buildings	79
26	Business District	96
27	Fortune 500 Headquarters	447
28	Major Places of Worship	266
29	Oil Systems	300
30	Financial Institutions	34
31	Casinos	101
32	Monuments	52
33	Scientific Installations	34
34	Outdoor Venues	103
35	Aerospace and Defense	230
36	Chemical Plants	500
37	Convention Centers	74
	Total Targets	7,827

Aon United States Terrorism Risk Database v. 3.4



Terrorist Attack Types

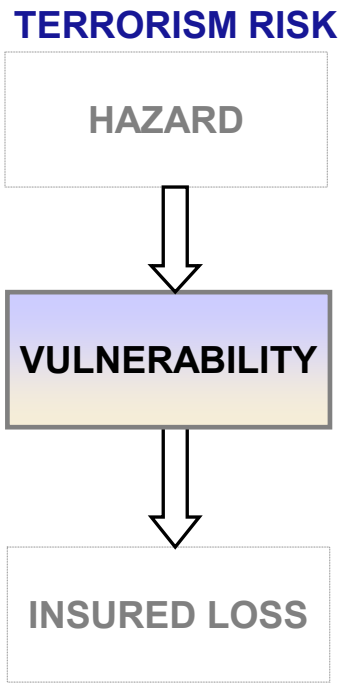
7	7	3	3	4
Conventional	**Radiological**	**Biological**	**Chemical**	**Nuclear**
Cruise missile	Cruise missile	Large event	Large event	100 kiloton
Multiple aircraft	Multiple aircraft	Medium event	Medium event	20 kiloton
Single aircraft	Single aircraft	Small event	Small event	10 kiloton
Large truck bomb	Large truck bomb			1 kiloton
Small truck bomb	Small truck bomb			
Car bomb	Car bomb			
Human bomb	Human bomb			

Collectively “CBRN” or “NBC”

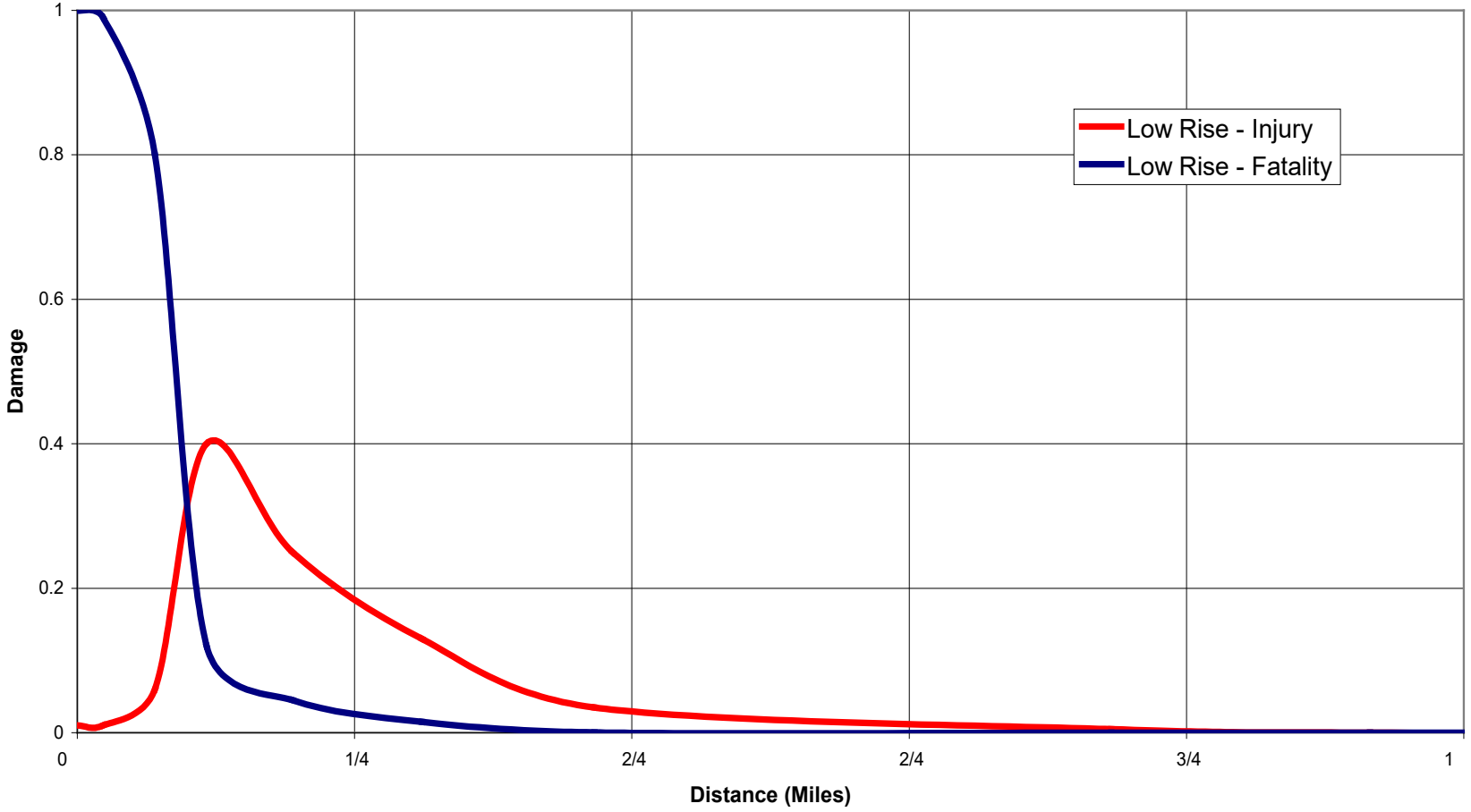
Total attack types = 24

Components of a Terrorism Model

- Vulnerability
  - Level of damage at each insured location
  - Each attack mode has its own damage pattern
    - Truck bomb, nuclear, radiological
    - Explosive attenuation relationships
  - Damage relationships vary by coverage

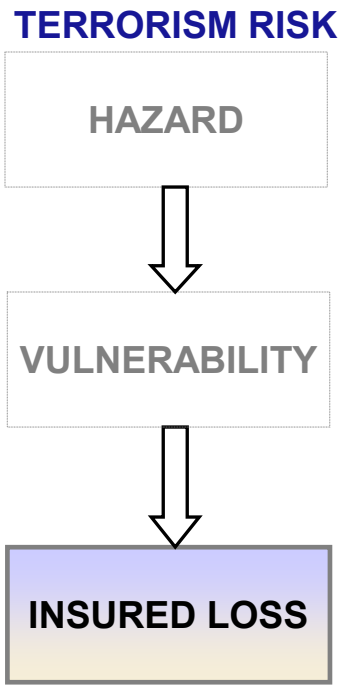


Damage Function Sample
Conventional Large Truck Bomb - Low Rise

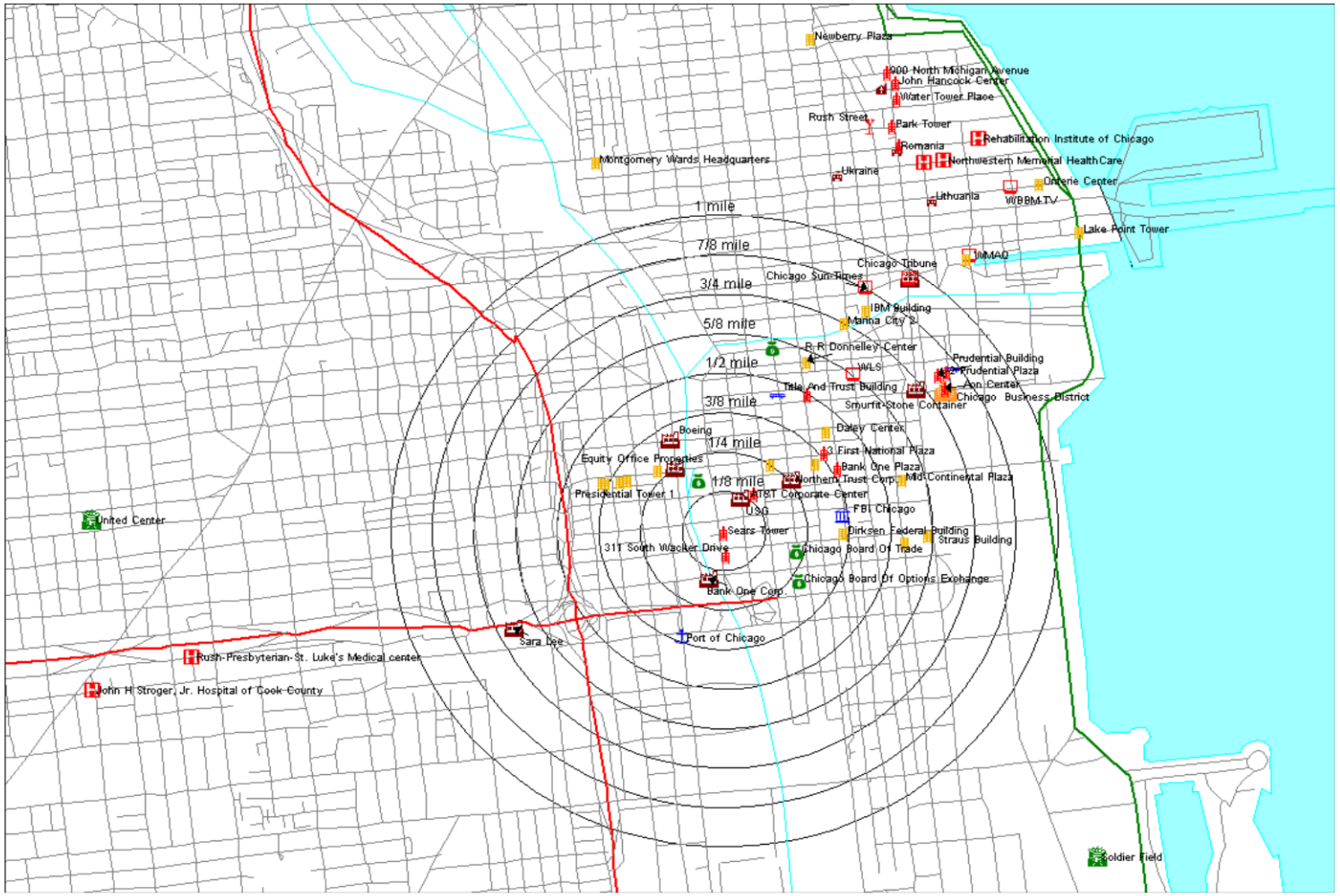


Components of a Terrorism Model

- Insured loss
  - Ground up losses
    - Coverage, site, policy level
  - Gross insured losses
    - Limits, deductibles, coinsurance and attachment points
  - Net losses
    - Facultative reinsurance
    - Proportional and non-proportional per-risk reinsurance coverage



Sample Deterministic Geo-spatial Analysis of Chicago



Terrorism Modeling
Life, Accident, and Disability

- Data requirements: life, accident, and disability insurance exposures by location
  - Life, accident, and disability – net retained insured values
  - Use of Dun & Bradstreet third party data to supplement client data
  - “At home” and “at work” scenarios establish range of PMLs
  - Transformation based on census statistics for individual and group portfolios

- Data resolution
  - Aggregated zip level data
  - Geo-coded location level data
  - At home and/or at work distribution

- Terrorism parameters
  - Probabilities for combination of target type and attack mode
  - Client input or default values

Section 3

Terrorism Modeling Output

- Exposure Summary
- Deterministic Loss Scenarios
- Probabilistic Analysis
- Reinsurance Solutions

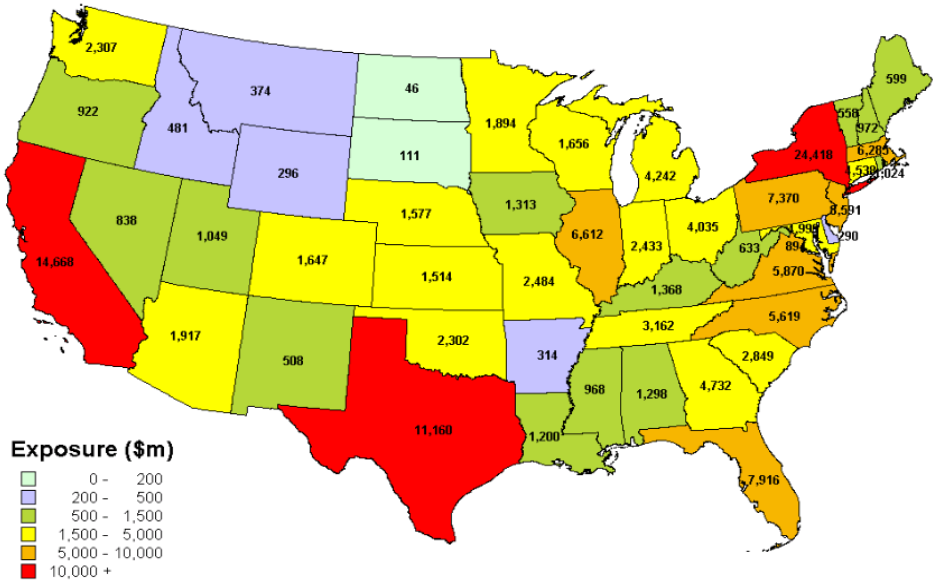
Terrorism Model Output

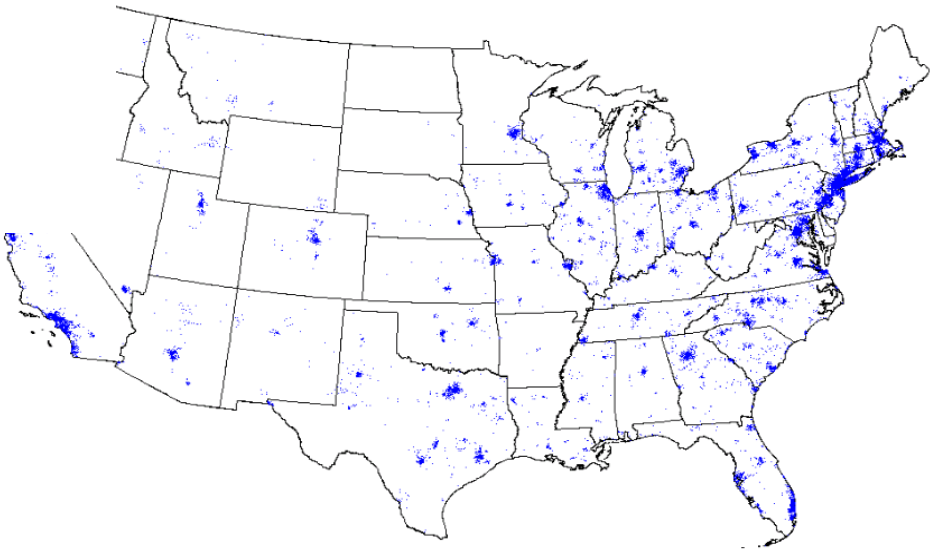
- Exposure concentration analysis
  - Exposure summary maps
  - Terrorism relativity analysis for major target types
  - Identification of largest exposure concentrations by location
  - Identification of largest exposure concentrations near terrorist targets
  - Detail maps of “hot spots”

- Probable Maximal Loss (PML) Analysis
  - Set of PML’s for different frequency assumptions
  - Average annual loss
  - By weapon type - conventional vs. CBRN attacks
  - By line

Exposure Summary

Company Exposure by State





1 dot = $5,000,000 Net Retained Volume

Top 25 Concentrations at Targets

Rank	Location	City	State	Exposure within 1/4 mile
1	Citigroup	New York City	New York	$907,708,901
2	Citicorp Center	New York City	New York	$881,550,658
3	General Motors Building	New York City	New York	$881,550,658
4	919 3rd Avenue	New York City	New York	$847,847,096
5	Metropolitian Tower	New York City	New York	$847,847,096
6	Downtown	New York City	New York	$772,720,743
7	Met Life Building	New York City	New York	$572,209,780
8	Grand Central Terminal	New York City	New York	$572,209,780
9	Chrysler Building	New York City	New York	$547,600,851
10	Chemical Bank	New York City	New York	$547,600,851
11	Chanin Building	New York City	New York	$547,600,851
12	101 Park Avenue	New York City	New York	$547,600,851
13	Gabon	New York City	New York	$547,600,851
14	Afghanistan Consulate	New York City	New York	$542,852,778
15	Pfizer	New York City	New York	$530,811,636
16	Interstate Tower	Charlotte	North Carolina	$515,807,068
17	2 First Union	Charlotte	North Carolina	$515,807,068
18	Charlotte-Gastonia-Rock Hill Business District	Charlotte-Gastonia-Rock Hill	North Carolina	$515,807,068
19	Bank of America Corp.	Charlotte	North Carolina	$515,807,068
20	Hearst Tower	Charlotte	North Carolina	$503,253,052
21	IJL Financial Center	Charlotte	North Carolina	$503,253,052
22	Carillon Tower	Charlotte	North Carolina	$503,253,052
23	Bus Station	Charlotte	North Carolina	$501,175,909
24	TIAA-CREF	New York City	New York	$477,895,713
25	Embassy of the Independent State of Samoa	New York City	New York	$475,650,528

- Concentrations also available by Zip Code

Top 25 Ten & Twenty Five Mile City Concentrations

Rank	Location	City	State	Exposure within ten miles	Exposure within twenty-five miles
1	Empire State Building	New York City	New York	$9,113,503,100	$18,476,244,302
2	United States Capitol	Washington D.C.	District Of Columbia	$1,881,842,149	$4,791,613,643
3	Prudential Tower	Boston	Massachusetts	$1,729,720,917	$3,526,095,672
4	Library Tower	Los Angeles	California	$1,704,084,433	$5,020,562,264
5	Bank of America Plaza	Dallas	Texas	$1,596,307,792	$3,244,599,471
6	Pitney Bowes	Stamford	Connecticut	$1,485,178,717	$9,310,634,416
7	South Coast Plaza	Santa Ana	California	$1,180,033,220	$2,792,524,544
8	Bank of America	Charlotte	North Carolina	$1,170,221,227	$1,808,521,595
9	Sears Tower	Chicago	Illinois	$1,148,852,989	$3,231,436,097
10	Chase Tower	Houston	Texas	$1,145,722,256	$2,000,255,040
11	Legg Mason Building	Baltimore	Maryland	$1,079,335,574	$2,568,578,521
12	Disneyland	Anaheim	California	$1,002,811,159	$3,294,489,991
13	1 Liberty Place	Philadelphia	Pennsylvania	$978,155,228	$3,371,756,583
14	Bank of America Plaza	Atlanta	Georgia	$910,006,253	$2,231,454,765
15	4 Seasons Hotel	Miami	Florida	$864,764,935	$1,805,523,568
16	Bank of America Tower	Seattle	Washington	$843,046,502	$1,542,346,572
17	State Capitol Building	Hartford	Connecticut	$786,884,680	$2,112,761,315
18	IDS Center	Minneapolis	Minnesota	$771,147,437	$1,503,525,047
19	Rochester Business District	Rochester	New York	$761,365,538	$1,063,034,557
20	USX Tower	Pittsburgh	Pennsylvania	$726,307,964	$1,084,860,661
21	State Capitol Building	Oklahoma City	Oklahoma	$699,459,806	$976,611,406
22	State Capitol Building	Providence	Rhode Island	$696,789,481	$1,423,393,405
23	Union Station	Charleston	South Carolina	$691,198,877	$981,591,961
24	Williams	Tulsa	Oklahoma	$688,363,343	$915,282,440
25	Creighton University	Omaha	Nebraska	$615,311,471	$776,067,388

Deterministic Loss Scenarios

Deterministic Scenario Loss

Name	**United States Capitol**
Address	**Pennsylvania Avenue**
City	**Washington**
State	**District of Columbia**

	Attack Type	Expected Loss
Nuclear	100 Kiloton	860,377,221
	20 Kiloton	705,685,051
	10 Kiloton	352,045,938
	1 Kiloton	214,465,267
Conventional	Cruise Missile Attack	415,224
	Multiple Aircraft	700,201
	Single Aircraft	404,202
	Large Truck Bomb	210,048
	Small Truck Bomb	163,014
	Car Bomb	5,140
	Human Bomb	1,187
Radiological	Cruise Missile Attack	438,376
	Multiple Aircraft	709,484
	Single Aircraft	428,625
	Large Truck Bomb	225,725
	Small Truck Bomb	177,111
	Car Bomb	11,297
	Human Bomb	1,780
Bio	Large Attack	44,294,688
	Medium Attack	5,880,632
	Small Attack	53,002
Chem	Large Attack	89,802,929
	Medium Attack	15,371,017
	Small Attack	63,149

Deterministic Scenario Damage by Target & Attack Type

	Target Type	Average Loss	Maximum Loss
Private Buildings	Business District	50,027,209	6,689,464,224
	Financial Institutions	163,255,053	4,363,893,802
	Fortune 500 Headquarters	104,365,167	6,770,139,694
	Major Media Company Locations	329,593,466	6,753,561,372
	Major Medical Facilitities	38,717,919	1,360,874,595
	Major Skyscrapers	386,621,608	6,756,714,942
	Other Skyscrapers	199,828,308	6,776,212,830
Utilities	Electric Power Facilities	38,184,978	6,238,630,158
	Natural Gas Facilities	1,764,641	213,410,791
	Major Dams	5,519,921	103,308,286
	Nuclear Power Plants	2,711,210	90,927,111
	Oil Systems	21,358,359	4,107,333,970
Public Buildings	Embassies and Consulates	263,174,817	6,753,786,816
	Major Federal Buildings	59,535,135	4,745,566,445
	Military Installations	25,242,144	3,467,986,293
	Major Places of Worship	31,657,392	6,700,295,754
	Monuments	86,291,165	6,639,393,510
	Presidential Offices and Residences	126,899,195	4,551,270,757
	State Capitals	23,500,884	979,780,745
Recreation	Amusement Venues	26,335,740	883,142,723
	Casinos	10,994,416	213,604,357
	Major Malls	27,194,111	4,193,980,369
	Night Club Districts	43,210,279	6,586,151,709
	Outdoor Venues	81,443,141	6,671,767,917
	Sports Venues	40,297,672	6,315,757,473
Transportation	Bus Stations	40,483,469	6,563,456,297
	Major Airports	10,074,161	3,312,696,052
	Major Bridges	344,408,328	6,567,729,357
	Major Ports	60,073,235	6,230,569,624
	Major Railway Stations	120,076,444	6,701,240,634
	Major Tunnels	363,108,232	6,570,503,494
Other Facilities	Scientific Installations	9,678,492	352,328,913
	Prisons	18,717,797	5,901,629,590
	Aerospace	19,183,638	1,676,500,329
	Educational Facilitities	37,730,201	6,546,359,918

	Attack Type	Average Loss	Maximum Loss
Nuclear	100 Kiloton	449,502,997	6,776,212,830
	20 Kiloton	386,510,752	6,373,032,576
	10 Kiloton	241,514,731	5,169,426,002
	1 Kiloton	182,970,963	4,261,328,916
Conventional	Cruise Missile Attack	11,367,943	783,019,828
	Multiple Aircraft	20,274,321	934,763,577
	Single Aircraft	10,544,438	772,679,173
	Large Truck Bomb	5,273,741	622,045,186
	Small Truck Bomb	4,128,137	544,391,614
	Car Bomb	558,425	232,214,081
	Human Bomb	281,755	155,109,483
Radiological	Cruise Missile Attack	12,085,553	795,545,387
	Multiple Aircraft	21,329,180	947,113,150
	Single Aircraft	11,804,325	792,759,296
	Large Truck Bomb	5,630,569	637,954,000
	Small Truck Bomb	4,471,914	566,996,927
	Car Bomb	666,106	248,688,670
	Human Bomb	348,719	166,131,924
Bio	Large Attack	52,946,961	1,504,515,896
	Medium Attack	19,634,456	749,959,885
	Small Attack	1,722,229	176,312,138
Chem	Large Attack	82,223,938	2,061,890,124
	Medium Attack	32,140,354	1,062,821,105
	Small Attack	2,107,682	202,327,877

Probabilistic Analysis

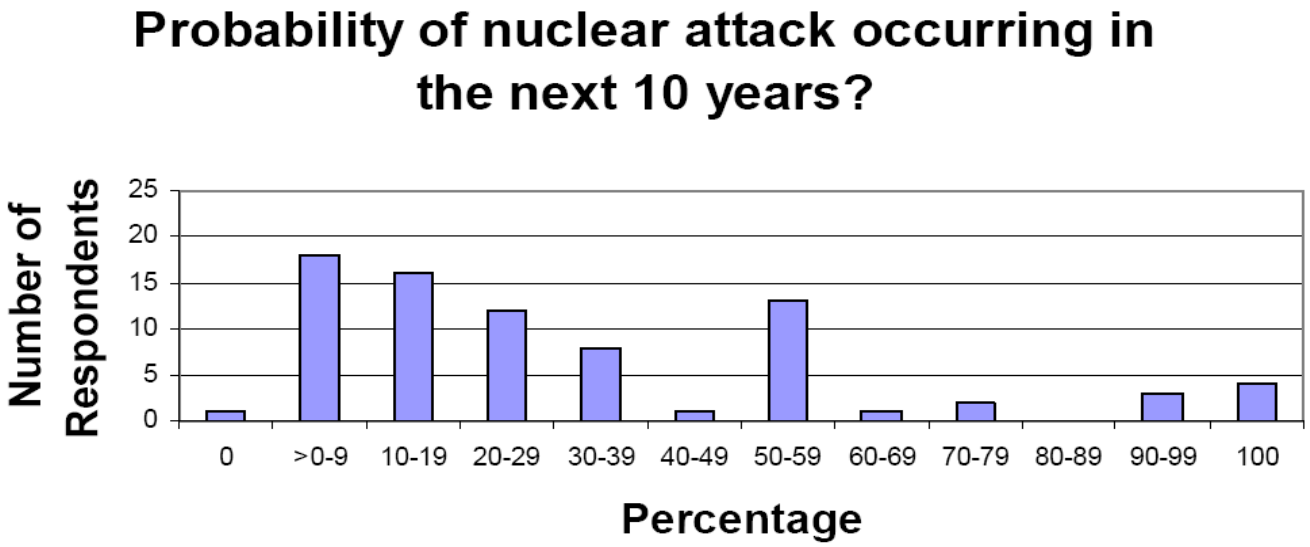
Conditional Probability by Target & Attack Type

	Target Type	Assumption	Analysis	Re-scaled	Expected Loss
Private Buildings	Business District	1.000%	1.000%	1.258%	88,534
	Financial Institutions	3.000%	3.000%	3.775%	393,305
	Fortune 500 Headquarters	10.000%	10.000%	12.582%	736,514
	Major Media Company Locations	5.000%	5.000%	6.291%	1,037,298
	Major Medical Facilitities	0.500%	0.500%	0.629%	8,002
	Major Skyscrapers	20.000%	17.085%	21.497%	6,446,402
	Other Skyscrapers	10.000%	7.917%	9.961%	1,617,971
Utilities	Electric Power Facilities	0.500%	0.028%	0.035%	952
	Natural Gas Facilities	0.500%	0.014%	0.017%	28
	Major Dams	1.000%	0.079%	0.100%	878
	Nuclear Power Plants	5.000%	0.295%	0.372%	739
	Oil Systems	1.000%	1.000%	1.258%	4,217
Public Buildings	Embassies and Consulates	3.000%	1.548%	1.948%	331,059
	Major Federal Buildings	5.000%	5.000%	6.291%	147,161
	Military Installations	5.000%	0.818%	1.030%	21,500
	Major Places of Worship	2.000%	2.000%	2.516%	23,857
	Monuments	0.100%	0.100%	0.126%	3,392
	Presidential Offices and Residences	2.000%	2.000%	2.516%	62,691
	State Capitals	1.000%	0.676%	0.850%	12,929
Recreation	Amusement Venues	1.000%	0.168%	0.212%	1,745
	Casinos	2.000%	2.000%	2.516%	8,260
	Major Malls	1.000%	1.000%	1.258%	9,290
	Night Club Districts	3.000%	3.000%	3.775%	100,780
	Outdoor Venues	0.200%	0.200%	0.252%	6,962
	Sports Venues	5.000%	5.000%	6.291%	180,973
Transportation	Bus Stations	0.500%	0.187%	0.236%	9,163
	Major Airports	5.000%	5.000%	6.291%	11,222
	Major Bridges	1.000%	0.318%	0.399%	50,637
	Major Ports	1.000%	0.403%	0.507%	12,001
	Major Railway Stations	1.000%	0.440%	0.554%	57,968
	Major Tunnels	1.000%	1.000%	1.258%	168,724
Other Facilities	Scientific Installations	0.100%	0.100%	0.126%	1,002
	Prisons	0.500%	0.500%	0.629%	2,632
	Aerospace	0.100%	0.100%	0.126%	567
	Educational Facilitities	2.000%	2.000%	2.516%	23,381
		100.000%	**79.476%**	**100.000%**	**11,582,736**

	Attack Type	Assumption	Analysis	Re-scaled	Expected Loss
Nuclear	100 Kiloton	0.010%	0.010%	0.013%	95,699
	20 Kiloton	0.020%	0.020%	0.025%	169,520
	10 Kiloton	0.030%	0.030%	0.038%	172,763
	1 Kiloton	0.040%	0.040%	0.050%	180,052
Conventional	Cruise Missile Attack	0.900%	0.786%	0.989%	227,037
	Multiple Aircraft	2.000%	1.782%	2.242%	933,720
	Single Aircraft	5.000%	4.365%	5.492%	1,171,299
	Large Truck Bomb	20.000%	17.001%	21.392%	2,216,771
	Small Truck Bomb	25.000%	21.252%	26.740%	2,160,616
	Car Bomb	20.000%	13.786%	17.347%	180,498
	Human Bomb	10.000%	6.087%	7.658%	42,902
		0.500%	0.436%	0.549%	134,158
		0.500%	0.445%	0.560%	245,586
		0.500%	0.436%	0.549%	131,252
		1.000%	0.850%	1.070%	118,472
		2.000%	1.700%	2.139%	187,773
		5.000%	3.824%	4.812%	58,265
		0.500%	0.304%	0.383%	2,673
		0.500%	0.498%	0.626%	669,346
		1.000%	0.945%	1.189%	487,882
		2.000%	1.700%	2.139%	72,225
		0.500%	0.498%	0.626%	1,007,614
		1.000%	0.980%	1.233%	828,170
		2.000%	1.700%	2.139%	88,441
		100.000%	**79.476%**	**100.000%**	**11,582,734**

Event Frequency Uncertainty

- Senator Richard Lugar, Chairman of Senate Foreign Relations Committee
  - Surveyed 85 arms experts on risk of nuclear attack
  - Predicted 29.2% chance of nuclear attack in the next decade
  - Report at: http://lugar.senate.gov/reports/NPSurvey.pdf
- IF model assumes yearly chance of
  - Nuclear attack at 0.01% - 0.04%
  - Nuclear and radiological attack at 1.0% - 4.0%
- Range based on overall event frequency of 0.1 - 0.4 events / year



All Terrorist Attack PMLs
Impact Forecasting, $M

Return Period (Yrs.)	1 in 10 Years	1 in 5 Years	2 in 5 Years	1 in 2 Years	1 per Year
1000	1,597.3	1,968.2	2,541.3	2,703.8	3,420.5
500	1,044.1	1,589.5	1,968.2	2,138.3	2,702.7
250	597.6	1,044.1	1,581.9	1,654.2	2,138.4
100	247.6	508.1	871.7	1,044.1	1,566.0
50	65.7	246.7	507.3	595.0	1,044.1
20	0.9	34.9	175.4	241.5	501.0
10	0.0	0.6	93.3	59.9	231.9
5	0.0	0.0	32.0	2.6	52.1
AAL	9.4	18.9	37.7	47.2	94.4

- Frequency based on average over all 24 attack modes
  - Human bomb to nuclear device
  - Frequency relativities can be adjusted based on client input
- Reinsurance purchase and other financial decisions can be calibrated to implied frequency – similar to way traders use Black-Scholes formula to impute volatility

Reinsurance Solutions

Reinsurance Solutions

- $800M+ conventional terrorism reinsurance available in marketplace
  - Excess of loss, occurrence based coverage
  - NBC coverage limited
- Uncertainty around frequency complicates pricing
- Covers priced to 0.1 to 0.4 events per year based on IF Terror model
- Effectiveness of reinsurance solution depends on
  - Cost of program = ceded margin (premium less expected recoveries)
  - Capital benefit of program
  - Rating agency credit for program
  - Intangible benefits of program, including stock analysts