2019 EIM
Risk Managers Information Meeting
"Changing Currents"

Quantitative Analytics:
Modeling Energy-Related Risks

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Quantitative Analytics

Quantitative Analytics utilizes sophisticated computer models to define both the frequency and severity of loss events.

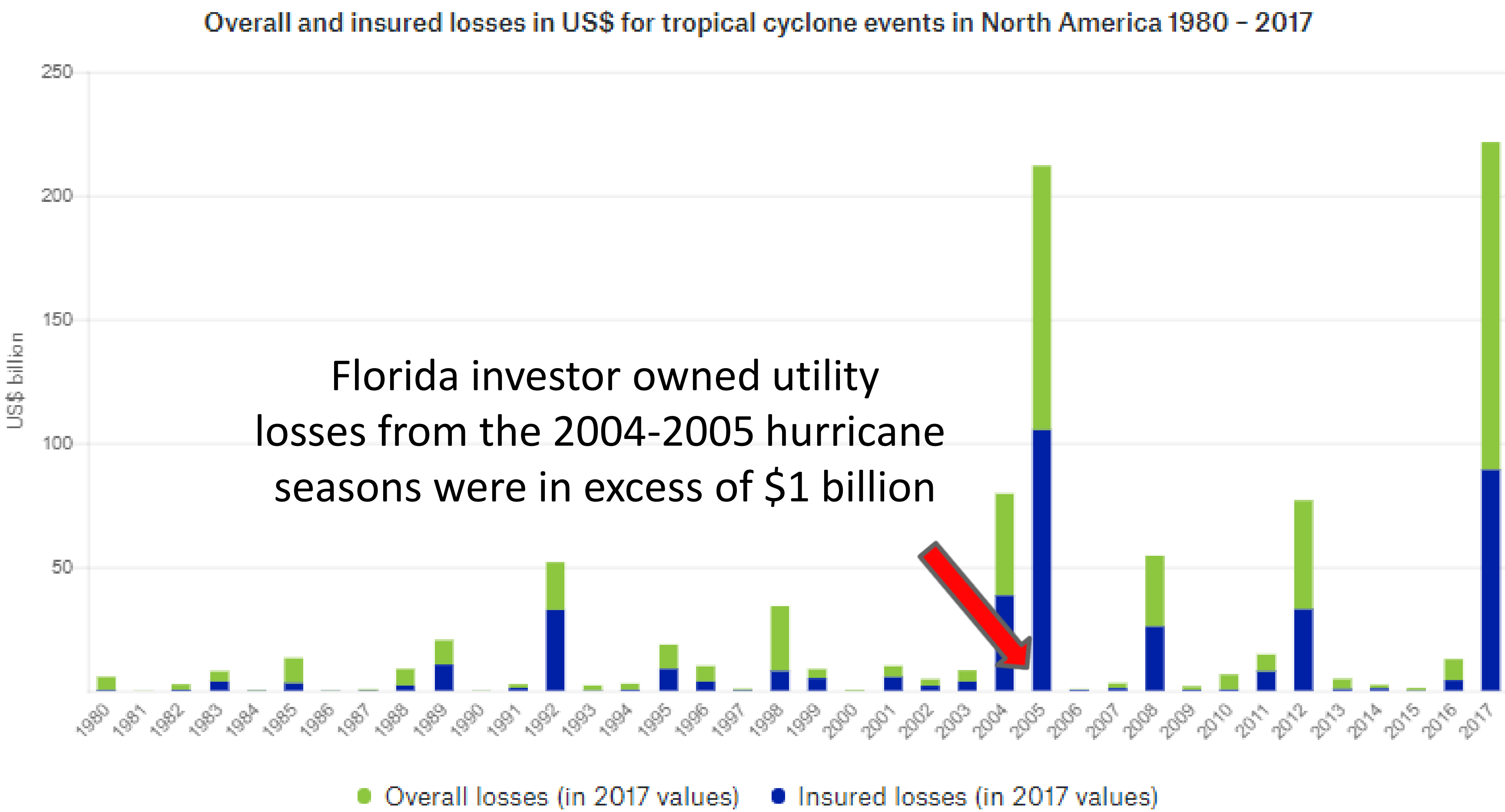
Examples include:

- Natural Catastrophe (NatCAT) Modeling
  has become the insurance industry standard
  - Hurricane,
  - Flood,
  - Earthquake,
  - Wildfires …
- Man-Made Catastrophe Hazard Modeling
  - Terrorism, blast, fire, and operational technology, events
  - Property, personal injury, workers compensation

What is Natural Catastrophe (NatCat) and Man-Made Catastrophe Modeling?

- Catastrophic events have low probabilities of occurrence and high consequences.
- There are small numbers of historical loss events so traditional actuarial data analysis of these perils can not be done.
- Catastrophe modeling uses computer-assisted calculations to estimate losses due to hurricanes, floods, earthquakes, wildfires, and similar man-made events.
- Computerized CAT modeling has developed over the past few decades to be the standard methodology utilized in the insurance industry.
- It is at the confluence of many disciplines including actuarial science, engineering, meteorology, seismology and computer science.
- GIS programs allow the storage, manipulation, and management, of the very large quantities of data required by Catastrophe simulation models.

Well Established Utility Perils: North America Hurricane Loss Trends

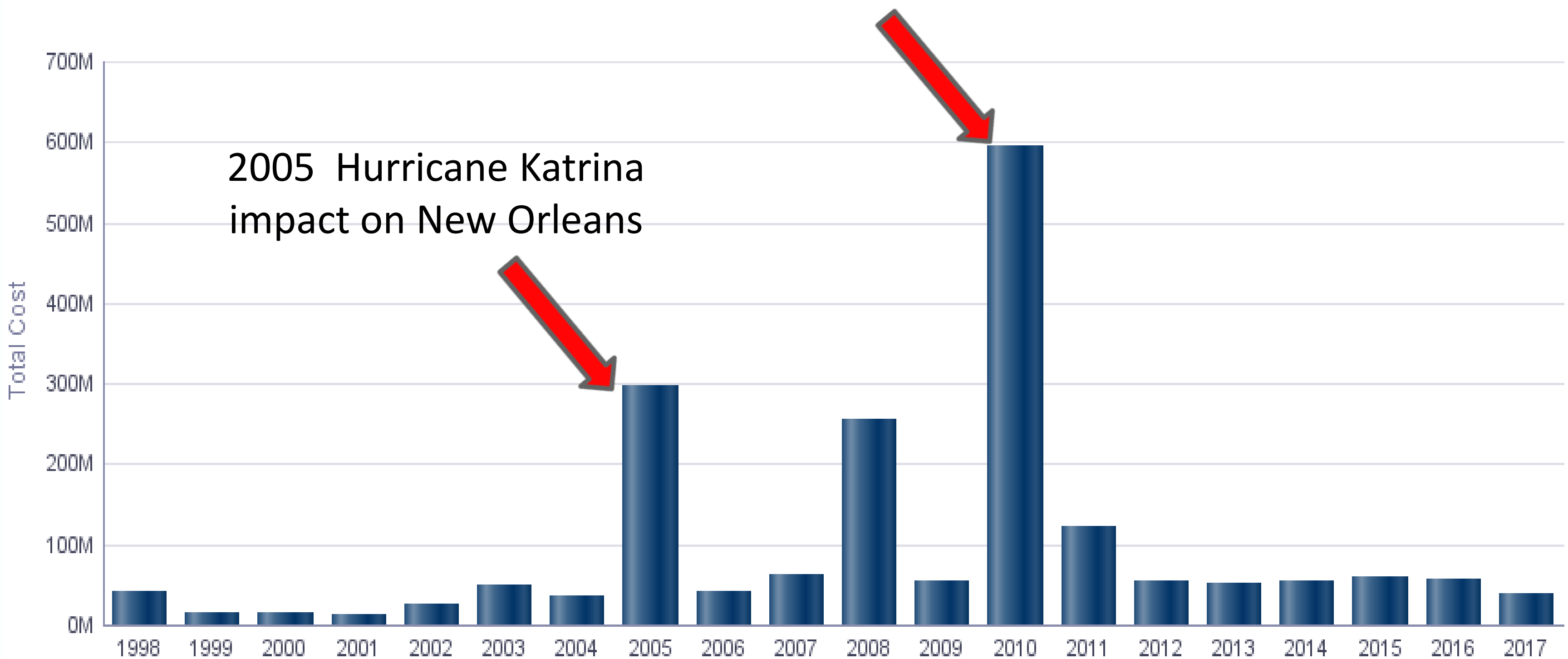


Florida investor owned utility losses from the 2004-2005 hurricane seasons were in excess of $1 billion

Munich RE

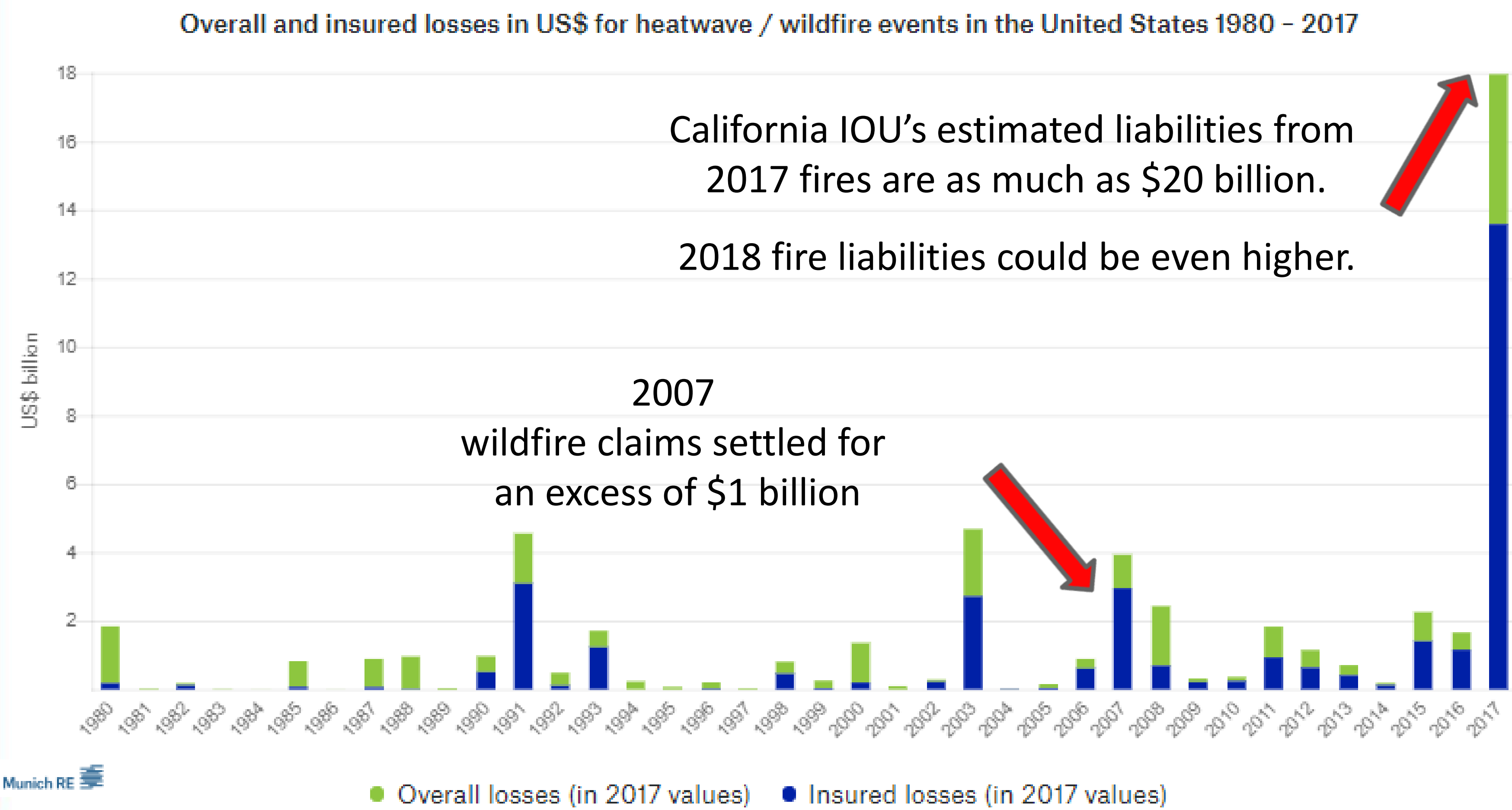
Well Established Utility Perils: U.S. Gas Transmission Cost Trends

2010 San Bruno Gas Pipeline
Year total 10 fatalities, 61 injuries ~$0.6 billion



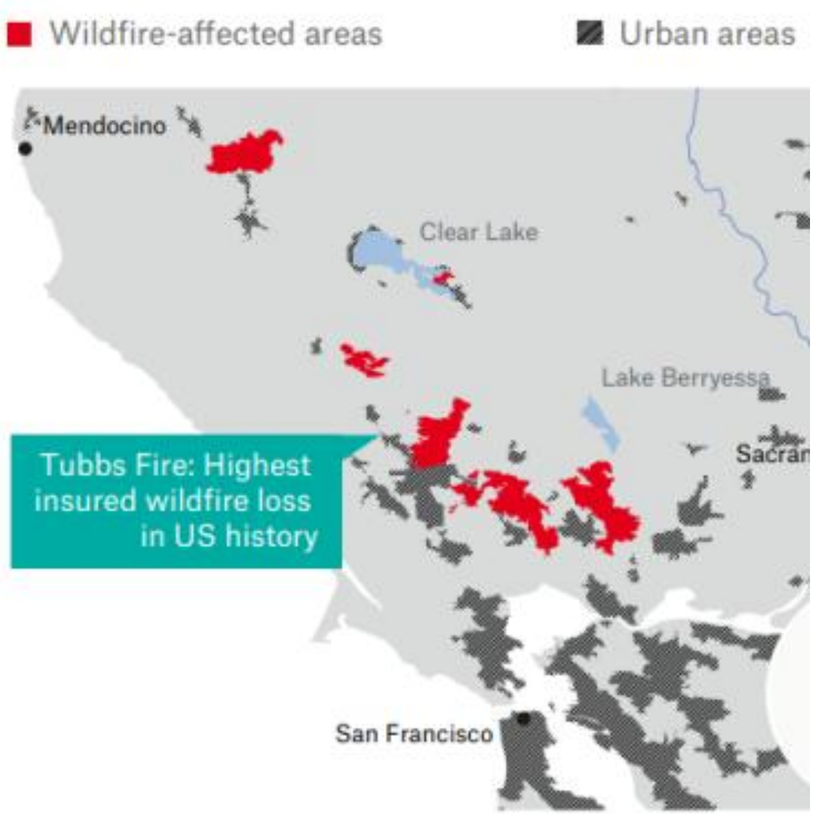
PHMSA Pipeline Incidents: Total Cost (1998-2017)
Incident Type: All Reported **System Type:** GAS TRANSMISSION **State:** (All Column Values) **Offshore Flag :** (All Column Values)

Emerging Utility Perils: Wildland Fire Loss Trends



California Wildland Fires

The legal doctrine of "inverse condemnation" makes utilities absolutely liable for damage caused by their equipment



Estimated liabilities from 2017 fires at as much as $17.3 billion

NEWS: State Regulators Investigating Equipment Linked To California Wildfires

Estimated liabilities from the 2017 Thomas fire are as much as $4 billion

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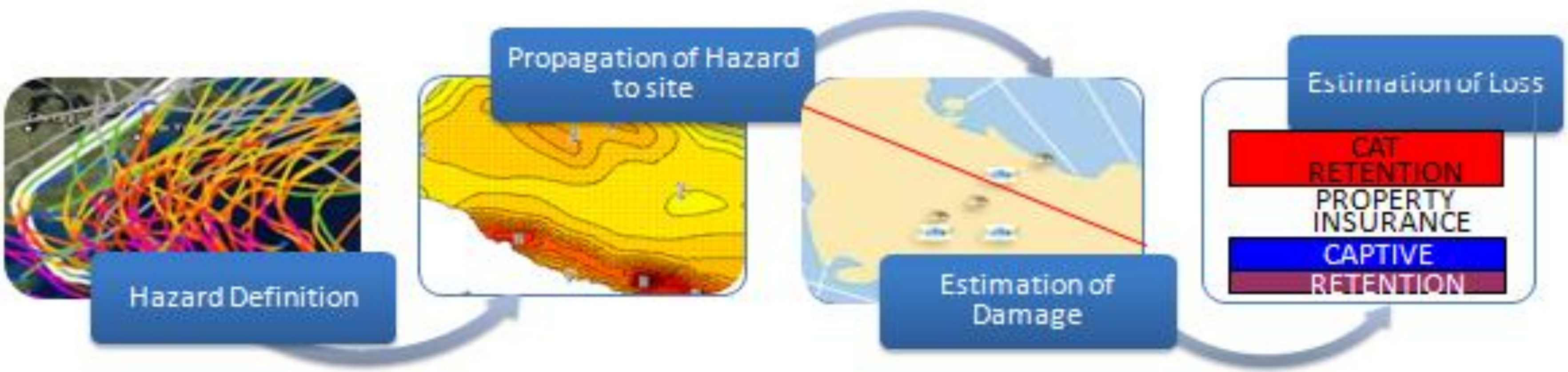
Natural Catastrophe (NatCat) Modeling Risk Basics

- Hazards
  - Hurricane Wind
  - Storm surge and wave action
  - Earthquake
  - Riverine Flood
  - Wildfire
  - Tornado and Hail
  - Ice Storms
- Assets at Risk
  - Locations, types of structures and values
- Potential Losses
  - Vulnerability of structures, equipment
  - Vulnerability of inventory, stock & supplies
  - Business Interruption
  - Third party liabilities - inverse condemnation

NatCat Risk Modeling Process

Unique energy assets and exposures require custom model inputs



- **Hurricane**
  - Storm Tracks
  - Category Storm
  - Frequency
- **Earthquake**
  - Epicenter
  - Magnitude
  - Frequency

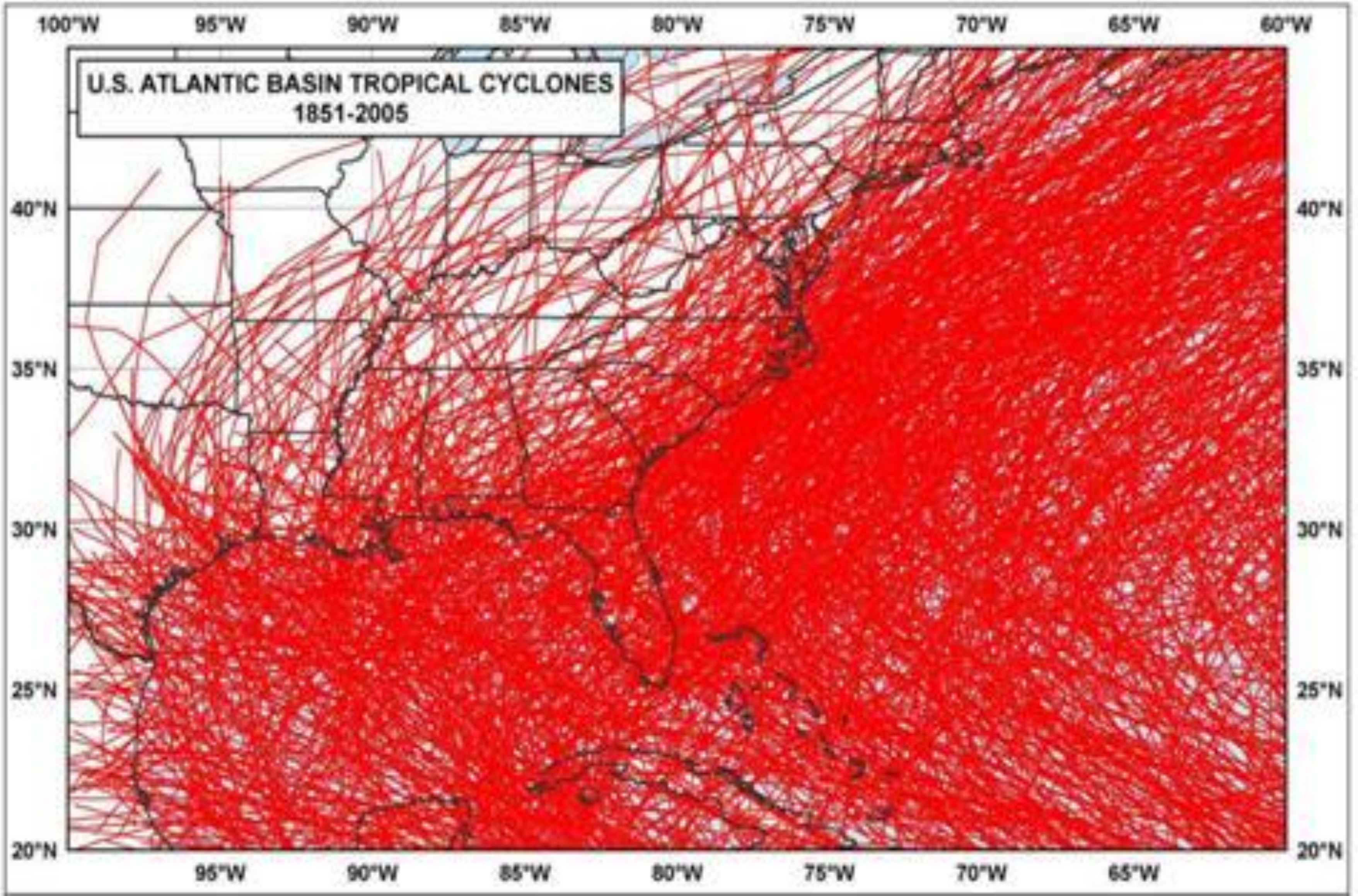
- **Hurricane**
  - Surface Wind Speed
  - Local Wind Gust
- **Earthquake**
  - Attenuation functions
  - Site Specific Soil
- **Winter Storm**
  - Custom Rime Icing

- **Vulnerability functions**
  - Age
  - By Coverage, Risk, and type of assets
  - Design Parameters
  - Construction

- **Loss Estimation**
  - Monte Carlo Simulation
  - Thousands of events
  - Frequencies and Severities for each event
  - Policy Structuring

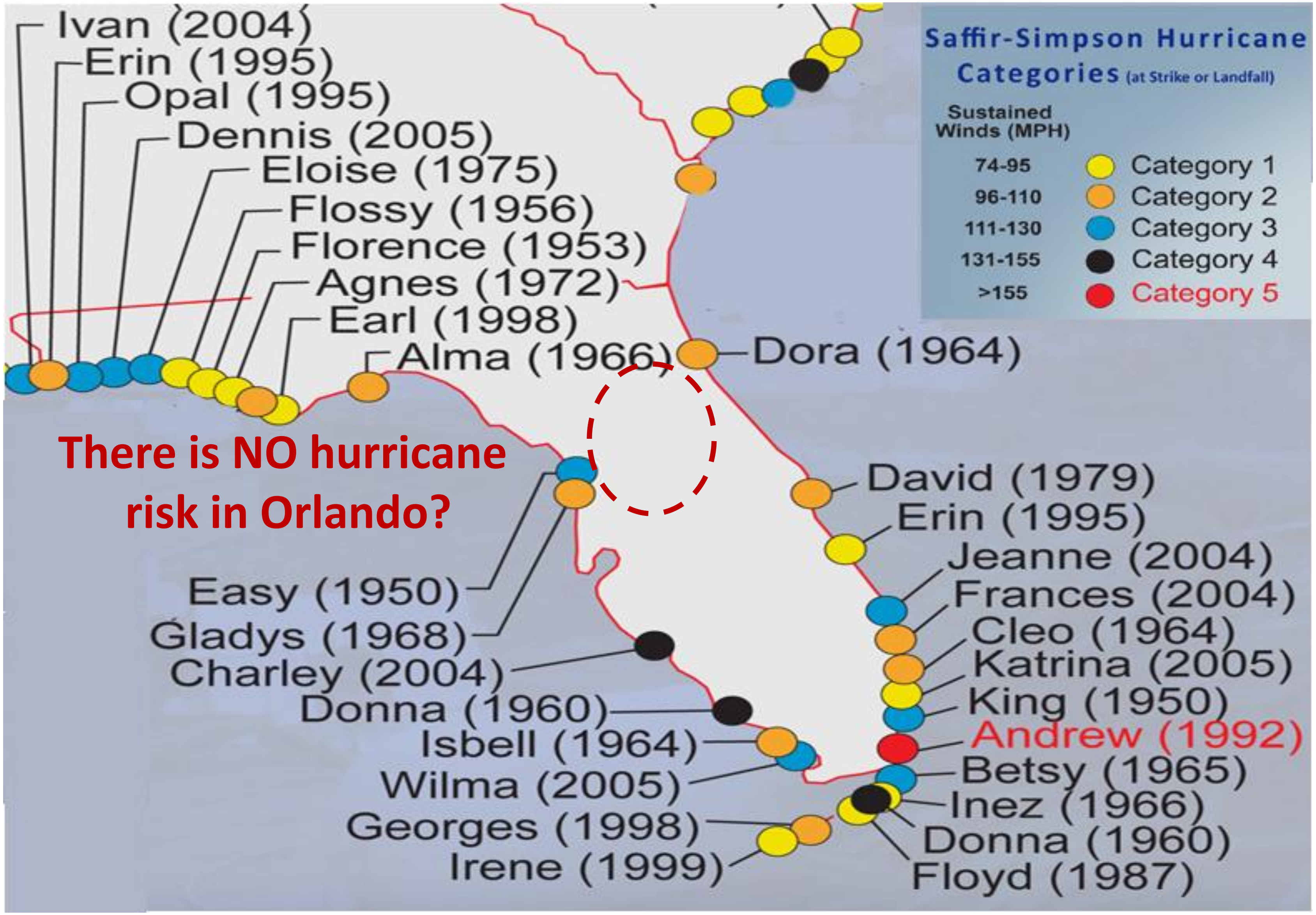
Example: Hurricane Catastrophe Modeling

History 1851-2005

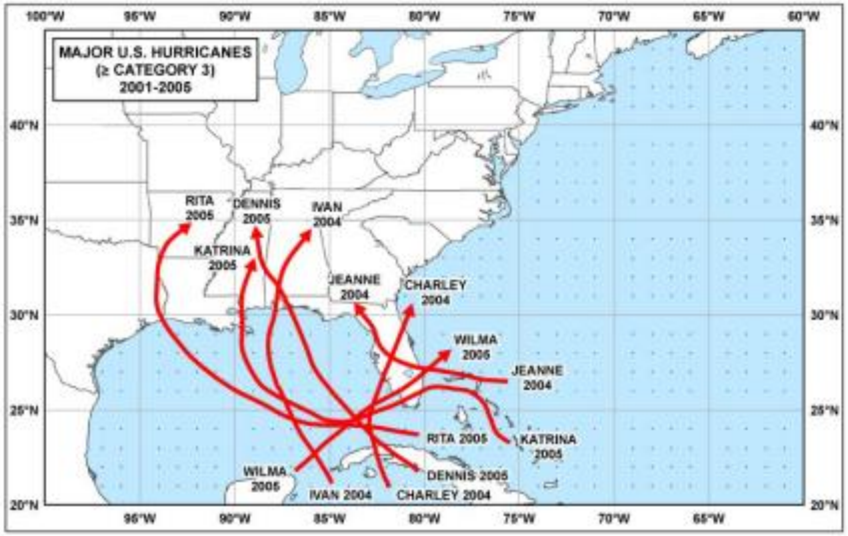


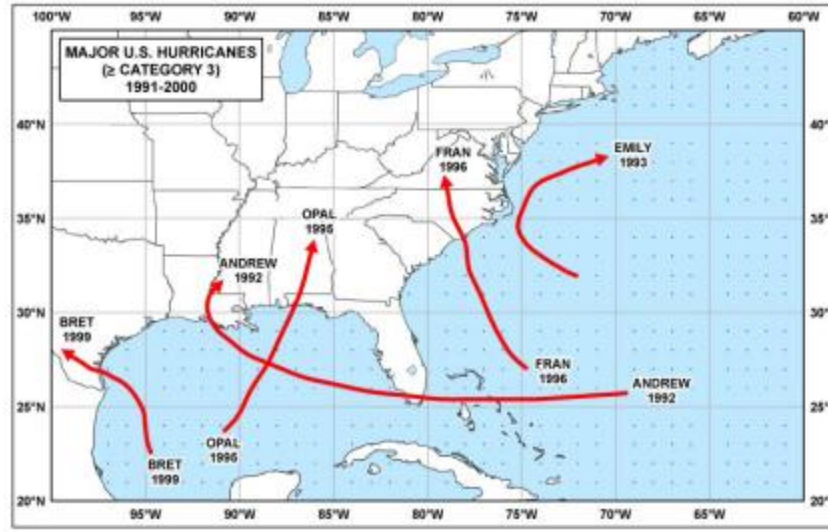
A Closer Look at Florida Hurricane Landfalls

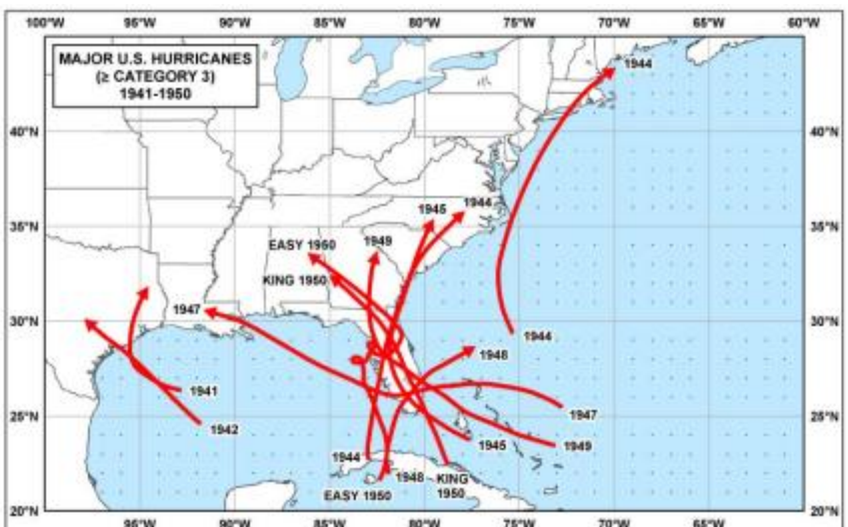
1950-2011

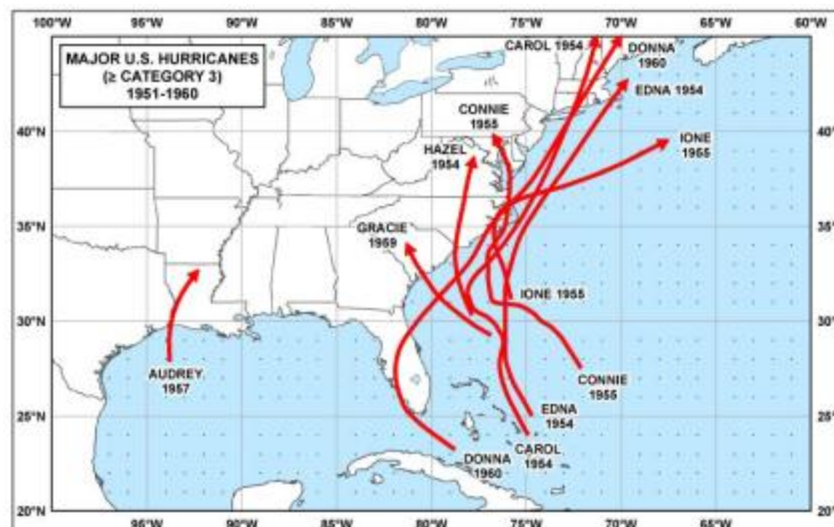


Hurricanes Have
Wide Temporal Variability in Occurrence
(by decades)









The Why of NatCAT Modeling

- There are major “gaps” in the historic records for all hazards!
- Modeling requires many more events than those in the historical record to smooth the gaps.
- NatCAT Modeling constructs thousands of synthetic events that are consistent with known science.
- Each simulated event has both a frequency (likelihood of occurrence) and severity

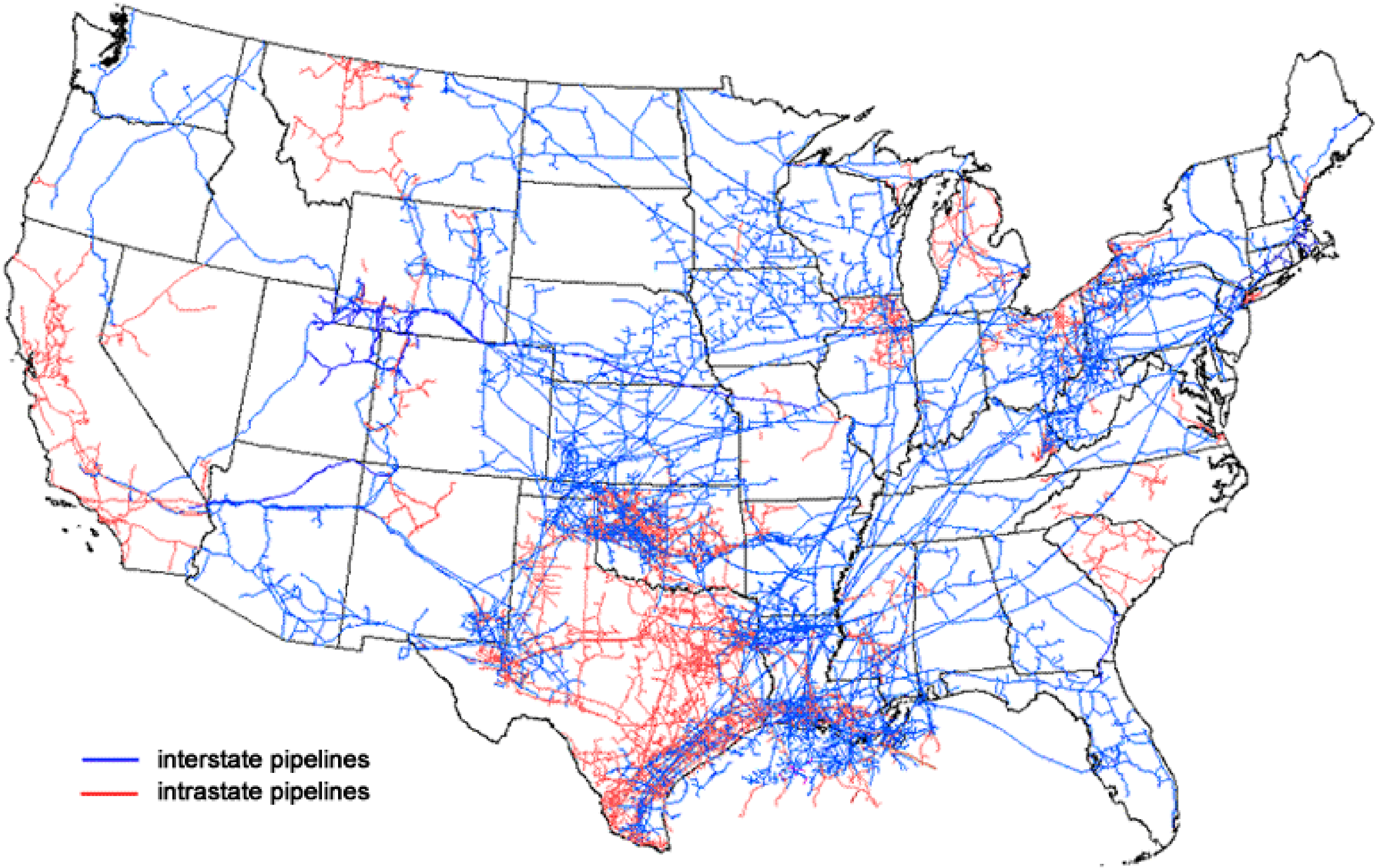
The How of NatCAT Modeling

- Each simulated event has a wind speed at each asset location, and a damage estimate for each event.
- Asset damage depends on the unique characteristics of the many kinds of energy assets.
- A portfolio of assets has a total damage and loss estimate for each event.
- The total of all the thousands of possible event provides the statistical data to develop a complete risk profile.

Man-Made Catastophe Hazard Modeling

- Man-made hazards include many perils:
  - Terrorism; blasts, chemical & biological, attacks …
  - Operational incidents related to technology;
    explosions at chemical and refinery plants, power plants, pipelines…
- Man-made hazards include many types of loss:
  - Loss of life, personal injury, property damage, business interruption, workers compensation …

Example: Gas Pipeline System Risks



Gas Transmission Pipeline Integrity Management

Gas Transmission is Highly Regulated by the US DOT

49 CFR 192.907(a) requires gas transmission pipeline operators to develop integrity management programs. Reporting on:

- High Consequence Areas (HCA), miles of HCA inspected, number of repairs completed in HCA
- Number of leaks, failures, incidents in HCA classified by cause …

Recent Risk Statistics: From 1998 through 2017

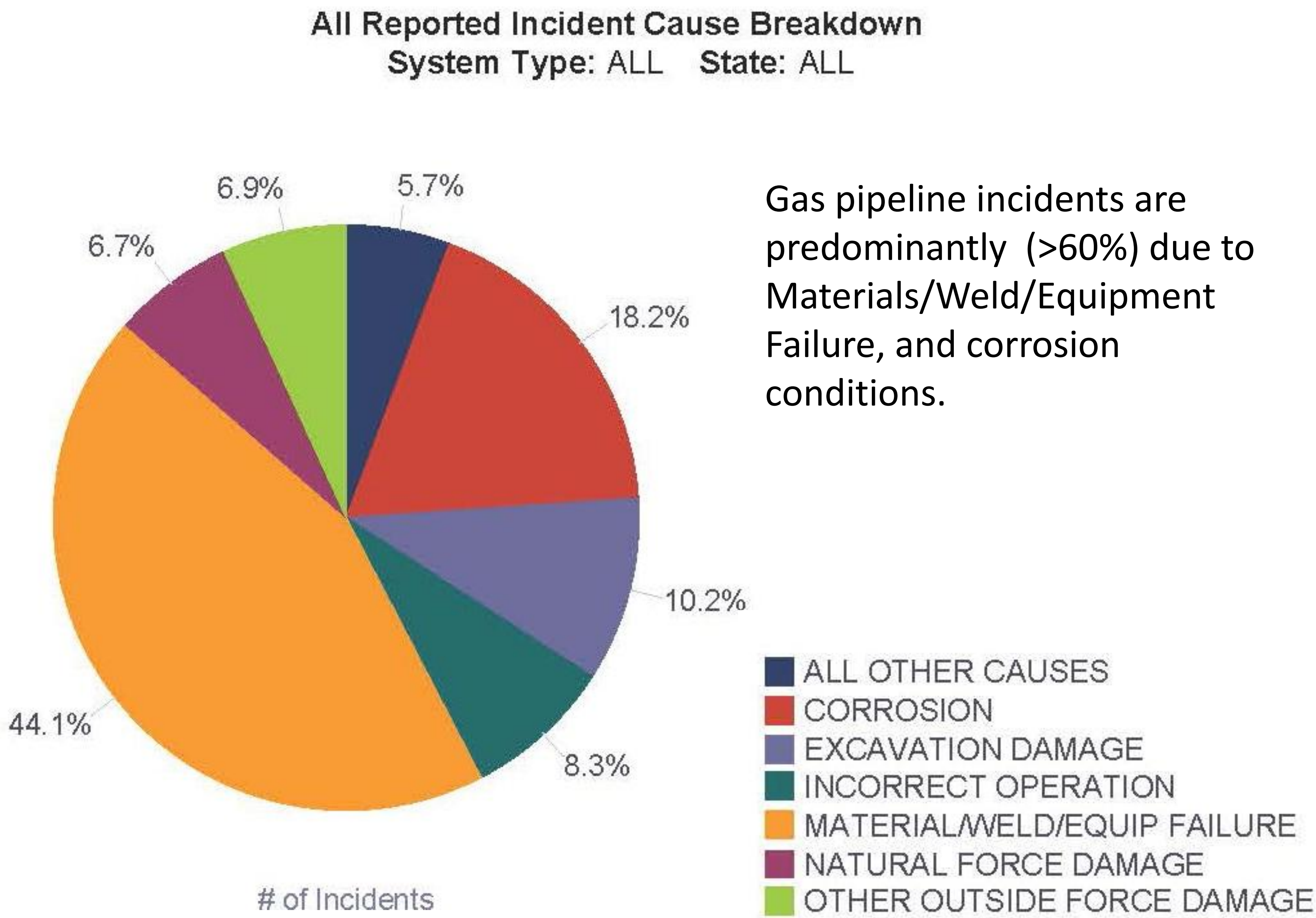
2,097 incidents with gas transmission, resulting in 50 fatalities, 179 injuries, and $1.9 billion in property damage (USDOT).

On average: ~100 events per year

~$1m property damage per event

~2% chance of fatalities per event

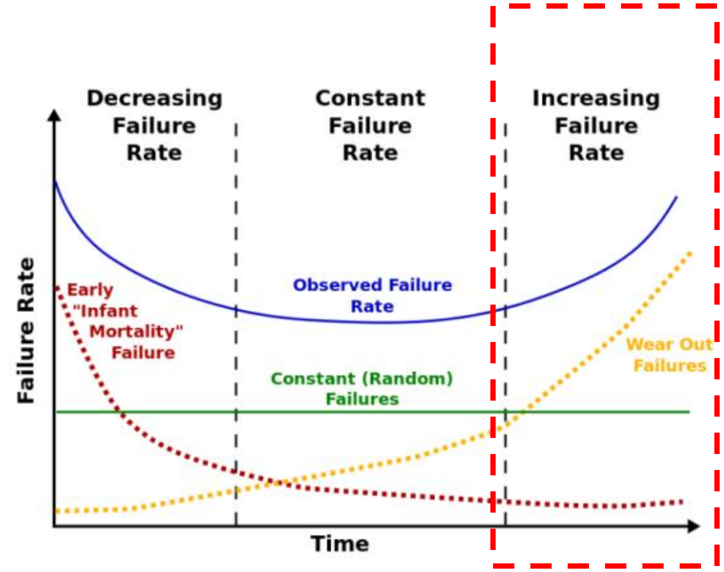
Gas Pipeline Incident Causes



Gas pipeline incidents are predominantly (>60%) due to Materials/Weld/Equipment Failure, and corrosion conditions.

Pipeline Infrastructure Risk Factors

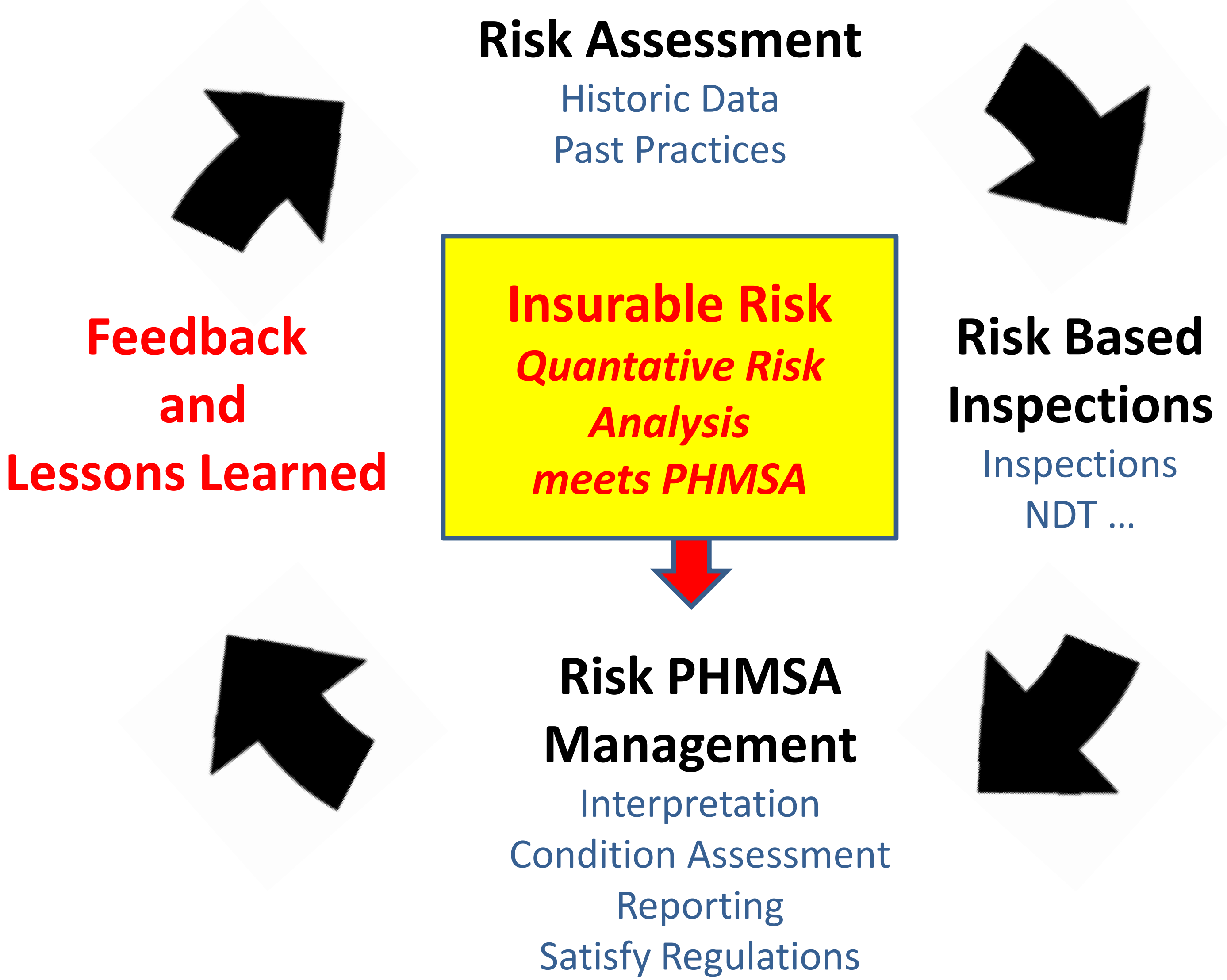
The "Bath Tub" curve



End of life failures

- Aging Infrastructure
  - Material conditions, Corrosion, …
  - Portions of systems may be nearing "end of life"
- Initiating Events
  - Cracked and thinning pipe walls, sudden piping failures due to stress under normal operating pressure …
- Operational Controls and Mitigation Measures
  - Maintenance/Inspection/Integrity Management, Leak Detection, Safety Plans …

Regulation Driven Process for Pipeline and Hazardous Materials Safety Administration (PHMSA)

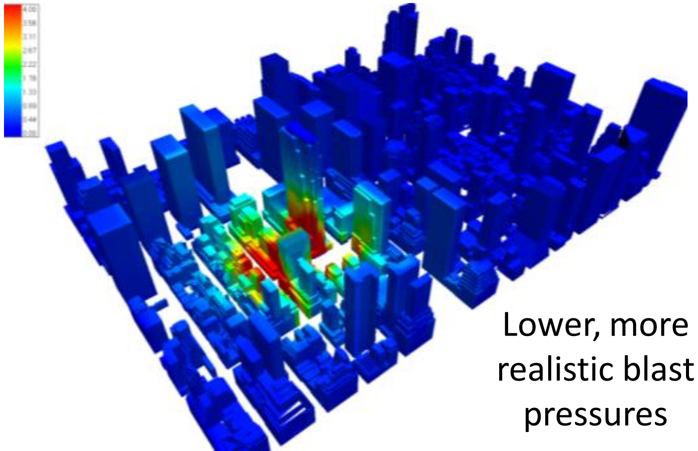


Gas Pipeline Explosion Influence Modeling

- Simple analytic blast models are used to develop overpressure influence models for screening.
- Urban areas with high populations and building stock, use 2-D or 3-D computational fluid dynamics (CFD) models for more realistic loss estimation.
- Variables include gas line size, pressure, burial depth, etc.

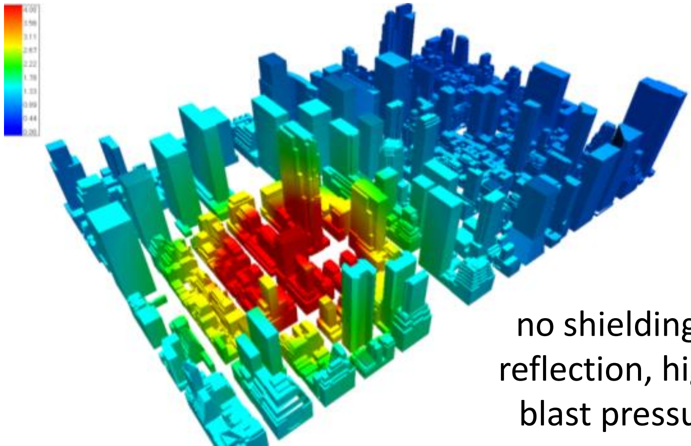
Blast Overpressure Effects
Simplified circle of influence

Blast Overpressure Effects
3-D CFD model
Includes shielding and reflections



Lower, more realistic blast pressures

Blast Overpressure Effects
2-D CFD model



no shielding or reflection, higher blast pressures

Gas Pipeline Blast Effects

- Large releases in open areas produce:
  - Lower pressures with long duration loads
  - They can damage commercial and residential buildings for thousands of feet.
- Releases in urban areas produce:
  - Damage to building glazing and facades for many city blocks.
  - These effects can cause widespread, severe injuries in a dense urban environment

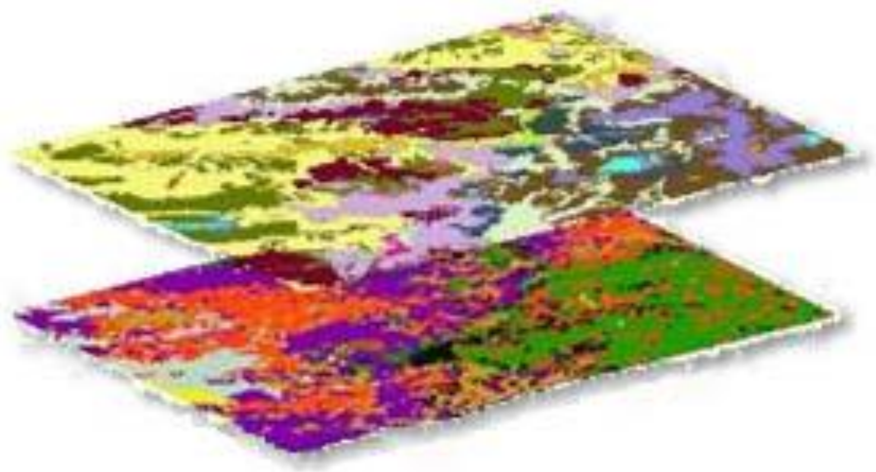
Gas Pipeline Risk of Loss: Data Elements for Modeling

- Residential & Commercial Exposures

  Reconstruction costs on a parcel or aggregate basis

- Population density and commercial occupancies

  Injury and loss of life on an aggregate basis



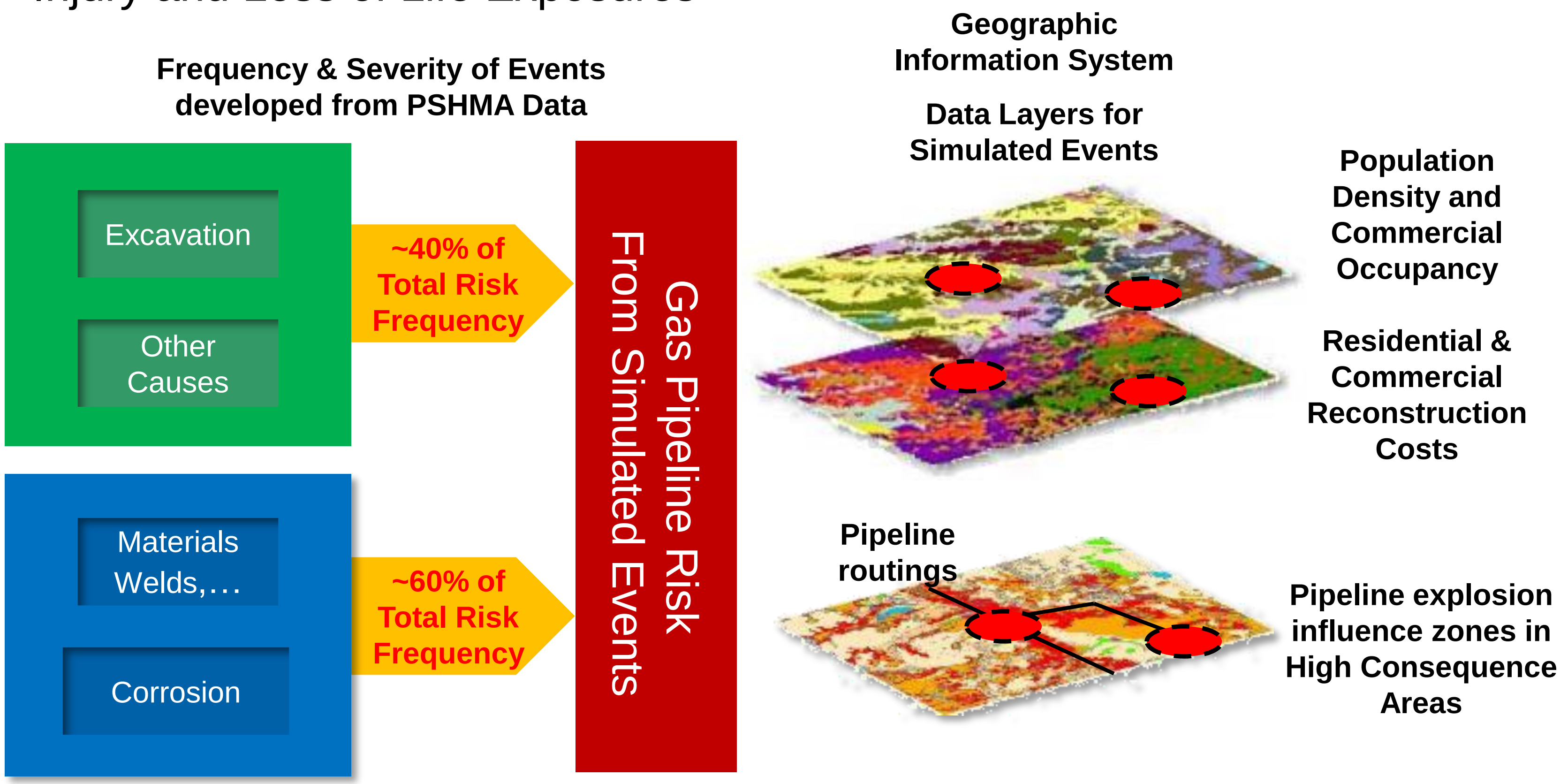
Population Density and Commercial Occupancy

Residential & Commercial Reconstruction Costs

Gas Pipeline Risk Quantification

Analysis Elements:

- Pipeline High Consequence Areas (HCA)
- Create scenario or stochastic pipeline failure events with frequency and severity (based on operator and Pipeline and Hazardous Materials Safety Administration –PSHMA- data)
- Residential & Commercial Property Exposures
- Injury and Loss of Life Exposures



Utility Scale Renewable Energy

- Economics are boosting new investments in renewables, and storage capacity.
- Energy policy pressure is still a dominant driver.
- Regulated utilities traditionally have entered PPAs to procure renewable energy from (IPPs), Versus
- Build-transfer transactions by 3rd party developer with transfer to utility at completion are increasing
- More than 6,000 Solar projects over 1 MW are in operation or development across the U.S.

Utility Scale Solar Energy Risks

- Utility scale solar and wind generation projects are highly concentrated.
- Residential solar portfolios tend to be small individual values and more diversified geographically.
- Natural hazards are not uniform perils. Some areas are exposed to hurricane, or flood, or earthquake, or wildfire, but not all.
- Drivers for risk quantification can be insurance, and finance protection from losses

Solar Farm Performance

2017 Hurricane Season

2017 Hurricane Season

- Many solar PV systems on the British Virgin Islands, Turks and Caicos, Puerto Rico, and St. Eustatius survived.
- Some PV systems in Puerto Rico, the US Virgin Islands, and Barbuda suffered major damage or complete failure.
- Differences in performance included the intensity of local wind fields, and solar installation design.

Hurricane Maria - Solar Farms

Category 5 winds and extensive damage on:

- Puerto Rico
- US Virgin Islands

PV System Details of Damage

Damage
to supports


Damage
to clips



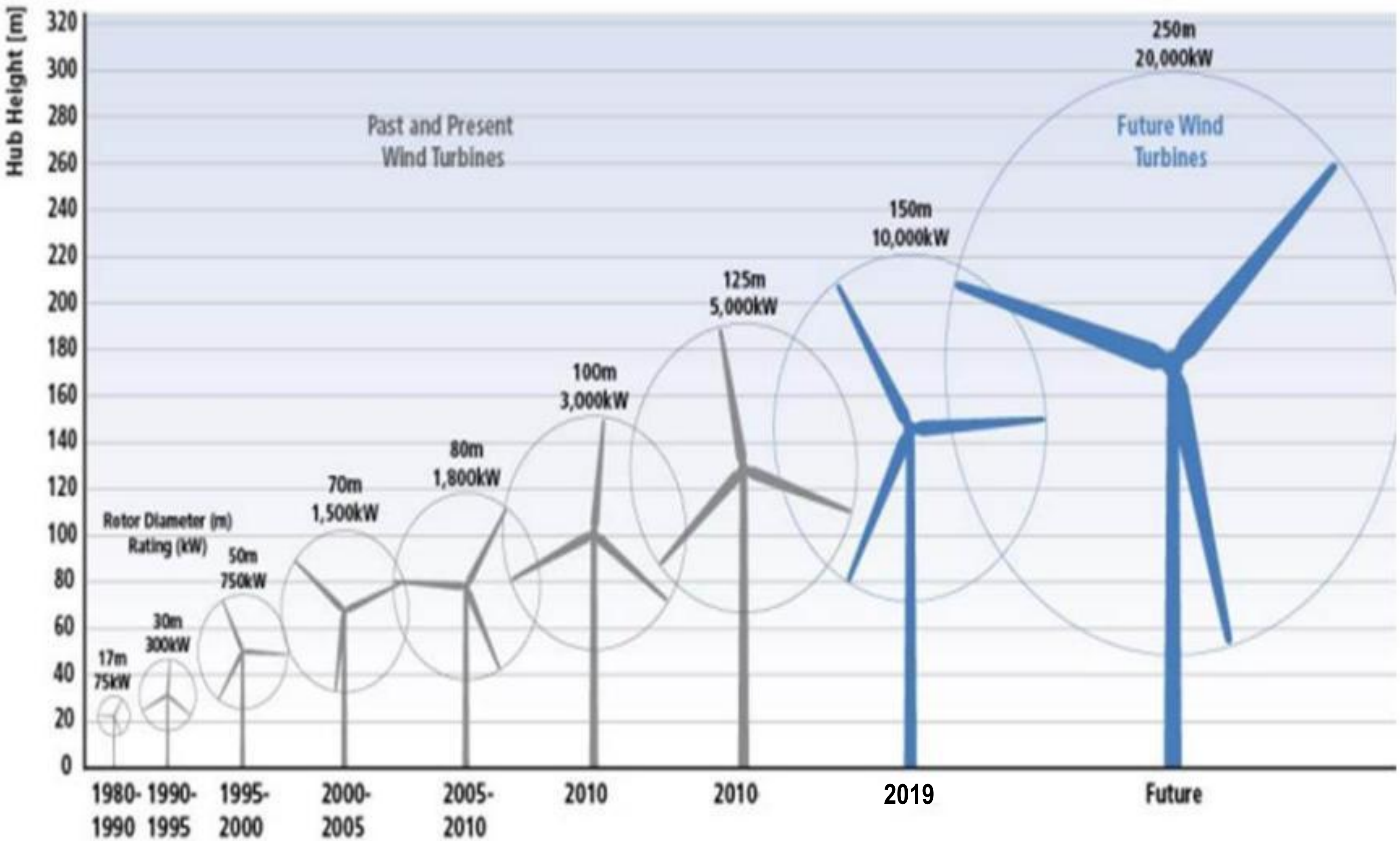
Damage
to cables

Photovoltaic (PV) System Damage Modes

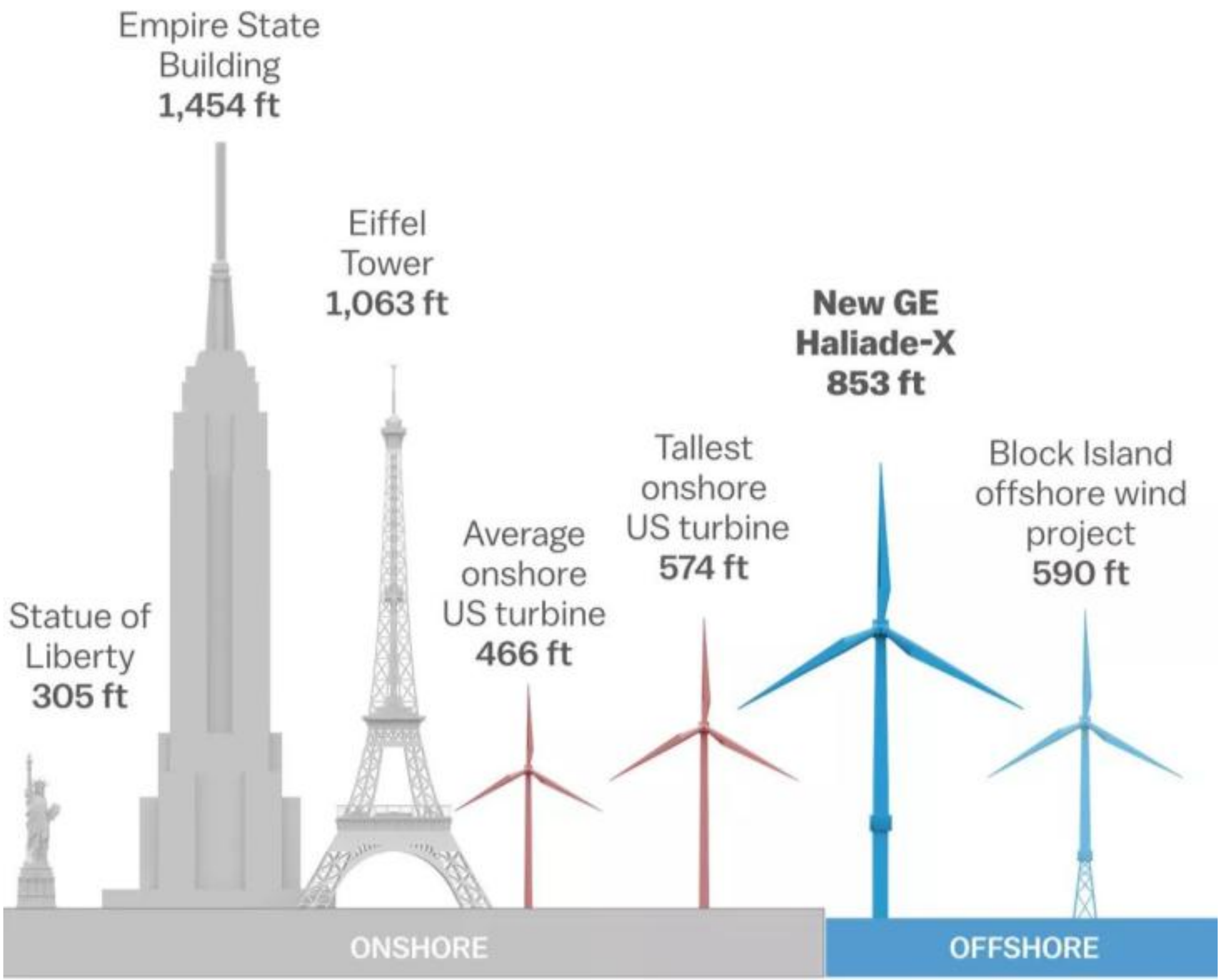
- PV rack structures and foundations are covered by building codes and performed better
- PV panels are non-structural components and are not covered by codes and standards for wind loadings
- Fixed and tracker panel installations appear to behave differently
- Types of damage;
  - PV panel impact from debris
  - Fastener failures leading to “un-zipping” of PV panels
  - Some foundation damage
  - Some water intrusion to electrical and cables
- Loss modeling requires customized vulnerabilties

Wind Turbine Generation

Size and investments continues to advance rapidly



Turbine Scale and Sophistication is Dramatic



Wind Turbine Hurricane Performance

Typhoon Maemi 2003
Okinawa Japan

Awaji Island Typhoon Cimeron 2018

Hurricane Maria Puerto Rico 2017

Wind Turbine Hurricane Performance

- Newer wind turbines are intensively engineered by the manufacturers for operational and wind loadings
- Foundations typically are owners designs
- Hurricane failures have been observed in blades, towers, and foundations.
  - Blades are the most vulnerable
  - Towers and foundations less vulnerable, but, their performance is design and site specific
- International Electrotechnical Commission (IEC) has 7 Classes of design criteria for wind hazard
- Newest machines may also have options of backup powered pitch and yaw systems for extreme wind protection

Wind Turbine Earthquake Performance

Turbine failures due to earthquake loading in New Zealand 2016 and Japan

Turbine soil/foundation failures in the Tohuku Earthquake 2011

Earthquake are rarer that hurricanes
And there are many fewer events

Some catastrophic damage has been observed and reported

North Palm Springs, CA Earthquake 1986

Wind Turbine Earthquake Performance

- Earthquake failures appear in towers and foundations
- Tower are tube buckling failures
- Foundations failures are due to soils performance, and foundation strength
- Even small changes in vertical plumb of machines can result in major costs for repairs
- Performance also appears to depend on:
  - Earthquake shaking and turbine frequencies, and
  - Turbine operational loadings at the time of earthquake events
- Loss modeling requires customized vulnerabilties

Quantitative Risk Analysis Has a Role in Optimal Risk Management

Quantitative risk analysis can answer both the "how often" and "how severe" questions about losses.