TERRORISM MODELING

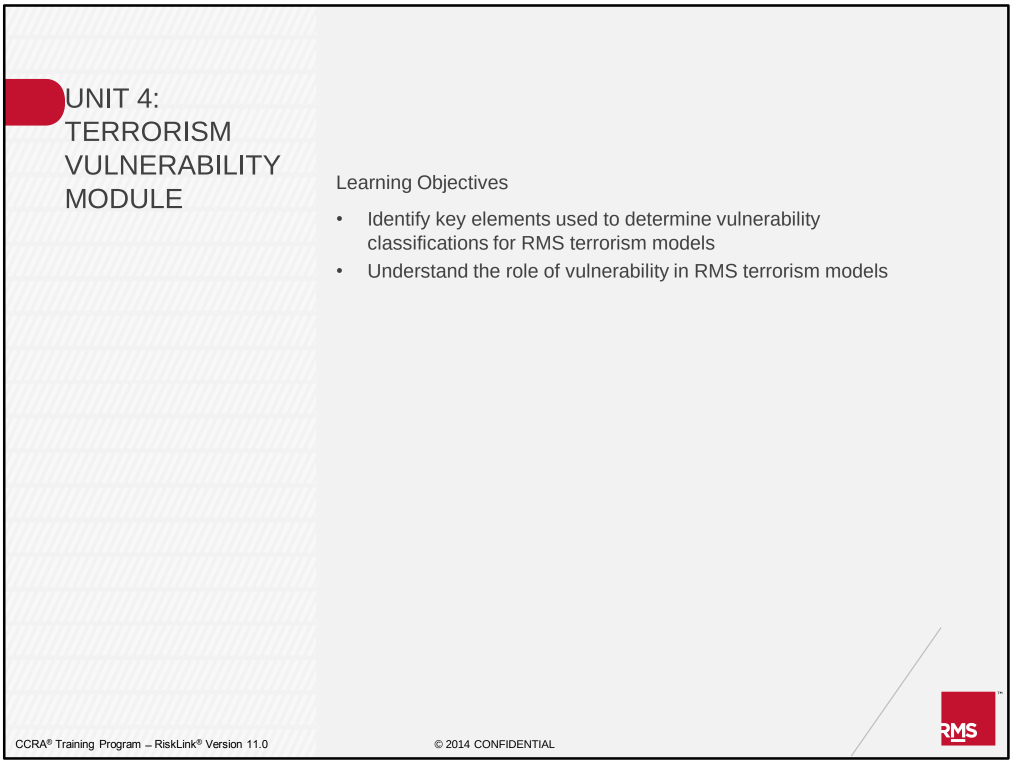
UNIT 4

RMS® CCRA® Training Program

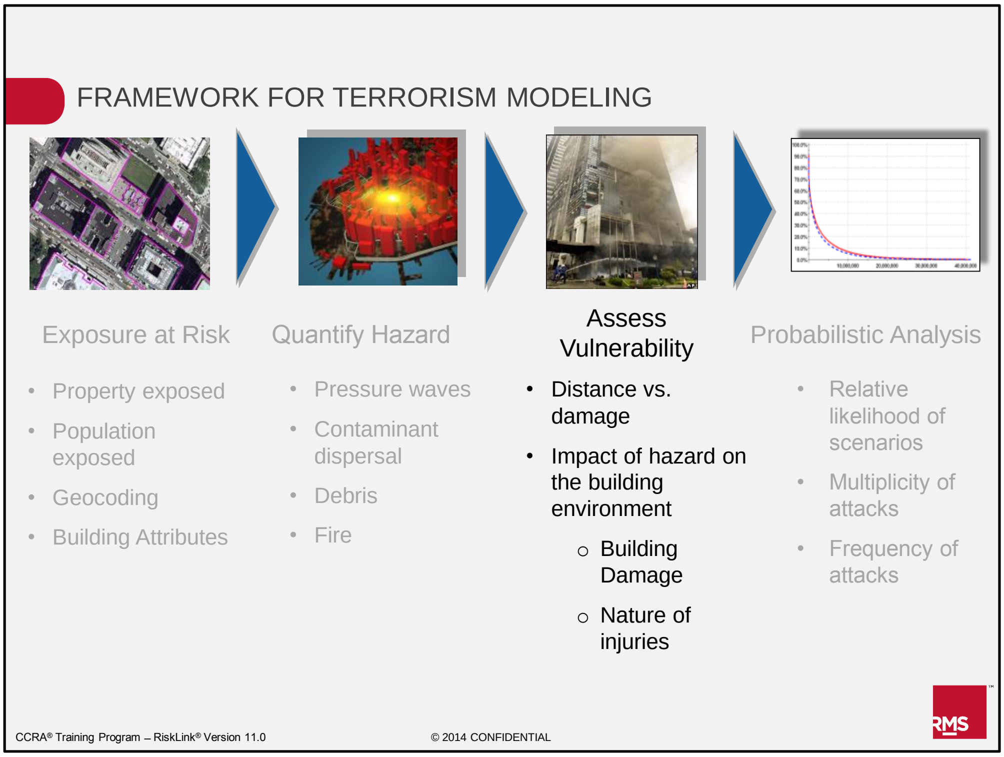
CCRA™
Certified Catastrophe Risk Analyst

AGENDA

- Unit 1: Understanding Terrorism Risk
- Unit 2: Terrorism Modeling Overview
- Unit 3: Terrorism Hazard Module
- **Unit 4: Terrorism Vulnerability Module**
- Unit 5: Terrorism Financial Modeling
- Unit 6: Probabilistic Terrorism Modeling



At the end of this unit you should have a good understanding of each of the five learning objectives listed on this slide.



Within our terrorism modeling framework, the assessment of vulnerability takes place after the quantification of hazard but before the financial model calculations. The level of hazard at each location is used to measure the damage to property and people.

VULNERABILITY MODULE FUNDAMENTALS

- Vulnerability of a location due to a terrorist attack is expressed through vulnerability functions (primary damage curves)
- Represents the relationship between damage to property and impact on people given a level of hazard
- Expressed as mean damage ratio or mean casualty rate
  - Property
    - Coverages: building, contents, BI
    - Mean damage ratio = physical damage / value
  - Casualty
    - Injury levels: medical only, temporary total, permanent partial - minor, permanent partial - major, permanent total, fatal
    - Mean casualty rate = # of people injured / total # of people exposed

The vulnerability of a structure and the nature of injuries resulting from a given level of hazard are represented through vulnerability functions or primary damage curves.

The resulting damage to property given a level of hazard is expressed through a mean damage ratio (MDR) and is defined as the ratio of the cost to repair a building, its contents, or loss of use associated with the damage to its total insured value or replacement cost. Similarly, the nature of injuries resulting from a given level of hazard is expressed through the mean casualty rate and is defined as the ratio of the number of people injured in various injury categories to the number of people exposed to the attack.

PRIMARY DAMAGE CURVES FOR TERRORISM MODEL

- Vulnerability is mainly a function of construction type and building height.
- Vulnerability functions (or primary damage curves) corresponding to 30 combinations of construction classes and number of stories.
- Each classification has a primary damage curve for:
  - Damage to buildings, contents, loss of use
  - Injury rates for six injury levels
- In most cases, terrorism vulnerability is country specific, not region specific as in the RMS natural peril models.
- Unknown construction and height uses a pre-compiled composite vulnerability curve based on regional industry building inventory data.

Vulnerability to terrorist attacks within the RMS terrorism models is mainly a function of building construction and building height. There are 30 combinations of construction classification and building height represented in the primary damage curves. Each classification has a primary damage curve to calculate damage to building, contents, and business interruption (or loss of use) as well as injury rates for the six injury levels. Pre-compiled composite vulnerability curves have been developed for the unknown building construction/unknown building height classifications based on regionalized industry inventory data.

RMS VULNERABILITY CLASSIFICATIONS FOR TERRORISM

Class	Construction	Stories
1	Unknown construction	Low-rise (1-3)
2	Unknown construction	Mid-rise (4-7)
3	Unknown construction	High-rise (8-14)
4	Unknown construction	Tall (15-50)
5	Unknown construction	Very Tall 50+
6	Unknown construction	Unknown height
7	Wood Frame	Low-Rise (1-3)
8	Unreinforced Masonry	Low-rise (1-3)
9	Unreinforced Masonry	Mid-rise (4-7)
10	Reinforced Masonry	Low-rise (1-3)
11	Reinforced Masonry	Mid-rise (4-7)
12	Reinforced Masonry	High-rise (8-14)
13	Reinforced Masonry	Tall (15-50)
14	Reinforced Concrete	Low-rise (1-3)
15	Reinforced Concrete	Mid-rise (4-7)
16	Reinforced Concrete	High-rise (8-14)
17	Reinforced Concrete	Tall (15-50)
18	Reinforced Concrete	Very Tall 50+
19	Steel Structure	Low-rise (1-3)
20	Steel Structure	Mid-rise (4-7)
21	Steel Structure	High-rise (8-14)
22	Steel Structure	Tall (15-50)
23	Steel Structure	Very Tall 50+
24	Wood Frame	Unknown Height
25	Unreinforced Masonry	Unknown Height
26	Reinforced Masonry	Unknown Height
27	Reinforced Concrete	Unknown Height
28	Steel Structure	Unknown Height
29	Unknown Construction Region 1	Unknown Height U.S. Region 1
30	Unknown Construction Region 2	Unknown Height U.S. Region 2

Here is the list of RMS vulnerability classifications for the RMS Terrorism Model. If building construction and height are unknown, the damage curve is represented by the average building inventory of the area, which is currently the country level except in the U.S. In the U.S., we do vary the unknown curves by region.

Note that unlike some of our natural catastrophe models, terrorism vulnerability does not utilize secondary modifiers but rather relies on construction and building height only.

The next few slides will detail the specifics of each component.

RMS CONSTRUCTION CLASSES FOR TERRORISM

- RMS terrorism model supports six base construction classes
  - Wood frame
  - Unreinforced masonry
  - Reinforced masonry
  - Reinforced concrete
  - Steel
  - Unknown
- Other construction types are supported and mapped to RMS terrorism construction classes during analysis
- When construction class is unknown for a location, a composite vulnerability curve is selected according to the height of the building
- Refer to the PTM_ACVCCUS table in the PTM_CONFIG database for a complete listing of construction class mappings

The relevant construction classifications supported by the RMS terrorism model fall into six base classes; wood frame, unreinforced masonry, reinforced masonry, reinforced concrete, steel, and unknown. As with all RMS models, other classifications are supported and mapped to the base construction class during analysis. If a location is coded as unknown construction class, a composite vulnerability curve based on industry inventory averages is selected according to the height of the building.

A complete listing of supported construction classifications, descriptions, and mappings can be found in the ptm_acvccus table in the PTM_CONFIG database.

NUMBER OF STORIES CLASSIFICATION FOR TERRORISM

- Building vulnerability differs across building height bands depending on the construction of the building.
- The following height ranges are supported in the U.S. terrorism model:
  - Wood buildings use one height range: 1-3 stories
  - Unreinforced masonry: 1-3 stories, 4-7 stories
  - Reinforced masonry: 1-3 stories, 4-7 stories; 8-14 stories; 15-50
  - Reinforced concrete: 1-3 stories, 4-7 stories; 8-14 stories; 15-50 stories; 50+
  - Steel: 1-3 stories, 4-7 stories; 8-14 stories; 15-50 stories; 50+
- Unknown building height utilizes a composite vulnerability curve based on the construction material of the building.

CCRA® Training Program – RiskLink® Version 11.0 © 2014 CONFIDENTIAL

RMS

The vulnerability of the structure is highly dependent upon the height of the building, as was illustrated in the hazard module when assessing the impact of blast pressure on various building environments. Building height is classified into various height bands depending upon the construction class of the building. The following height ranges are supported in the RMS terrorism model for the U.S.

- Vulnerability of a wood frame construction is differentiated by only one height range, 1 – 3 stories.
- Vulnerability of an unreinforced masonry construction is differentiated by two height ranges: 1-3 stories, 4-7 stories
- Vulnerability of an reinforced masonry construction is differentiated by four height ranges: 1-3 stories, 4-7 stories; 8-14 stories; 15-50 stories.
- Reinforced concrete and steel frame structures are each classified into five height ranges: 1-3 stories, 4-7 stories; 8-14 stories; 15-50 stories and more than 50 stories.

If a location is coded with an unknown building height, a composite vulnerability curve based on industry inventory averages is selected according to the construction of the building.

Each of the six base construction classifications have an unknown height band vulnerability curve.

Construction and height are the primary building attributes used to assess the vulnerability of a structure and ultimately determine the damage to a building and the nature of injuries sustained.

USAGE OF OCCUPANCY CLASSES FOR TERRORISM

- Occupancy class is not used to determine vulnerability function for the RMS terrorism model.
  - For example, if you code a steel frame, 25-story building, entering commercial or residential occupancy is irrelevant – the damage function will be the same.
- Coding occupancy class determines exposure adjustment factors when analyzing casualty exposure.
- Refer to the PTM_ACVOCCUS in the PTM_CONFIG database for a complete listing of occupancy class mapping.

Occupancy is not used to determine the vulnerability function for the RMS terrorism models. This means that if you code a steel frame, 25-story building, entering commercial or residential occupancy is irrelevant – the damage function will be the same. Occupancy does, however, impact loss results in other ways.

The occupancy class of the building (or occupation class of human exposure, if provided) determines the percentage of the population exposed during analysis. When analyzing human exposure, an assumption is made which adjusts the number of people exposed to a given event. These adjustments vary depending upon the option selected (for example, a time of day adjustment or temporal distribution) and will vary depending upon the occupancy of the building (or occupation of the employees inside the building).

OTHER DATA COMPONENTS

- Number of buildings
  - No impact on the RMS terrorism model
- Year Built
  - Currently not used to determine the vulnerability functions for analyzing terrorism exposures

CCRA® Training Program – RiskLink® Version 11.0 © 2014 CONFIDENTIAL

At this time, number of buildings is not used in the RMS terrorism models. Year of construction is not considered in the assessment of vulnerability due to terrorism attack.

REGIONAL DIFFERENCES

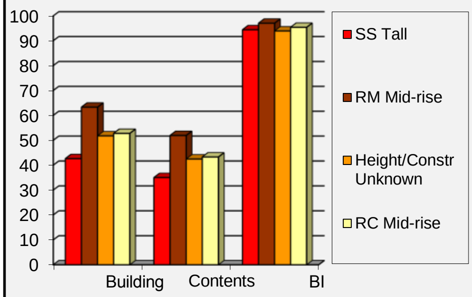
- The vulnerability of a structure due to a particular attack mode will vary based on geographic location.
  - For example, for a particular level of hazard, damage to a steel frame, 25-story building will vary depending on the country of the location.
- The inventory database for the terrorism model reflects country differences.
  - An average of construction and height is used to develop a composite vulnerability curve for each country.
  - Within the U.S. model, an average of construction and height is used to develop the composite vulnerability curves for three separate regions.

The vulnerability of a structure due to a particular attack mode is dependent on the country of the location being modeled. For instance, given a particular level of hazard (say 25 psi), damage to a 25-story steel frame building will differ if the location of the building is located in the U.S. vs Turkey. This is due to differences in building construction practices within different countries. Additionally, the VRG footprints have been developed taking into consideration the building environment of each target which results in regional differences within each VRG cell. This pertains to the vulnerability assessment of a location based on the hazard value calculated using the simple damage footprint.

In the U.S., the inventory database for the terrorism model does vary by geographic region as it does for other RMS models. An average of construction and height is used to develop the composite vulnerability curves for three separate regions. Outside the U.S., building inventory is captured at the country level

EXAMPLE: 2-TON BOMB ATTACK, EMPIRE STATE BUILDING

- Company A insures a property located 100 meters from the Empire State Building
  - Building value = $25M; Contents value = $12M; BI value = $1M
  - Construction and height are unknown
- Vulnerability of the structure will vary for the same level of hazard depending upon the characteristics of the building



Vulnerability Description	Total Insured Loss ($)
Height and Construction Unknown	18,983,251
Reinforced Masonry Mid-rise (4-7)	23,032,424
Reinforced Concrete Mid-rise (4-7)	19,338,894
Steel Structure tall (15-50)	15,800,213

CCRA® Training Program – RiskLink® Version 11.0

RMS

We can quantify the impact of construction and height on the vulnerability of a structure, given a particular level of hazard, by stepping through the following exercise. Let's assume a 2-ton bomb has been detonated at the Empire State Building. Your company insures a building located 100 meters from the Empire State Building and you need to determine the loss to the insured property. The property has a building coverage of $25 million, a contents value of $12 million and business interruption coverage of $1 million. Unfortunately, you do not know the building construction or height of this building. Assuming unknown height and unknown construction, the mean damage ratio of the building coverage is approximately 52%, contents coverage is approximately 42%, and BI coverage is approximately 95%, which translates into a $19 million loss.

According to the ESDB building attributes database, the insured building is a 50-story, steel frame structure. You incorporate this information into your analysis and the mean damage ratio for building coverage is approximately 42%, MDR for contents coverage is approximately 35%, and the MDR of BI coverage is approximately 94%, which translates into a loss of $15 million, a difference of roughly 22%. You will notice the construction and height of the building impacts the vulnerability of BI less than the other coverages because the hazard associated with loss of use factors, clean-up, and civil exclusion areas are less dependent on the building characteristics.

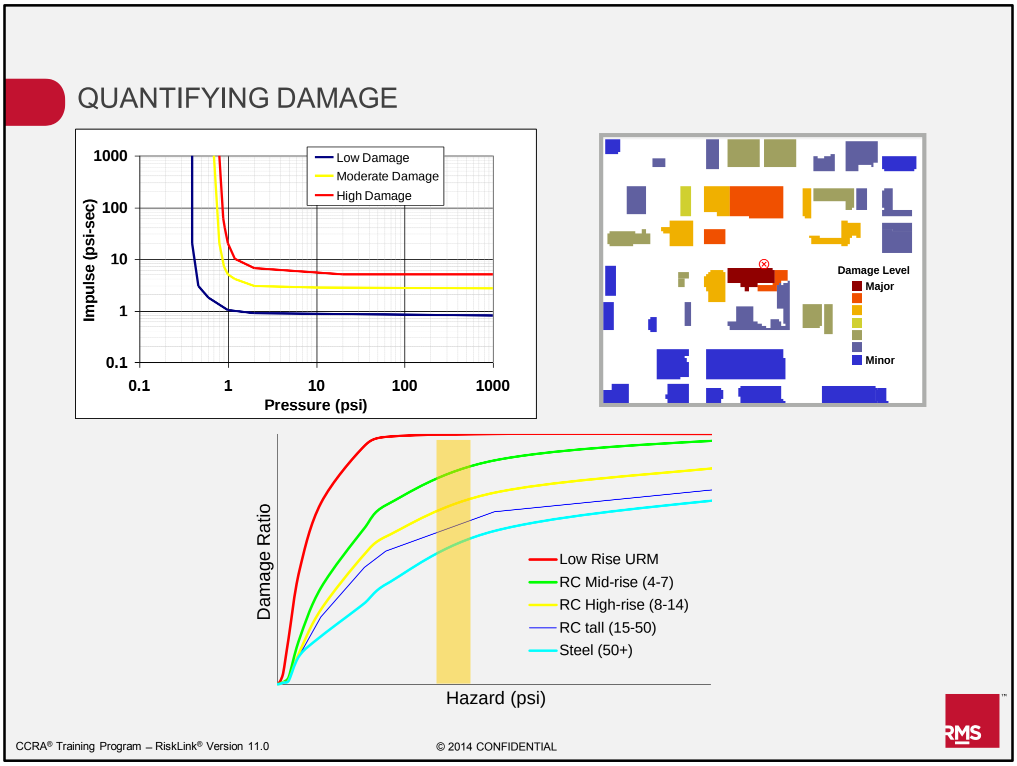
TERRORISM VULNERABILITY ATTACK GROUPS

- Vulnerability Attack Groups
  - Bombs
  - Aircraft impact
  - Conflagration
  - Dirty bombs
  - Chemical (Sarin) attacks
  - Biological (anthrax) attacks
  - Biological (smallpox) attacks
  - Nuclear bomb
  - Industrial plant sabotage
  - Nuclear plant sabotage
  - Hazardous transportation sabotage

At this point, we have identified the key elements used to determine vulnerability classifications for RMS terrorism models. It is also important to understand the role vulnerability classifications play in the RMS terrorism models.

Attack group vulnerability can be classified into eleven classifications: bombs, aircraft impact, conflagration, dirty bombs, chemical (Sarin) attacks, biological (anthrax) attacks, biological (smallpox) attacks, nuclear bomb, industrial plant sabotage, nuclear plant sabotage, and hazardous transportation sabotage.

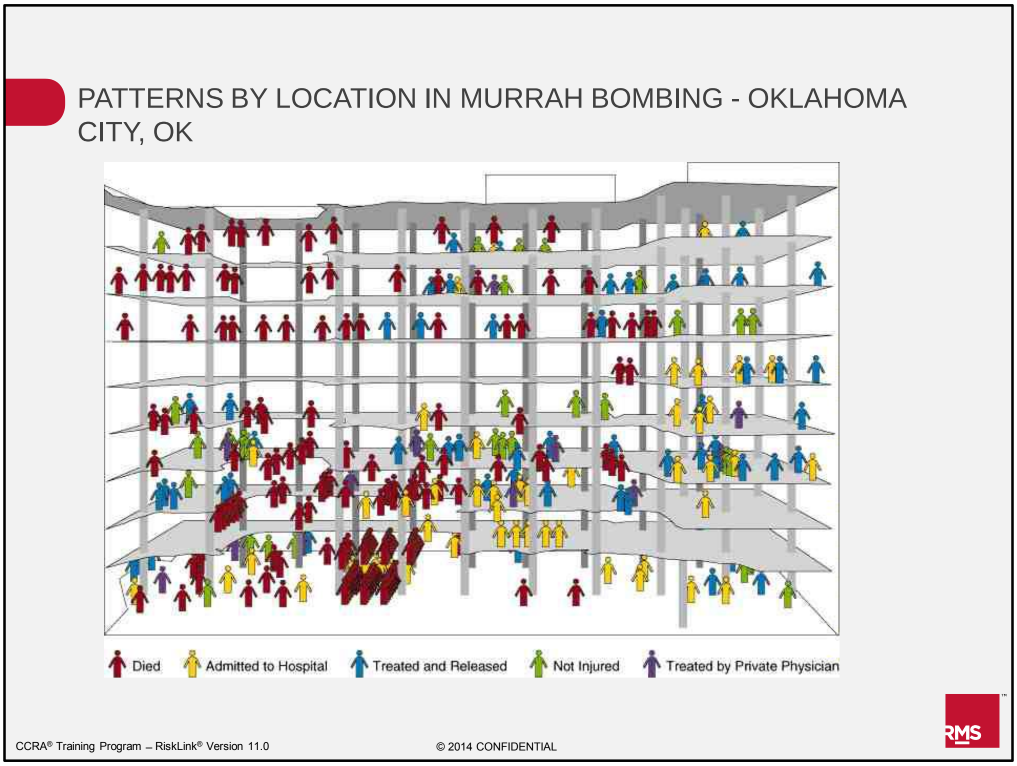
What this means is that the 30 vulnerability functions (found in slide 7) will vary depending upon the hazard associated with each of these attack groups.



As an example, refer back to the bomb blast example from the hazard module. In the top left chart, we can see that high damage (represented by the red curve) requires large pressure and large impulse waves and low damage (represented by the blue curve) occurs with lower pressure and impulse waves. Given that a bomb blast occurs, we can quantify the level of hazard present at a particular location. How does this level of hazard translate into damage?

Remember the vulnerability of a structure is dependent upon the construction and height of the building. In the bottom chart, we can see how the damage ratio (measured on the Y-axis) increases as the level of hazard (measured in psi for blast) increases. This psi to MDR relationship varies by the construction and height of the structure (represented by the vulnerability curve). Depending upon the level of hazard present, the construction and height will impact the vulnerability of the structure differently. If you refer to the yellow highlighted area in the bottom chart, you can see there is less variation in a low rise unreinforced masonry structure than a steel frame high rise structure for different levels of hazard.

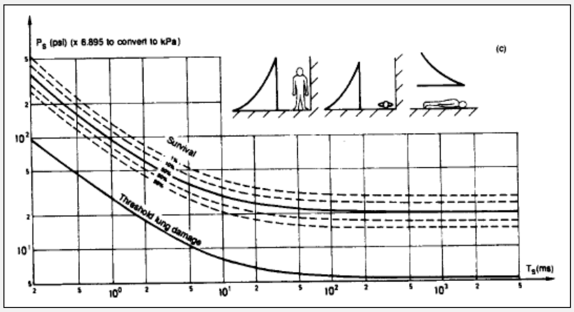
This process of vulnerability assessment is carried out for each of the eleven attack groups listed on the previous slide.



This illustration shows the impact of the blast on people inside the Murrah building in Oklahoma City, Oklahoma. The location of people inside the building is directly related to the types of injuries they sustained. At the front center, where the attack occurred, you will see the more severe injuries. There are minor injuries on the front end of the building. Once a level of hazard is defined for a physical point, this value is used to assess the damage to both property (as seen in the previous example) and people. Information obtained from research and historical events are used to develop and validate the hazard footprints and are used to calibrate casualty rates. Hazard value for a specific point is used to estimate the vulnerability to the structure and the people in and around the structure.

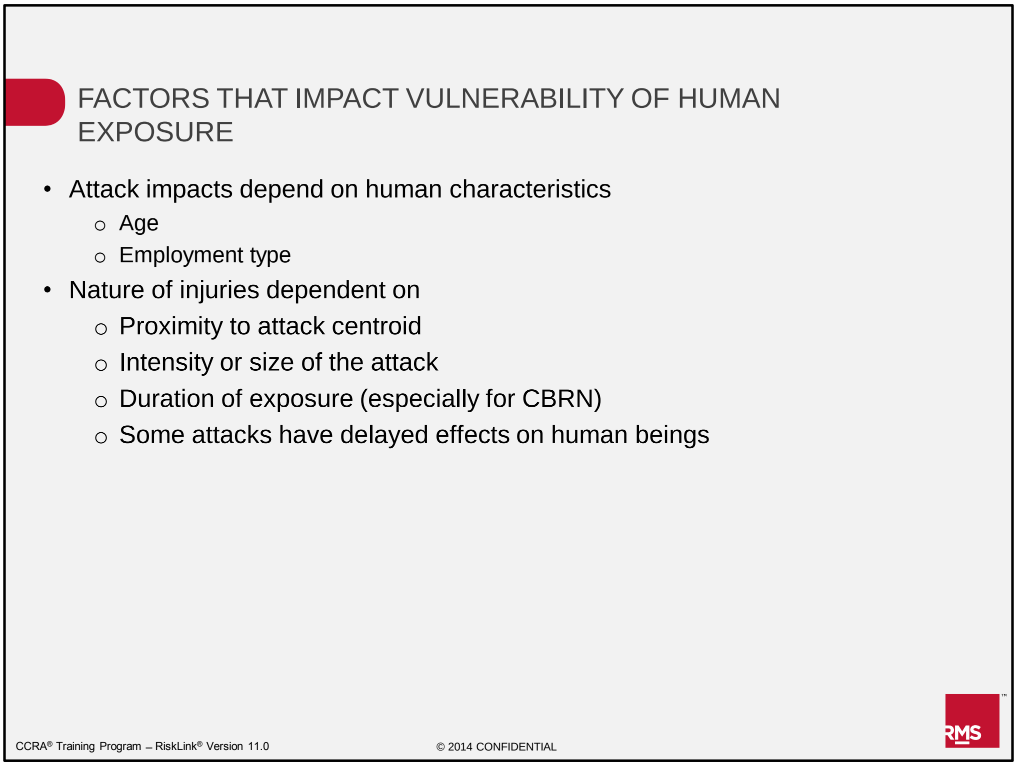
PRIMARY SOURCES OF INJURY DUE TO BLAST HAZARDS

- Injury sources
  - Primary: direct blast pressure (ear, lung damage)
  - Secondary: missile (glass chards, cladding) impact
  - Tertiary: body projected and impacted on objects
- Each of the above modeled as a function of incident pressure and impulse
- Accounts for
  - Indoors pressure wave impacts
  - Building collapse impacts



There are three sources of non-fatal injury due to blast - primary, secondary, and tertiary.

Primary blast injury is organ and tissue damage caused solely by the blast wave. Sources of injury resulting from the primary blast injury include lung damage, ear damage, and eye rupture. “Blast lung” is a direct consequence of the blast wave and results in tearing, hemorrhage, and contusion. Secondary sources of injury result from flying debris and bomb fragments including blunt injury, cuts due to glass chards, and eye penetration. Tertiary injuries resulting from a body being projected include fractures and head or brain injury. Each of these sources is a function of the blast pressure and impulse from the measured hazard.



Factors that impact the vulnerability of human exposure include demographics such as age, gender, and occupation type. The nature of injuries are dependent upon multiple factors such as proximity to the attack centroid, the intensity or size of the attack, and the duration of exposure (especially for exposure to chemical, biological, radioactive, or nuclear materials). Some attacks have delayed effects on human beings. For example, the health effects of a nuclear blast might take days or weeks to appear.

INJURY LEVELS; NCCI-BASED

Injury State	Description
Uninjured	No injuries or health impacts requiring treatment
Medical Only	Minor injury that can be easily treated and will not cause any permanent impairment. For workers compensation, this does not result in any indemnity benefit because the duration of the injury or illness falls within the "waiting period" for workers compensation benefits.
Temporary Total	Injury that results in an individual's inability to work and/or function for some period of time but from which the individual can fully recover within a reasonably short period of time (e.g. an individual breaks a limb).
Permanent Partial – Minor	A permanent injury that results in only partial disability, that is, the individual can continue to work or function normally in some fashion. Minor injuries might include loss of a toe or finger, respiratory problems, and so on. Typically, this is a 0%-25% disability.
Permanent Partial – Major	Similar to Permanent Partial – Minor. However, these injuries result in 25%-100% disability Examples include loss of a leg, loss of an eye, etc.
Permanent Total	The most severe type of non-fatal injury, these individuals fall into a total (100%) disability state. Typically, this is the most expensive type of injury as disability is permanent & the individual is unable to work again. Examples include loss of all limbs, paralysis, & other debilitating injuries.
Fatal	Death

CCRA® Training Program – RiskLink® Version 11.0

The range and extent of injuries vary widely and depend on the attack mode and factors such as proximity to the attack centroid and the length of time of the exposure. This wide spectrum of injuries are classified into six different injury states. The six injury states used by the model are consistent with those of the National Council on Compensation Insurance (NCCI) and are described in this slide in greater detail.

SOURCES OF INJURY FOR CBRN ATTACKS

- Nuclear Bomb
  - Effects on humans depend on the size of the bomb and the distance to the explosion.
  - Injury or death result from the blast itself or as a result of debris from the blast.
  - Injuries include skin burn, eye damage, radiation sickness, and death.
- Anthrax
  - Infected by inhalation, ingestion, or through skin.
  - Severity of injury dependent upon form of contraction.
  - Injury includes skin infections, breathing problems, swelling of lymph glands, and death.

The impact on humans from a nuclear blast will depend on the size of the bomb and the proximity to the explosion. However, the nature of a nuclear blast would likely cause extensive damage, injury, and death.

In a nuclear blast, injury or death may occur as a result of the blast itself or as a result of debris thrown from the blast. Injuries include skin burns and eye damage resulting from looking directly at the blast. Individuals near the blast site would be exposed to high levels of radiation and could develop symptoms of radiation sickness.

Another type of CBRN attack may include anthrax, which is one of several category A agents identified by the Center for Disease Control as a potential terrorist biological weapon. Used effectively, even a small quantity could be highly deadly. Anthrax can be contracted through inhalation, ingestion, or through the skin when handling contaminated products. The severity of the injury is highly dependent on the way the disease is contracted. For example, inhaled anthrax leads to severe breathing problems and shock, and is usually fatal. Other types of injuries include skin infections and swelling of lymph glands.

UNCERTAINTIES IN DECONTAMINATION CRITERIA

- The acceptable level of decontamination required after an attack is uncertain for biological, chemical, and radiation exposures.
- Example, evacuation/remediation requirements for radiation exposure
  - Environmental Protection Agency (EPA)
  - Nuclear Regulatory Commission (NRC)
  - Chernobyl
- The uncertainty in required decontamination levels is a factor in quantifying uncertainties in property decontamination losses.

Decontamination is required following a CBRN event to ensure it is safe to return to the area. For example, if there is a radiation leak at a facility, the level of contaminate present will determine whether the building needs to be shut down and evacuated.

While acceptable levels of certain contaminates are defined by the EPA, there are uncertainties in the acceptable levels of exposure following a biological, chemical, nuclear, or radiological release and standards may not be clearly defined. There are no regulatory standards for decontamination of anthrax spores – the costs of reaching different levels of safety could be an area of dispute between insurance companies and the insureds. This uncertainty in required decontamination levels is a factor that is used to quantify the level of uncertainty in loss estimates.

VULNERABILITY OF BUSINESS INTERRUPTION

- Factors that impact BI loss in a dense urban area
  - Critical revenue generating locations
  - Extra expense
  - Civil authority
  - Service interruption
  - Ingress/egress

Business interruption is challenging to model due to the high level of uncertainty in variables which impact business interruption. This slide gives a list of factors that impact BI loss. If an attack occurs at a bridge or tunnel, it will impact the capability for people to get both in and out of the area. Decontamination of anthrax spores from buildings requires expensive clean-up operation. A "civil authority" exclusion zone beyond the unaffected area causes BI loss as well.

FIRE LOSSES

- For the following applicable attack modes, losses attributable to fire can be quantified:
  - Bombs
  - Aircraft impact
  - Conflagration
  - Industrial sabotage
  - Nuclear bomb

Some regions mandate fire coverage for a terrorist attack on a standard commercial fire policy, even if property terrorism coverage is excluded. For those attack modes that include fire as a damaging agent, the impact of fire can be isolated from the damage of the terrorist attack. RMS has isolated the fire component of loss in the U.S. and Canada within the PTM.

TERRORISM VULNERABILITY MODULE
KEY CONCEPTS

- The key elements used to determine vulnerability are building height and construction.
- The hazard value measured at a specific point is used to calculate the vulnerability of the structure and the casualty rates.
- Vulnerability is estimated separately for each attack mode.
- For applicable attack modes, losses attributed to fire can be quantified.

This slide summarizes the key points from Unit 4. If any of these points are unclear, please revisit the associated slides within the unit.