Medical and Public Health Considerations in the Aftermath of Nuclear Terrorism

Brooke Buddemeier, CHP
Global Security Principal Directorate
Characteristics of different R/N Events

**Nuclear Power Plant Incident**
- Often early warning of release (like a kettle boiling)
- Release occurs over time (like a smoke stack, often in “puffs”)
- Evacuation effective at reducing future exposures to releases, but must be timed to avoid “puff” release

**Dirty Bomb Event**
- No Notice
- All Material Released early
- 1 rem (in 4 days) area might be “a few blocks”
- Hazard comes from both breathing contaminants and direct radiation shine

**Nuclear Detonation**
- No Notice
- All Material Released at once
- 1 rem (in 4 days) area can be 100 miles (10kT)
- Hazard is “direct shine” from fallout
- Highest hazard early (more than half the energy released in the 1st hour)

Example of potential long term relocation areas (> 500 mrem in the second year) for (a) INDs and (b) RDDs
### EPA 400 (1992) Early Phase Protective Action Guides for Evacuation and Sheltering of Members of the Public

<table>
<thead>
<tr>
<th>Protective Action (or sheltering)</th>
<th>PAG (rem) Projected Dose Averted</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evacuation (or sheltering)</td>
<td>1 - 5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Evacuation (or, for some situations, sheltering&lt;sup&gt;a&lt;/sup&gt;) should normally be initiated at one rem.</td>
</tr>
</tbody>
</table>

**Notes:**
- Sheltering may be the preferred protective action when it will provide protection equal to or greater than evacuation, based on consideration of factors such as source term characteristics, and temporal or other site-specific conditions.

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**"...[The planning guidance] does not consider very high doses or dose rate zones expected following a nuclear weapon detonation ..."**
Recent Effort Acknowledgements

- Supporting Science by DHS Science and Technology
- Initial Vision by DHS Office of Health Affairs
- Leadership and Support by DHS FEMA
- Extensive collaboration by DOE National Laboratories, technical organizations, and interagency partners.
Block by Block Assessment of Effects:

- Daytime Population
- Overpressure (psi)
- Thermal Effect (cal/cm²)
- Prompt Radiation
- Fallout dose and dose rate
Evaluating Line-Of-Sight Exposures

- Reduced range of:
  - Thermal Burns
  - Prompt Radiation

Green and blue represent areas of little or no injury for the hazard being analyzed.

In the IND model, people are placed in one of several types of structures or outside:

- Wood Frame Building (WF)
- Light Steel-Frame Industrial Building (SSLSF)
- Multistory Wall-Bearing Building (MSWB)
- Multistory Office Building (MSSF)
- Multistory Office Building, Earthquake Resistant Building (MSSF-ER)

Evaluating how structures both protect and harm their occupants.

**Building Periphery**
- Significant radiation exposure
- Reduced thermal burns
- Glass injuries possible

**Building Core**
- Reduced radiation exposure
- No thermal pulse burns
- No glass injuries

**Fallout**
- Outside, 13%
- MSWB, 30%
- MSSF-Per, 36%
- MSSF-Core, 18%
- MSSF-ER-Per, 1%
- MSSF-ER-Core, 36%
- MSSF-ER-Core, 18%
Advanced Casualty Determination

Population Distributed into buildings
(example: Suburban)

Population @ location X,Y

MSSF-C
MSSF-ER-C
MSSF-ER-P
MSSF-P
MSWB
Outside
SSLF
WF

Buddemeier
Supporting Documentation & Guidance

Planning Guidance for Protection and Recovery Following Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents (2008 Federal Register Notice)
Zoned Approach to Response

- Defining zones; a useful approach to planning:
  - Identify priority zones
  - Prioritize actions within each zone
  - Identify responder protection in each zone
  - Determining where to locate staging areas

“The goal of a zoned approach to nuclear detonation response is to save lives, while managing risks to emergency response worker life and health.”

~Planning Guidance for Response to a Nuclear Detonation
The Light of a Thousand Suns
seen at 1 mile for those with line of sight

- Scenario Presumptions:
  - 10kT Yield (equivalent to 5,000 Oklahoma City Truck Bombs)
  - Ground Level Detonation at 1600 K St. NW
  - Fallout Predicted using Weather from noon on Feb 14, 2009
  - Casualty Numbers Using Daytime Population Estimates

The follow slides contain modeling and analysis and some of our newly developed “first person point of view” visualization products requested by State and Locals to help them understand how an IND event unfolds, what key decisions need to be made, and where new plans and policies should to be considered.
Severe Damage Zone
Major Building Damage / Collapse
>8psi  ~½ mile
Severe Damage Zone
Major Building Damage / Collapse
>8psi ~½ mile

Moderate Damage Zone
from ½ to 1 mile
significant structural damage, blown out building interiors, blown down utility poles, overturned automobiles, some collapsed buildings, and fires
Outer Edge of Moderate Damage Zone

~ 1 Mile from 10KT

Animation depicts timing and damage from the outer edge (1 mile for 10KT) of MDZ.
Light Damage Zone

- Windows broken & glass injuries
Light Damage Zone (1 to 3 miles)

~ 2 Miles from 10KT

Damage caused by “shockwave” of peak free field overpressure.

Damage to windows and other large area, weak building features.

Images taken at 2.6km (1.5 miles) away from PEPCON (conventional accidental explosion estimated to be equivalent to a 1KT free air burst), estimated overpressure shock was ~ 0.9 psi.
FALLOUT

- Fallout is generated when thousands of tons of excavated by the explosion is combined with radioactive fission products and drawn upward by the heat of the event.

- This cloud rapidly climbs through the atmosphere, up to **five miles high for a 10kt**, and highly radioactive particles coalesce and drop back down to earth as they cool.

- Within 10 – 20 miles of the detonation, particles will be the size of table salt or sand as they **fall back to earth contaminating horizontal surfaces**

- These particles give off **penetrating radiation** that can injure people (even inside cars or inadequate shelter)

- **Fallout decays rapidly away with time**, and is most dangerous in the first few hours after the detonation
Blast Shockwave Damage Zone
Outer boundary may be defined by injuries out to ~3 miles (10 kT Example)
Fallout Zone Changes with Time

Day 7

~ 2 hours Cloud over BWI

~ 1 hour Cloud Reaches Atlantic
Dangerous Fallout Zone (DFZ)

- Bounded by radiation levels of 10 R/hr
- Reaches 25 miles downwind
- Reaches maximum extent at 1 hour
- Also Called:
  - High-Hazard Zone (Key Response Factors)
  - Dangerous Radiation Zone (NCRP Report #165)

“Identifying the dangerous-radiation zone [exposure rate ≥10 R/h] will have critical implications on response activities in or near fallout areas. The dangerous-radiation zone is an area where large doses could be delivered to emergency responders in a short period of time.”

~National Council of Radiation Protection and Measurement, Report #165
Hot Zone (0.01 R/h boundary)

- Bounded by radiation levels of 10 mR/hr (0.01 R/h) (1/1000\(^{th}\) of the DRZ)
- Extends 150 miles
- Reaches maximum extent at ~ 12-24 hours
- Extended Response Actions will NOT result in life threatening exposures (>100 rem)

- Also Called:
  - 0.01 R/h Boundary (Planning Guidance for Response to a Nuclear Detonation)

In routine radiation emergency response entering the zone bounded by 0.01 R/h entails donning appropriate personal protective equipment (PPE) and being properly monitored for radiation. For a nuclear detonation, the 0.01 R/h line can reach a maximum extent of several hundred miles within hours of the incident.

2008 Federal Register Notice
Focus on Low Exposure Levels

Consider shelter or evacuation (1 rem)
1.5 million people

Shelter or evacuation warranted (5 rem)
702,000 people
Recommended Initial Action: Shelter

“The best initial action immediately following a nuclear explosion is to take shelter in the nearest and most protective building or structure and listen for instructions from authorities.


Sheltering in the most accessible and sufficiently protective building or structure is the best initial action immediately following a nuclear explosion. This includes ‘Shelter-in-place,’ which means staying inside or going immediately indoors inside the nearest yet most protective structure. People should expect to remain sheltered for at least 12-24 hours.
Exposure similar to routine medical procedures. No immediate health effects expected, probability long term (e.g., cancer) effects small (< 1%) [0.1 – 1 R].

No immediate health effects expected, however exposure high enough that probability long term (e.g., cancer) effects warrant protective actions according to DHS and EPA Protective Action Guidance (PAG) [1 - 100 R].

Integrated Exposure (0 – 2 Hours)
Radiation Injury (Fallout) Presumes First 2 Hours Spent Outside

Integrated Exposure (0 – 2 Hours)
Those that do not shelter:<br>Exposures high enough for some to experience immediate health effects (e.g., nausea and vomiting within 4 h), fatalities unlikely for healthy adults. (100 – 300 R)

Those that do not shelter:<br>Exposures high enough for most to experience immediate health effects (e.g., nausea and vomiting within 4 h), fatalities likely without medical treatment. (300 – 800R)

Those that do not shelter:<br>Outdoor exposures high enough that fatalities are likely with or without medical treatment. (> 800R)
Location of “At Risk” Injured

NCR Population: Exposures and Injuries

Descriptions

- People with Moderate Exposure (125-300R) with mild injuries.
- People with Moderate Exposure (125-300R) without injuries.
- People with Significant Exposure (300-500R) with mid injuries.
- People with Significant Exposure (300-500R) without injuries.
Where are the Injured we can help the most?

Survivors with some type of injury or insult: 320,000
Minor injury: 175,000
At Risk: 100,000 (could benefit most from care)
Expectant: 45,000
Population Reaction

- The obvious hazard of the dust and debris inspire many to shelter in the highest hazard areas,
- Those closest (< 3 miles) to the event will have difficulty evaluating the scale and direction of hazard.
- Some public messaging (radio / TV) does get out and helps inspire additional sheltering in VA, MD, and DE.
- On average, about 50% shelter and 50% spontaneously evacuate away from apparent hazard.
- The largest % of spontaneous evacuees comes from DC who are so close to the event it is difficult to evaluate current / impending hazard.

Assumptions for Discussion
Northeast DC & PG

- 550,000 people (DC + N PG)
- +50,000 from Heavy Fallout
- Fallout Cloud
  - Initially south of the area sweeping to the east like a wall of dust and smoke.
  - The wall of dust/smoke will then drift North
- 250,000 spontaneously evacuate, filling all northward roads first with cars, then with people as cars are abandoned
- Many try (unsuccessfully) to outrun the fallout cloud
90 minute Fallout

10,000 people

100,000 people

250,000 people

450,000 people

400,000 people

Assumptions for Discussion
Evacuation Considerations

- Those in shelters threatened by fire, building collapse, or other life endangering hazard should evacuate or relocate immediately.

12-24 hours: Once DFZ and Hot Zone are established

- Evacuation planning should begin to move sheltered populations out of harms way.
- Evacuation routes should be cleared if possible
- Routes that take advantage of sheltered passage:
  - subways,
  - underground connectors, and
  - building lobbies
- Execution should be phased to reduce the time spent transiting through fallout areas
When evacuations are executed, travel should be at right angles to the fallout path (to the extent possible) and away from the plume centerline, sometimes referred to as “lateral evacuation.”

~Planning Guidance 2nd Ed
### Potential Triage and Casualty Collection Sites

| Site   | Radiation | Physical  
<table>
<thead>
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<tbody>
<tr>
<td>RTR 1</td>
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<tr>
<td>RTR 2</td>
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<td>0</td>
</tr>
<tr>
<td>RTR 3</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Note:**
- **MC** - Medical Care
- **AC** - Assembly Center
- **EC** - Evacuation Center

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**Planning Guidance for Response to a Nuclear Detonation, 2nd Ed.**
National Security Staff
June 2010
Putting It Into Perspective

Potential Outdoor Radiation Illness Area
25 miles long, 500,000 people in area

Blast Zones
3 miles; ~850,000 people in area
Decontamination Issues

- Simple self-decontamination techniques (such as removing outer clothing, showering, and brushing away fallout material) are effective.
- Techniques should be used as the impacted population leaves the high-hazard zone or enters a shelter.
Conclusions

- Assessment of a low yield, ground level nuclear detonation in a modern US city has improved over the last few years.
- Critical, lifesaving actions have been identified and incorporated into planning guidance and federal, state, and local preparedness and response planning activities.

Critical Lifesaving Accomplished through Early, Adequate Shelter followed by Delayed, Deliberate Evacuation.

- Efforts underway in DHS S&T and FEMA to improve understanding of how to save and sustain lives through risk assessments and community specific analysis.
Illustrative Weather Variations

Dec 15, 2006
Noon

Weather Matters!
Rosslyn was the most significantly affected as the window of most of the office building were violently broken and much of the glass and building collapse into the street filling the street below. Flying/falling glass injury ~ 8,000 people in the area.

Crystal City / Pentagon City Area significantly affected as the window of most of the office building were violently broken and much of the glass and minor building collapse create rubble. Flying/falling glass injury ~ 6,000 people in the area.
~100,000 Rosslyn Population
~ 6,800 injuries
(~1,200 serious injuries)

~100,000 Crystal City Population
~5,000 injuries
(~1,000 serious injuries)
Heavy Fallout Area (DC & PG)

- 400,000 people in the heavy fallout area
- Many may not recognize the nature of the event
- 250,000 will shelter regardless because of the dust and injuries
- 150,000 evacuees
  - 50,000 go south,
  - 50,000 go north,
  - 50,000 go east
Southern Washington DC

- 500,000 people south of the event are in an area heavily damaged by blast
  - 50,000 with severe injuries
  - 200,000 with mild injuries

- Although not in the Fallout, the cloud will be menacing
  - 300,000 will flee
    - 10,000 people/hr (166/minute) each bridge cross the S Capital, 11 St., and Penn Ave. bridges (~25% injured)
    - 5,000 people/hr each bridge cross memorial and 14 st. bridges (~50% injured)
Daytime Population Estimates Based on Augmented LandScan

- Northern PG County: 450,000
- District of Columbia: 10 Kt Detonation
  - 100,000
  - 150,000
  - 350,000
  - 50,000
  - 100,000
  - 200,000
  - 300,000
  - 50,000
  - 100,000

*Source:* LandScan, Global Security
Support Regional Situational Assessment

- Designate a regional situational assessment center
- Establish communication with responders in the affected area.
- Obtain approximate radiation levels in the area.
  - Identification of high hazard zones (reading greater than 10R/hr) is a priority, but
  - reporting safe areas (reading less than 10mR/hr) is also important for safe evacuation routes and response staging areas.
- Establish communication with Interagency Modeling and Atmospheric Assessment Center (IMAAC)

Photo: Los Angeles County’s Emergency Operations Center was activated for Operation Golden Phoenix. Photo by Paul Williams.
Early Priority: Obtain approximate radiation levels in the area.

- Identification of high hazard zones (reading greater than 10 R/hr) is a priority, but
- Reporting safe areas (reading less than 0.01 R/hr) is also important for safe evacuation routes and response staging areas.
- Share / Coordinate information across the region to inform Shelter & Evacuations.
Support Public Safety

- Use emergency broadcast systems to shelter populations

- Once the DFZ has been determined, the following activities can occur outside of the DFZ:
  - Establish receptions centers and triage sites
  - Direct response resources to the moderate Damage Zone to support injured extraction
  - Fight fires and control hazards
Emergency Broadcast Messages

- Communication infrastructure may be damaged, plan for multiple communication methods.

- Planners should select individuals with the highest public trust and confidence to deliver messages and should be prepared to deliver key information to the public in the affected areas about protection almost immediately in order to maximize lives saved.

Sample Message from Federal Government IND Messaging Effort

**Immediate Action Message**

**Impacted Community**

- **Suggested for local or state spokesperson**: Fire Chief, Mayor, Governor
- We believe a nuclear explosion has occurred at [Location] here in [City].
- If you live anywhere in the metropolitan area, get inside a stable building immediately.

**You can greatly increase your chance of survival if you take the following steps**

- **Go deep inside:**
  - Find the nearest and strongest building you can and go inside to avoid radioactive dust outside.
  - If better shelter, such as a multi-story building or basement can be reached within a few minutes, go there immediately.
  - If you are in a car, find a building for shelter immediately. Cars do not provide adequate protection from radioactive material.
  - Go to the basement or the center of the middle floor of a multi-story building (for example the center floors (e.g. 3–8) of a 10-story building). These instructions may feel like they go against your natural instinct to evacuate from a dangerous area; however, health risks from radiation exposure can be greatly reduced by:
    - Putting building walls, brick, concrete or soil between you and the radioactive material outside, and
    - Increasing the distance between you and the exterior walls, roof, and ground, where radioactive material is settling.
- **Stay inside:**
  - Do not come out until you are instructed to do so by authorities or emergency responders.
  - All schools and daycare facilities are now in lockdown. Adults and children in those facilities are taking the same protective actions you are taking and they will not be released to go outside for any reason until they are instructed to do so by emergency responders.
  - Stay tuned to television and radio broadcasts for important updates.
  - If your facility has a National Oceanic and Atmospheric Administration (NOAA) Weather Radio, this is a good source of information.
  - If you have been instructed to stay inside, stay tuned because these instructions will change:
    - Radiation levels are extremely dangerous after a nuclear detonation, but the levels reduce rapidly in just hours to a few days.
    - During the time when radiation levels are the highest, it is safest to stay inside, sheltered away from the material outside.
    - When evacuating is in your best interest, you will be instructed to do so.
    - People in the path of the radioactive plume—downwind from the detonation—may also be asked to take protective measures.

Sample Key Message from Planning Guidance for Response to a Nuclear Detonation
Recognizing the Severe Damage Zone

- Few, if any, buildings are expected to be structurally sound or even standing.

- Very few people would survive; however, some people protected within stable structures (e.g., subterranean parking garages or subway tunnels) at the time of the explosion may survive the initial blast.

- Very high radiation levels and other hazards are expected in the SDZ, significantly increasing risks to survivors and responders. Responders should enter this zone with great caution, only to rescue known survivors.

- Rubble in streets is estimated to be impassable in the SDZ making timely response impracticable.
Recognizing the Moderate Damage Zone

- Responders may expect they are transitioning into the MDZ when building damage becomes substantial, such as blown out building interiors, blown down utility lines, overturned automobiles, caved roofs, some collapsed buildings, and fires.

- In the MDZ, sturdier buildings (e.g., reinforced concrete) will remain standing, lighter commercial and multi-unit residential buildings may be fallen or structurally unstable, and many wood frame houses will be destroyed.

- The MDZ is expected to have the highest proportion of ‘survivable victims’ who require medical treatment.

- The MDZ presents significant hazards to response workers, including elevated radiation levels, unstable buildings and other structures, downed power lines, ruptured gas lines, hazardous chemicals, asbestos and other particulates released from damaged buildings, and sharp metal objects and broken glass, for which consideration and planning is needed.
Recognizing the Light Damage Zone

• Nearly all windows will be broken and there will be external panel damage on most structures.

• The damage in this area will be highly variable as shock waves rebound multiple times off of buildings, the terrain, and even the atmosphere.

• As a responder moves inward, windows and doors will be blown in and gutters, window shutters, roofs, and lightly constructed buildings will have increasing damage.

• The severity of injuries responders will encounter in the LD zone should be relatively light and, consist of mostly superficial wounds with occasional flash burns.
Caveat to the 2008 Planning Guidance

“...[The planning guidance] does not consider very high doses or dose rate zones expected following a nuclear weapon detonation and other complicating impacts that can significantly affect life-saving outcomes... **Scientifically sound recommendations** for responders are a critical component of post-incident life-saving activities, including implementing protective orders, evacuation implementation, safe responder entry and operations, and urban search and rescue and victim extraction.”
Dec 15, 2009
Noon

Weather Matters!
# Accounting for Glass and Blast Injuries

<table>
<thead>
<tr>
<th>Psi</th>
<th>Damage</th>
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<tbody>
<tr>
<td>50</td>
<td>( \text{LD}_{50} ) from Lung Damage</td>
</tr>
<tr>
<td>15</td>
<td>Lung Damage</td>
</tr>
<tr>
<td>5</td>
<td><strong>Eardrum Rupture</strong></td>
</tr>
<tr>
<td></td>
<td>Brick houses destroyed; parked aircraft</td>
</tr>
<tr>
<td></td>
<td>destroyed; trucks overturned; telephone</td>
</tr>
<tr>
<td></td>
<td>poles collapsed</td>
</tr>
<tr>
<td>3</td>
<td>Wall of 12-inch concrete shattered; parked</td>
</tr>
<tr>
<td></td>
<td>aircraft destroyed</td>
</tr>
<tr>
<td>2</td>
<td>Aluminum panels ripped off</td>
</tr>
<tr>
<td>0.5</td>
<td>Windows shattered</td>
</tr>
</tbody>
</table>

Graphic presumes 50% injury to glass breakage ratio.

![Casualty Profile for a Wood Frame House](image)

- **Uninjured**
- **Non-Operative Injury**
- **Operative Injury**
- **Fatality**

Overpressure (psi):
- 1.7 psi
- 4 psi
- 5 psi

5 psi
Evacuation Risks

Evacuation is most effective if it can be accomplished *before* the radiological contamination arrives at the point of concern. For a no notice dispersal, this is generally not practical because:

- Those outdoors and in buildings near the event will not have time before the contaminates (smoke/particulate plume) reach them, and
- The radiological nature of the event may not be recognized until after responders arrive.

Immediate evacuation also carries a high degree of risk because:

- In the initial confusion of the event, evacuees may inadvertently evacuate into more heavily contaminated areas, and
- Immediate evacuation tends to be rushed, increasing breathing rates (and therefore internal exposure to airborne contaminates) and the possibility of accidents (either running or driving erratically).
Northwest DC

- 150,000 people
- Rock Creek eastern border
- Fallout Cloud menacing but not moving closer.
- Most significant damage is in Georgetown area (50,000 injuries)
- 75,000 spontaneously evacuate, filling all NW roads first with cars, then with people as cars are abandoned
Hot Zone size 1 week later
Public Strategy

- Public Protection Strategy: Early, adequate shelter followed by informed, delayed evacuation.

  - Adequate Shelter is houses with basements, large multi-story structures, and underground spaces (e.g., parking garages and tunnels)
  
  - Sheltering the first hour in an adequate shelter can keep exposures non-lethal
  
  - Optimal shelter departure time will vary by shelter quality and evacuation path
  
  - Informed evacuation helps ensure rapid exit of the dangerous fallout zone

- Knowing what to do before the event is critical
Improvised Nuclear Device (IND) Response Planning Efforts of the Department Homeland Security
Supporting Documentation & Guidance
Supporting Documentation & Guidance

Planning Guidance for Protection and Recovery Following Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents (2008 Federal Register Notice)

Planning Guidance for Response to a Nuclear Detonation

Second Edition
June 2010

Developed by the National Security Staff Interagency Policy Coordination Subcommittee for Preparedness & Response to Radiological and Nuclear Threats

Global Security
Anticipate • Innovate • Deliver

LLNL-PRES-610932

Buddemeier
Primary “At Risk” Injury Categories

Low exposure (< 125 R), mild trauma: 175,000 people

~4,000 of the ~5,000 potential fatalities can be saved with medical care

These will generally be populations that are upwind of the fallout but in the light on moderate damage zones (LDZ & MDZ). In the case of our Feb 14 scenario, this means South and West DC and Virginia.

Since the injury of concern is trauma, a prompt medical support (<12 hours) will be most effective. Since the number of potential mortalities is only 3% of the overall population in this category, separating and saving the ones on a mortality trajectory may be difficult.

Moderate Exposure (125 – 300R), with and without mild trauma: 60,000 people

~10,000 of the ~15,000 potential fatalities can be saved with medical care

This represents the greatest life saving potential. The radiation levels are high enough to complicate an injury or recovery, but not so high as to be acutely life threatening.

Since the primary mortality mechanism is complications (i.e. immune-suppression) from ARS, medical care can be applied throughout the acute radiation syndrome (ARS) stages to improve prognosis (even as late as weeks later), however early intervention, especially with anti-Neutropenics, can greatly improve outcomes. These survivors will come from downwind areas in dangerous fallout zone (DFZ), also often in the light damage zone (LDZ).

Significant Exposure (300– 530R), with and without mild trauma: 33,000 people

~10,000 of the ~25,000 potential fatalities can be saved with medical care

Although a significant life saving potential, these individuals will require sooner (<3 days) and more intensive care than those with less severe exposures (above). Even with advanced medical care ~50% will perish.

These candidates come from the area where the DFZ overlaps the LDZ and MDZ.
Burn Injury (Secondary)

- Burns from *secondary fires* likely to be a primary thermal injury mechanism
- Based on burns caused by building collapse during earthquakes, this event could result in 1,700 burn patients.
  - 200 have mild burns,
  - 650 have moderate burns
  - 900 have severe burns.

*Information from Gryphon Scientific*
Where are the Injured we can help the most?

Initial survivors with some type of injury or insult: 323,000
Without medical assistance, 99,000 of the injured will turn into fatalities:
With medical assistance, 73,000 will still be fatalities
This means that we can save 26,000 people with medical assistance
<table>
<thead>
<tr>
<th>Dose (Gy)</th>
<th>Trauma</th>
</tr>
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<tbody>
<tr>
<td>&lt; 0.5</td>
<td>None, Non-operative, or operative</td>
</tr>
<tr>
<td>0.5 to 0.7</td>
<td>None, Non-operative, or operative</td>
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<tr>
<td>0.7 to 1.25</td>
<td>None, Non-operative, or operative</td>
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<td>1.25 to 3.0</td>
<td>None, Non-operative, or operative</td>
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<tr>
<td>3.0 to 5.3</td>
<td>None, Non-operative, or operative</td>
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<td>5.3 to 8.3</td>
<td>None, Non-operative, or operative</td>
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<tr>
<td>8.3 to 15</td>
<td>None, Non-operative, or operative</td>
</tr>
<tr>
<td>&gt; 15</td>
<td>None, Non-operative, or operative</td>
</tr>
</tbody>
</table>

Initial Results of Advanced Casualty Modeling

Injuries placed into 3 Categories

- **Recover < 5% fatalities**
  Likely to survive, minimal immediate care requirements

- **5% < Risk < 95% fatality**
  Acute radiation syndrome and other injuries requires advanced medical care

- **95% < Expectant**
  Unlikely to survive even with advanced medical care
<table>
<thead>
<tr>
<th>Short-Term Whole-Body Dose [rad (Gy)]</th>
<th>Acute Death&lt;sup&gt;a&lt;/sup&gt; from Radiation Without Medical Treatment (%)</th>
<th>Acute Death&lt;sup&gt;a&lt;/sup&gt; from Radiation with Medical Treatment (%)</th>
<th>Acute Symptoms&lt;sup&gt;b&lt;/sup&gt; (nausea and vomiting within 4 h) (%)</th>
<th>Lifetime Risk of Fatal Cancer Without Radiation Exposure (%)</th>
<th>Excess Lifetime Risk of Fatal Cancer Due to Short-Term Radiation Exposure&lt;sup&gt;c&lt;/sup&gt; (%)</th>
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</thead>
<tbody>
<tr>
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<td>0</td>
<td>0</td>
<td>24</td>
<td>0.08</td>
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<tr>
<td>10 (0.1)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>24</td>
<td>0.8</td>
</tr>
<tr>
<td>50 (0.5)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>24</td>
<td>4</td>
</tr>
<tr>
<td>100 (1)</td>
<td>&lt;5</td>
<td>0</td>
<td>5 - 30</td>
<td>24</td>
<td>8</td>
</tr>
<tr>
<td>150 (1.5)</td>
<td>&lt;5</td>
<td>&lt;5</td>
<td>40</td>
<td>24</td>
<td>12</td>
</tr>
<tr>
<td>200 (2)</td>
<td>5</td>
<td>&lt;5</td>
<td>60</td>
<td>24</td>
<td>16</td>
</tr>
<tr>
<td>300 (3)</td>
<td>30 - 50</td>
<td>15 - 30</td>
<td>75</td>
<td>24</td>
<td>24&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>600 (6)</td>
<td>95 - 100</td>
<td>50</td>
<td>100</td>
<td>24</td>
<td>&gt;40&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>1,000 (10)</td>
<td>100</td>
<td>&gt;90</td>
<td>100</td>
<td>24</td>
<td>&gt;50&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup>Short-term refers to the radiation exposure during the initial response to the incident. The acute effects listed are likely to be reduced by about one-half if radiation exposure occurs over weeks.

<sup>b</sup>Acute deaths are likely to occur from 30 to 180 d after exposure and few if any after that time. Estimates are for healthy adults. Individuals with other injuries, and children, will be at greater risk.

<sup>c</sup>Most cancers are not likely to occur until several decades after exposure; although leukemia has a shorter latency period (<5 y).

<sup>d</sup>Applies to those individuals that survive ARS.