

# Nuclear Evacuation Analysis Code (NUEVAC)

Improvised Nuclear Device (IND) Response Options Analysis

Presented to:

**FEMA's Modeling and Data Working Group**

By:

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**Sandia National Laboratories**

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# Background

- **The national labs have addressed IND response with DHS support (OHA and FEMA) since FY08.**
  - Technical collaborations enabled by the Modeling and Analysis Coordination Working Group (MACWG)
- **Sandia has focused on evaluation of post-detonation sheltering and evacuation strategies.**
- **Our work has evolved through several phases:**
  - Tool development and general analyses (FY08-09)
  - Support of interagency IND response guidance (FY10)
  - Analysis of specific U.S. urban areas:
    - *Los Angeles (FY10)*
    - *Chicago and National Capital Region (FY11)*
    - *Houston and Boston (FY12)*



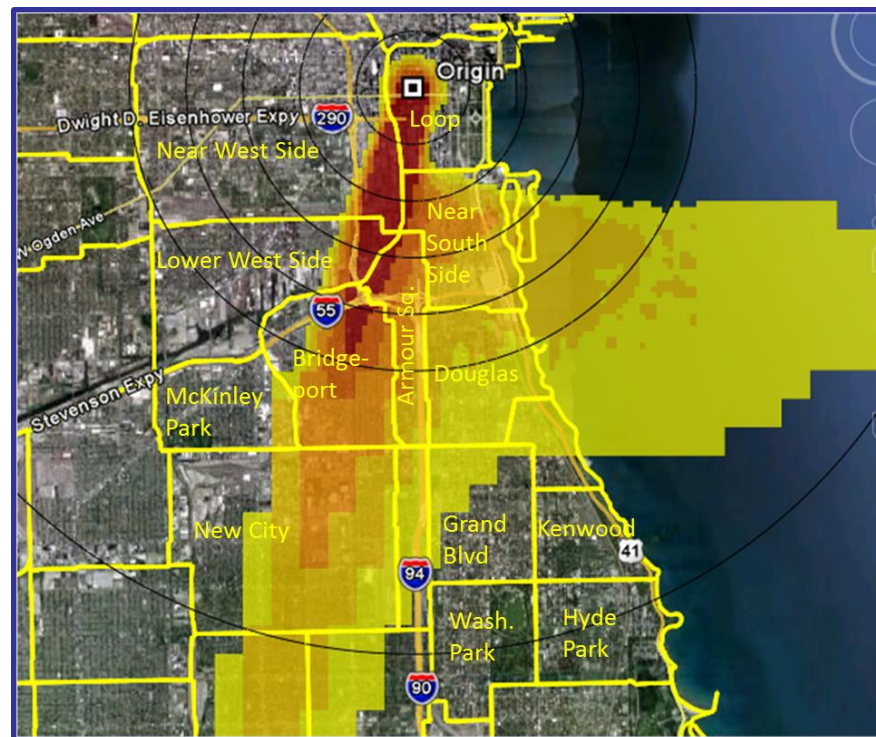
# Context and Key Assumptions

- **Baseline is the IND National Planning scenario**
  - 10 kT ground burst
  - Evaluate responses within the first 72 hours
  - Metric: Acute radiation casualties and fatalities due to fallout exposure
- **Two types of analysis are performed**
  - Regional results show overall impact of alternative strategies
  - Exemplary point analyses highlight local decision making
- **Diverse shelter-evacuate (S-E) strategies are considered**
  - Shelter-in-Place
  - Uninformed Evacuation
  - Informed Evacuation
  - Shelter-to-Shelter transit
  - User Requests (e.g., Shelter-dependent Transit, Route-based Evacuation)



# The Nuclear Evacuation Analysis Code (NUEVAC)

- **NUEVAC permits user-friendly regional zoning and flexible S-E strategies within each zone.**
  - Graphics linked to Google Earth
  - Incorporation of city-specific shelter quality (“Svalin”) data
- **NUEVAC enables specification of a shelter-evacuate strategy for each zone**
  - A diverse range of shelter versus evacuation strategies can be assessed
- **NUEVAC calculates the total radiation dose due to fallout exposure for each individual in the region and models the health effects of that accumulated dose.**

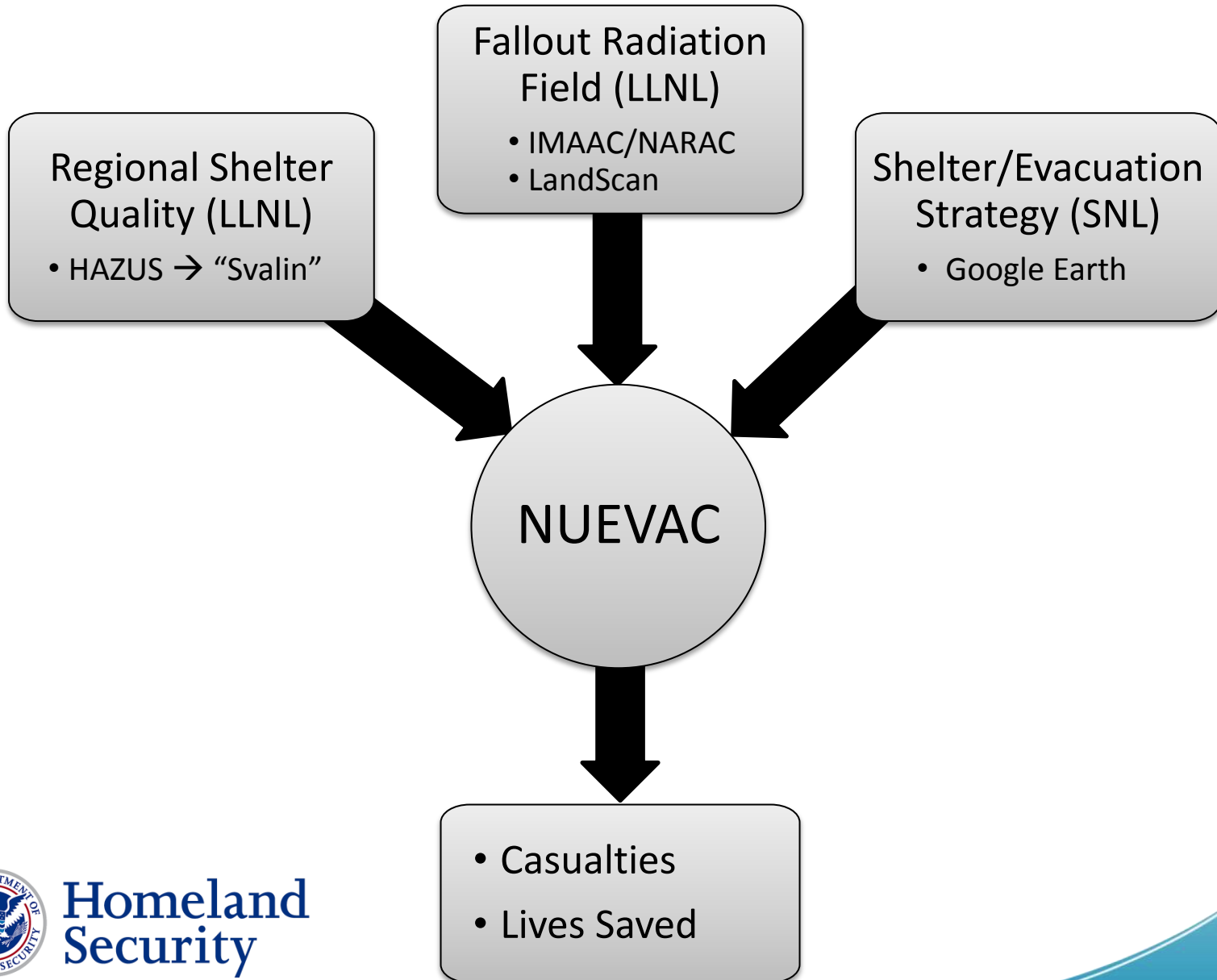


Plume at  $t = 1$  h in the Chicago area with community-based zoning



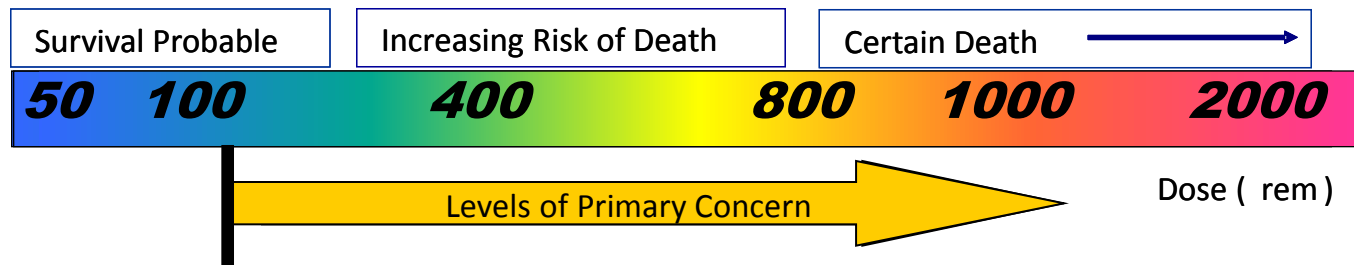
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# NUEVAC's Relationship to Other Models



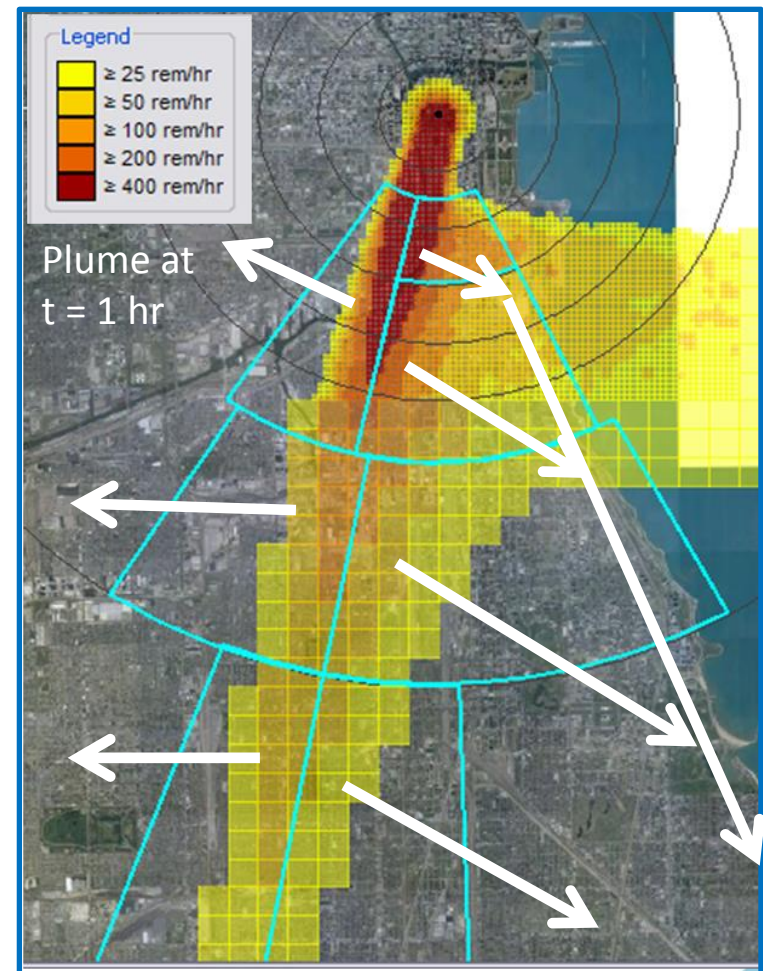
# Assumptions for Exposure Calculations

- Evacuation plans are applied to individuals beyond the outer edge of moderate damage zone (1.5 km for 10 kT)
- Evacuation generally assumed to be by foot (3 km/hr) in intense fallout region
- Acute radiation sickness (injury or death) is primary metric, but latent cancer incidence also calculated
- NUCVAC uses EPA probit parameters:
  - 50% fatality incidence at 300 rem
  - 50% acute injury incidence at 150 rem
  - 10% acute injury incidence at 100 rem



# Primary Shelter-Evacuate Options

- **Shelter-in-place**
  - Individuals remain inside a building with specified protection factor, or in Svalin-designated protection factor distribution
- **Uninformed Evacuation**
  - Individuals evacuate radially from the point of detonation after an initial interval of shelter-in-place
- **Shelter-to-Shelter Transit**
  - Individuals transit outdoors to a higher quality shelter after an initial interval of shelter-in-place
- **Informed Evacuation**
  - Individuals evacuate from fallout region after an initial interval of shelter-in-place;
  - Evacuation uses a path optimized to avoid the most hazardous portions of the fallout region
- **Shelter-dependent Transit**
  - Requires use of Svalin shelter quality data
  - Individuals transit to better, nearby shelter only if their initial shelter is inadequate. Otherwise, they shelter-in-place.



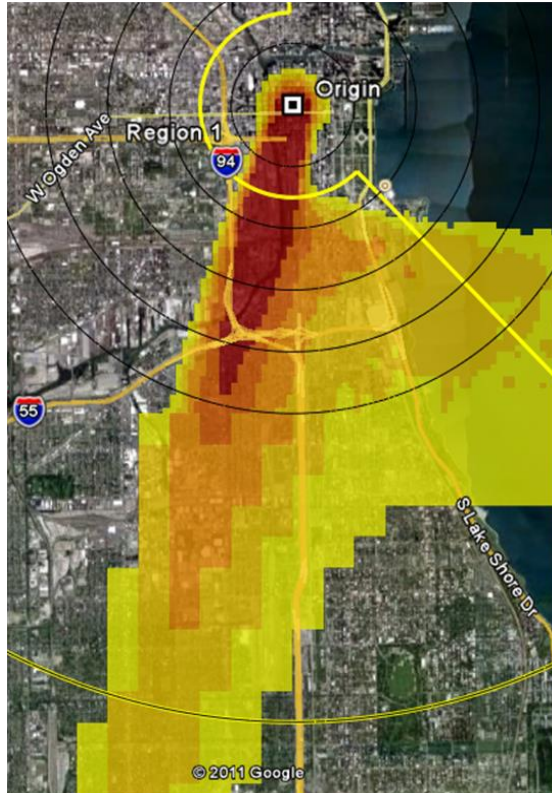
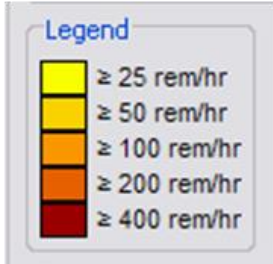
**Informed Evacuation Paths in Chicago**



# Differential Casualty Incidence

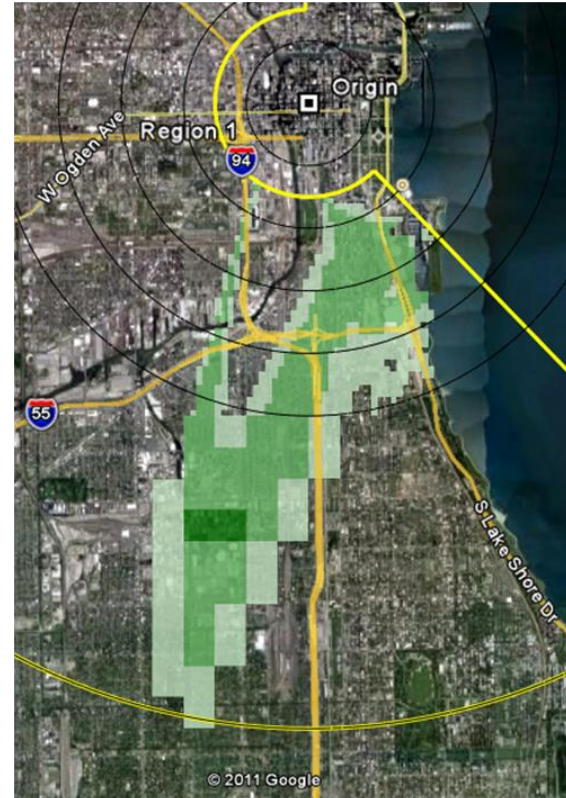
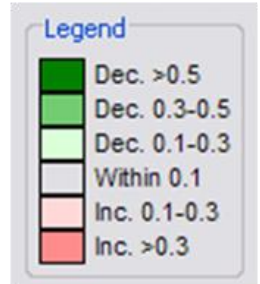
Shelter Transit (PF=2 to PF=10) relative to Shelter-in-Place (at PF=2)

Dose Rate



Plume at  
t = 1 hr

Differential Incidence



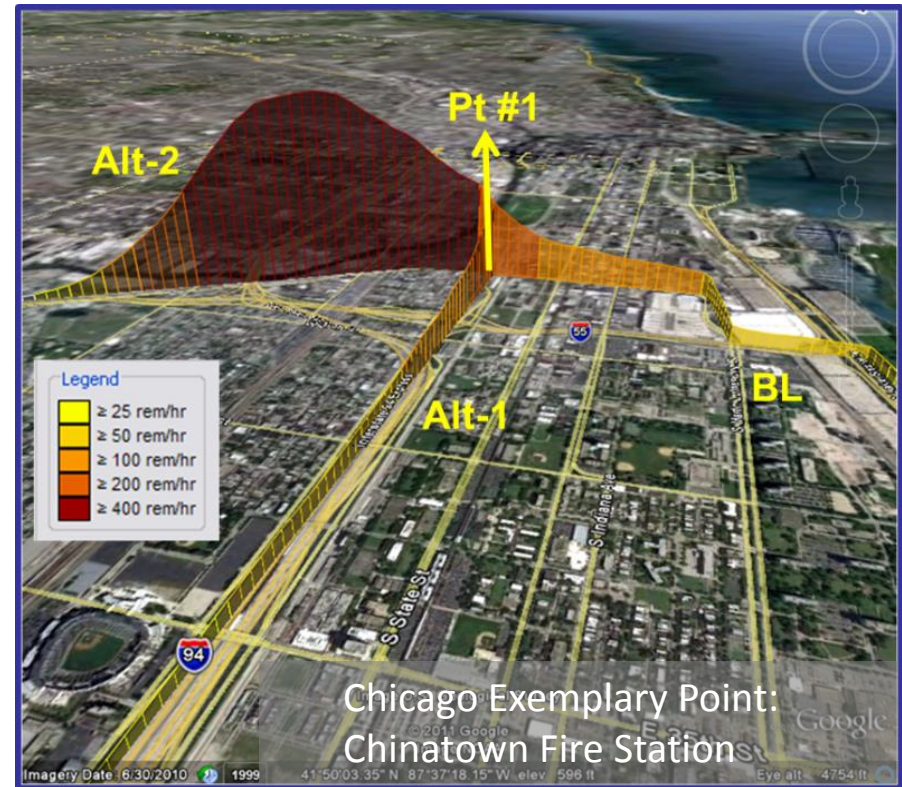
Departure Time = 1 hour  
Transit Time = 12 minutes



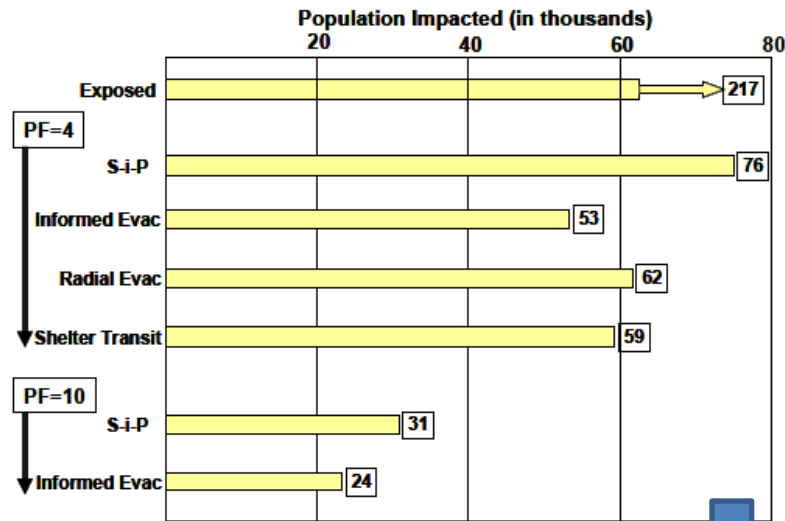
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# Exemplary Point Analyses

- Exemplary point analyses add realism to the decision environment.
  - Specific initial shelter factors
  - Realistic evacuation route alternatives
  - Specific nearby shelters for possible transit
- Departure time is a critical decision variable.
  - Early evacuation absent good situational awareness is risky
- Often the “natural” decision is not the right decision.



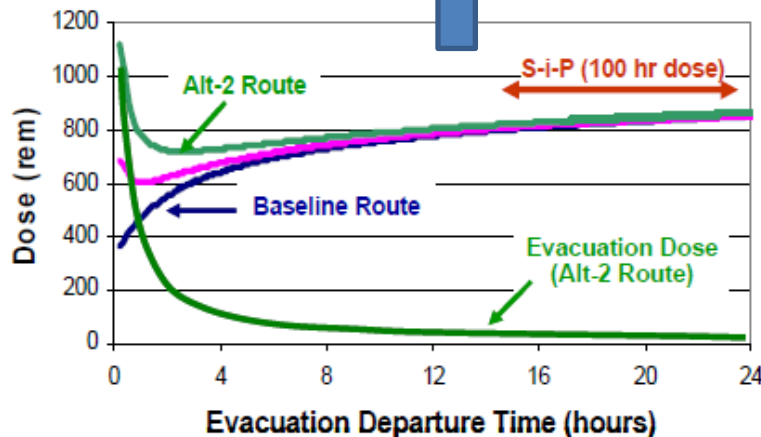
# S/E Analysis Results are Summarized in an Technical Report to Support FEMA's IND Planning Program



## 1) Regional Results



## 2) Exemplary Point Analysis



**SANDIA REPORT**  
 SAND2009-3299  
 Unlimited Release  
 Printed June 2009


**Analysis of Sheltering and Evacuation Strategies for an Urban Nuclear Detonation Scenario**

Larry D. Brandt, Ann S. Yoshimura

Prepared by  
 Sandia National Laboratories  
 Livermore, California 94550

Sandia is a multprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-84OR21400.

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## Backup slides:

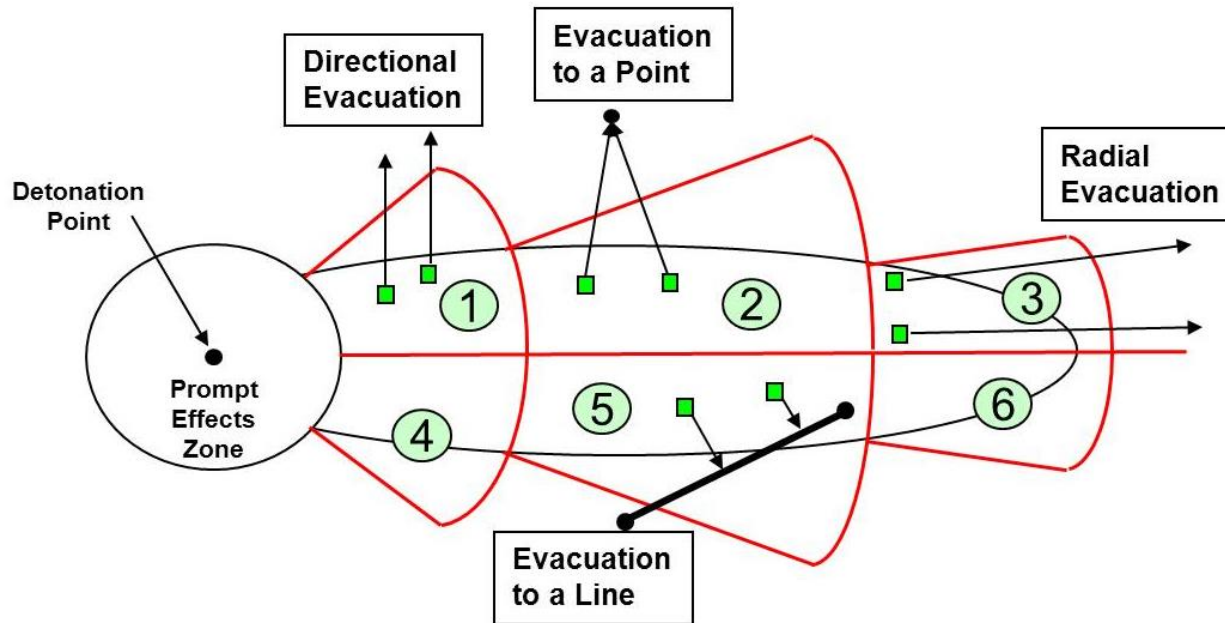
- Additional information on NUEVAC tool
- References and publications



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# NUEVAC Zoning and Movement Protocols



## NUEVAC Regional Zoning Options

- Arc-based zones (as shown above)
- Polygonal zones
- Imported zone files

## NUEVAC Movement Segment Options

- Stationary for specified time
- In fixed direction for specified velocity and time
- To fixed point at specified velocity
- Radial from detonation point
- To a designated line (shortest path)



# NUEVAC Analysis Environment

**Evacuation Region Editor**

Name:

Evacuation Behaviors (Paths)

0 - 100

Shelter Transmission Range:  % -  %

**Initial Shelter**

Duration (hr)

**Action**

type:

Shelter transmission factor:

Speed (km/hr):

Point 1 distance East of burst (km):

Point 1 distance North of burst (km):

Point 2 distance East of burst (km):

Point 2 distance North of burst (km):

**Action**

type:

Shelter transmission factor:

Speed (km/hr):

Direction (deg CW from N):

Duration (hr):

Display Time Control

Time: **1 hr 0 min**

5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95

The map displays a grid-based dose rate distribution with a color scale from yellow (low) to dark red (high). Cyan lines represent evacuation routes starting from a central point and moving outwards. A green dot indicates the current time position on the map.

**Grid Display**

Opacity:

**Legend**

- $\geq 25$  rem/hr
- $\geq 50$  rem/hr
- $\geq 100$  rem/hr
- $\geq 200$  rem/hr
- $\geq 400$  rem/hr

Population Distribution

Shelter Transmission Factor

Dose Rate (exposed)

Health Effects (96 hr)

(none)

**References**

- Satellite Image
  - Low Resolution
  - High Resolution
- Origin
- Range circles (1-5, 10, 20, 30 km)
- DC\_EvacRoutes.kml
- Emergency Services.kml
- NCR Exmp Pts.kml
- New Cardozo Rts 24Oct.kml

# NUEVAC Analysis Environment

**NUEVAC v3.2.4**

File Tools Model

**Population & Shelter Database**  
 DC.city  
 population min radius: 1.5 km  
 population max radius: 10.0 km  
 Initial Shelter Transmission Factor  
 Uniform  
 0.25

**Radiation Field**  
 DC\_Feb14.10KT.rad  
 Rotation  
 0 degrees cw

**Evacuation Plan**  
 IE-1;Td3hr.xml

**Casualty Calculations (96hr)**  
 Totals Show Table

	Fatality	Injury	Cancer
Evacuation	5,605	24,496	9,504
No Evac.	12,769	41,987	12,105

Calculate

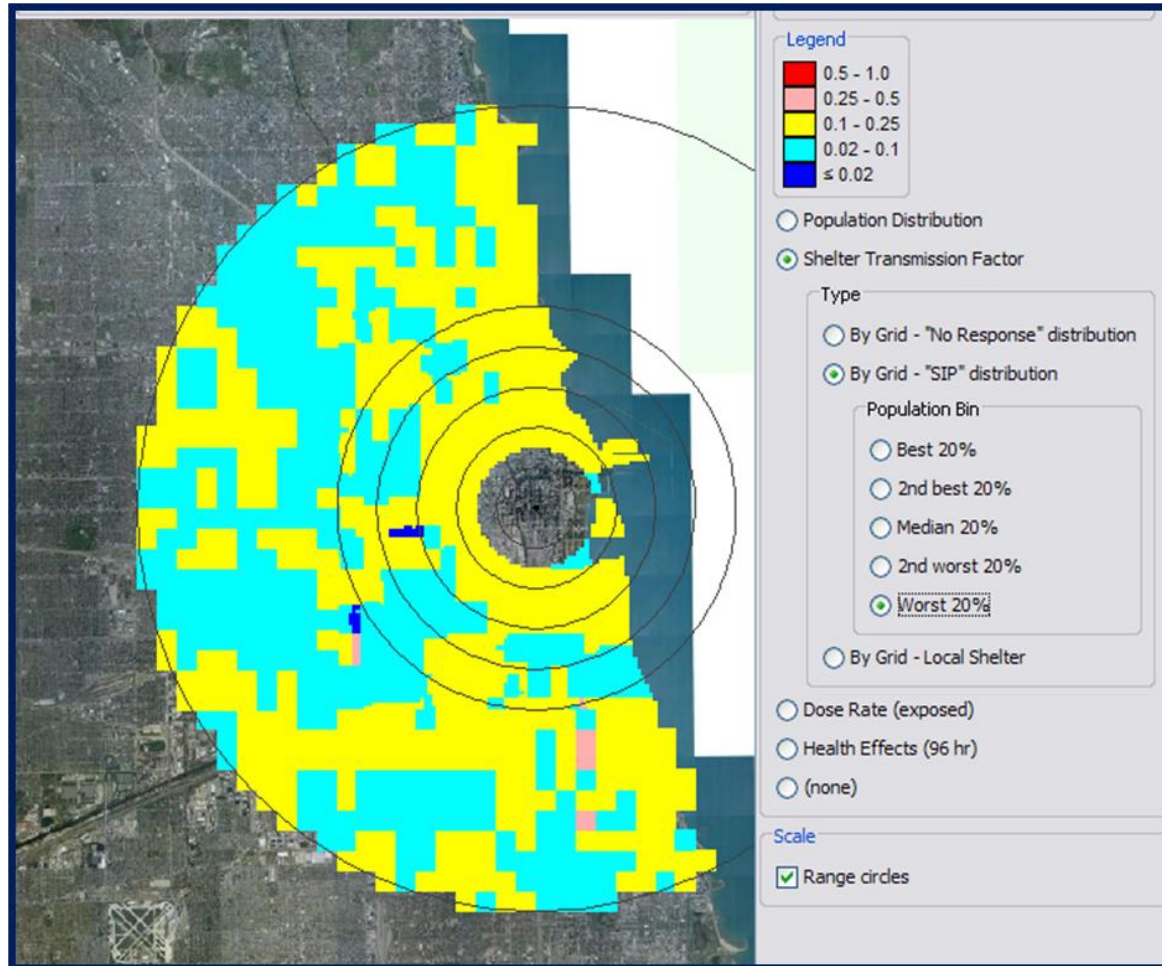
**Display Time Control**  
 Time  
 1 hr 0 min  
 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95

**Grid Display**  
 Opacity  
 Legend  
 ≥ 0.1  
 ≥ 0.3  
 ≥ 0.5  
 ≥ 0.7  
 ≥ 0.9  
 Population Distribution  
 Shelter Transmission Factor  
 Dose Rate (exposed)  
 Health Effects (96 hr)  
 Type  
 Fatality  
 Injury  
 Cancer  
 Scenario  
 Evacuation  
 No Evacuation  
 Differential (Evac. vs No Evac.)  
 (none)  
 References  
 Satellite Image



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# NUEVAC visualization of regional shelter quality data (SVALIN data)



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# Selected References

## Sandia Publications

- Brandt, L. D. and A. Yoshimura, “Analysis of Sheltering and Evacuation Strategies for an Urban Nuclear Detonation”, Sandia National Laboratories, SAND2009-3299, June 2009.
- Brandt, L. D. and A. Yoshimura, “NUclear EVacuation ANalysis COde (NUEVAC): A Tool for Evaluation of Sheltering and Evacuation Responses Following Urban Nuclear Detonations”, Sandia National Laboratories, SAND2009-7507, November 2009.
- Brandt, L. D., “Mitigation of Nuclear Fallout Risks Through Sheltering and Evacuation”, Sandia National Laboratories, SAND2009-7367C, presented at the American Nuclear Society Topical Meeting on Risk Management, November 18, 2009.
- Brandt, L.D. and A.S. Yoshimura, “Analysis of Sheltering and Evacuation Strategies for a Chicago Nuclear Detonation Scenario,” Sandia National Laboratories, SAND2011-6720, September 2011.
- Brandt, L.D. and A.S. Yoshimura, “Analysis of Sheltering and Evacuation Strategies for a National Capital Region Nuclear Detonation Scenario,” Sandia National Laboratories, SAND2011-9092, December 2011.
- Joint Reports with LLNL
- Buddemeier, B.R. et al, “Chicago Region Key Response Planning Factors for the Aftermath of Nuclear Terrorism,” Lawrence Livermore National Laboratory, LLNL-TR- 507192, October 2011, For Official Use Only.
- Buddemeier, B.R. et al, “National Capital Region Key Response Planning Factors for the Aftermath of Nuclear Terrorism,” Lawrence Livermore National Laboratory, LLNL-TR-512111, November 2011.

