SAND2007-1394P

Consequence Analysis and Modeling

University of Missouri-Rolla

March 12, 2007

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Sandia National Laboratories

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Transportation Consequence Analysis

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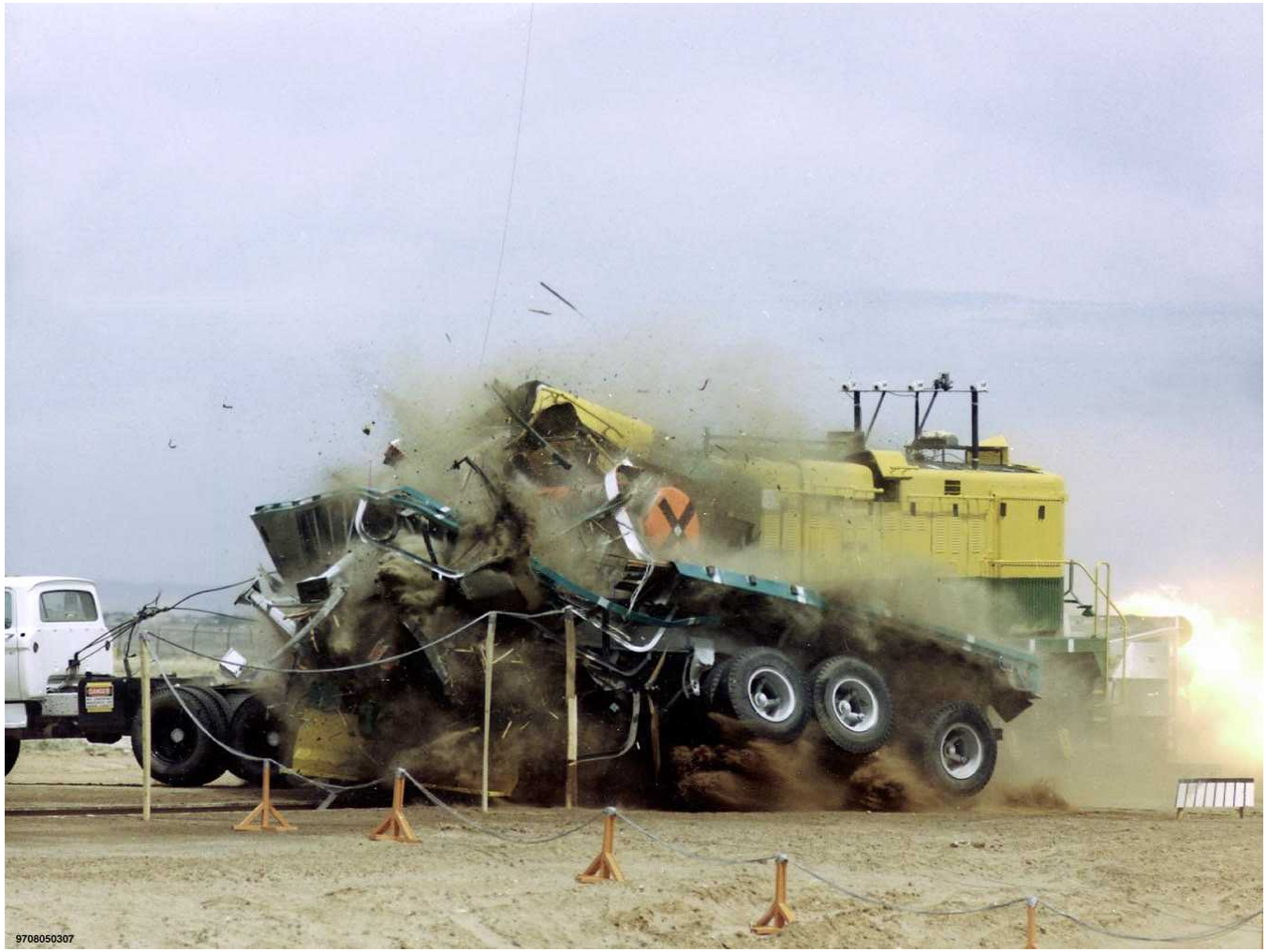
Cask Testing

- Drop Test
  - 30 mph onto an unyielding target
- Crush Test
  - 1,100 lb steel plate at 30 mph
- Puncture Test
  - 6 inch diameter steel spike at 10 mph
- Fire Test
  - 30 minute fire at 1,475 F
- Immersion Test
  - Under 50 feet of water for 8 hours

Severe Accident Cask Testing



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Assumptions

- Worst case accident release fractions used (Yucca Mtn. FEIS).
  - If an accident occurred, probability of this type of accident is:
    - 1 in 1.1 billion

- 2000 Census used to determine population density within each isopleth.

- Local weather conditions were used at time of analysis.

- Only 30 km downwind of accident were analyzed.

- Modeled as an ground level release
  - Elevated releases

Basic Gaussian Dispersion Model for Dilution at Ground Level for an Elevated Release

$$\frac{X}{Q} = \frac{1}{\pi \cdot \sigma_y \cdot \sigma_z \cdot \mu} \cdot e^{\left(\frac{-y^2}{2 \cdot \sigma_y^2}\right)} \cdot e^{\left(\frac{-H^2}{2 \cdot \sigma_z^2}\right)}$$

where:

X = Concentration of dispersed substance at ground level (Ci/m^3)
Q = Rate of release of dispersed substance (Ci/sec)
μ = Wind speed (m/sec)
σ_y = Crosswind meteorological constant (m) [y-axis Gaussian half-width]
σ_z = Vertical meteorological constant (m) [z-axis Gaussian half-width]
y = Distance off centerline (m)
H = Release height (m)

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Basic Gaussian Dispersion Model for Dilution at Ground Level for an Elevated Release with Dry Deposition

$$\frac{X}{Q} = \frac{V_s}{\pi \cdot \sigma_y \cdot \sigma_z \cdot \mu} \cdot e^{\left(\frac{-y^2}{2 \cdot \sigma_y^2}\right)} \cdot e^{\left(\frac{-\left(H - \frac{V_s \cdot x}{\mu}\right)}{2 \cdot \sigma_z^2}\right)}$$

where:

X = Concentration of dispersed substance at ground level (Ci/m^3)
Q = Rate of release of dispersed substance (Ci/sec)
μ = Wind speed (m/sec)
σ_y = Crosswind meteorological constant (m) [y-axis Gaussian half-width]
σ_z = Vertical meteorological constant (m) [z-axis Gaussian half-width]
H = Release height (m)
y = Crosswind distance off centerline (m)
x = Downwind distance along the centerline (m)
V_s = Dispersed substance deposition velocity (m/sec)

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Basic Gaussian Dispersion Model for Dilution at Ground Level along the Plume Centerline with Dry Deposition

$$\frac{X}{Q} = \frac{V_s}{\pi \cdot \sigma_y \cdot \sigma_z \cdot \mu}$$

where:

X = Concentration of dispersed substance at ground level (Ci/m^3)
Q = Rate of release of dispersed substance (Ci/sec)
μ = Wind speed (m/sec)
σ_y = Crosswind meteorological constant (m) [y-axis Gaussian half-width]
σ_z = Vertical meteorological constant (m) [z-axis Gaussian half-width]
V_s = Dispersed substance deposition velocity (m/sec)

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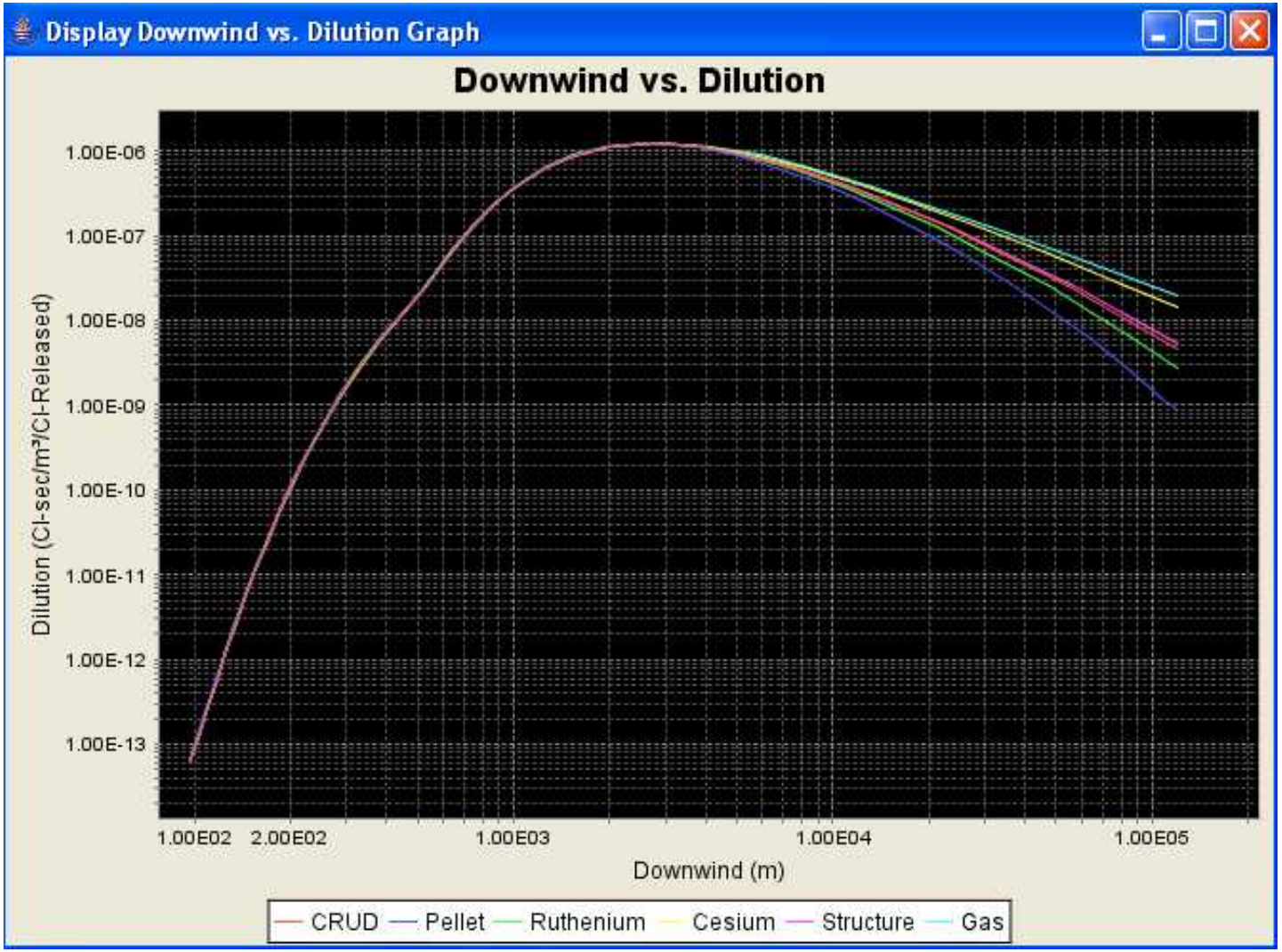
Elevated Releases



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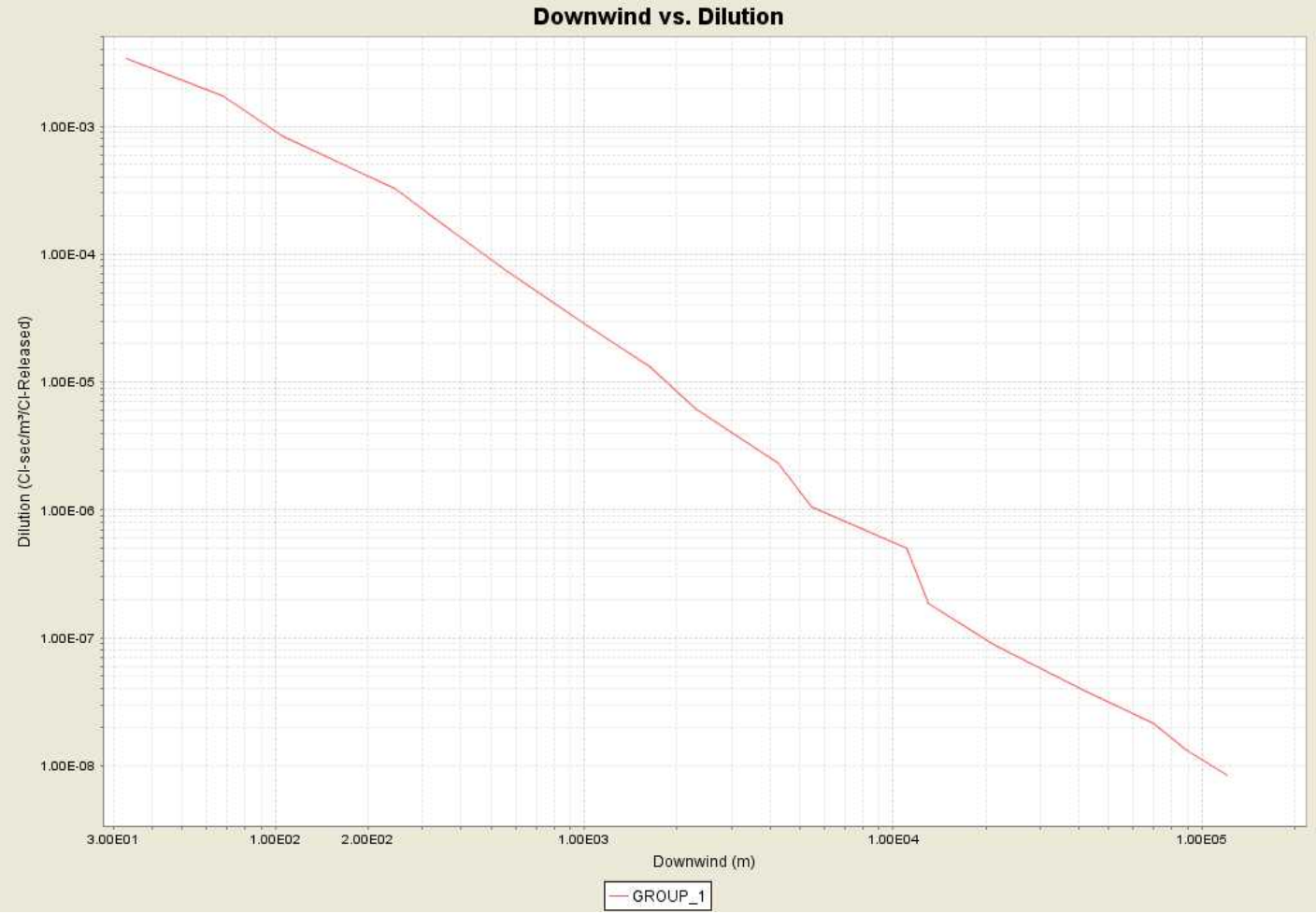
Ground Level Releases



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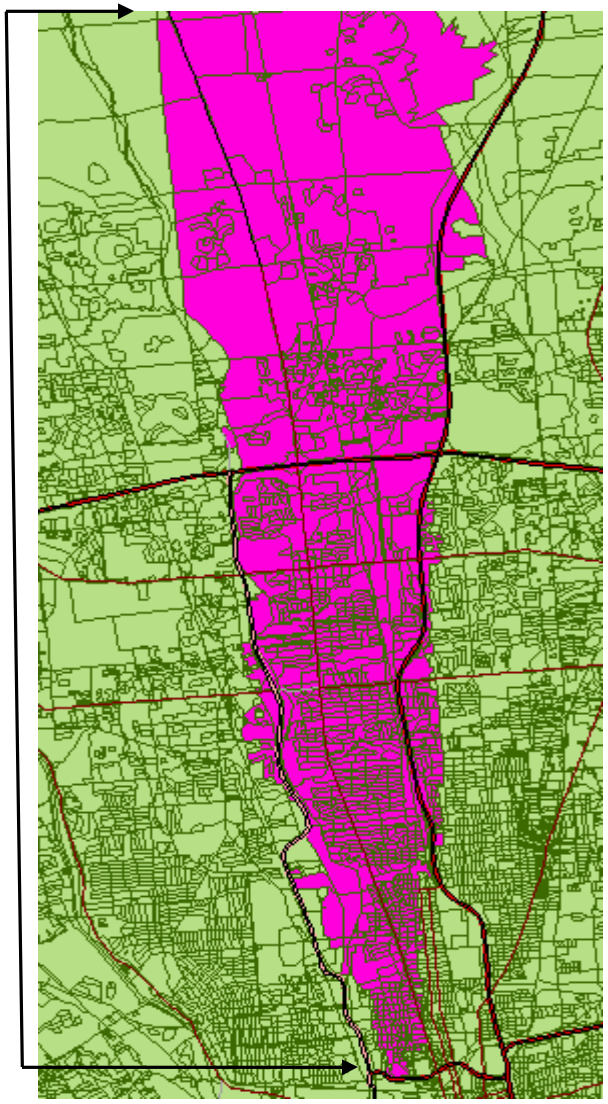
Urban Area Release

Released near the downtown of a major metropolitan area

- **The plume was analyzed for 30 km**
- **Used user-defined weather with local weather patterns**
- **Population ~1.1 million**



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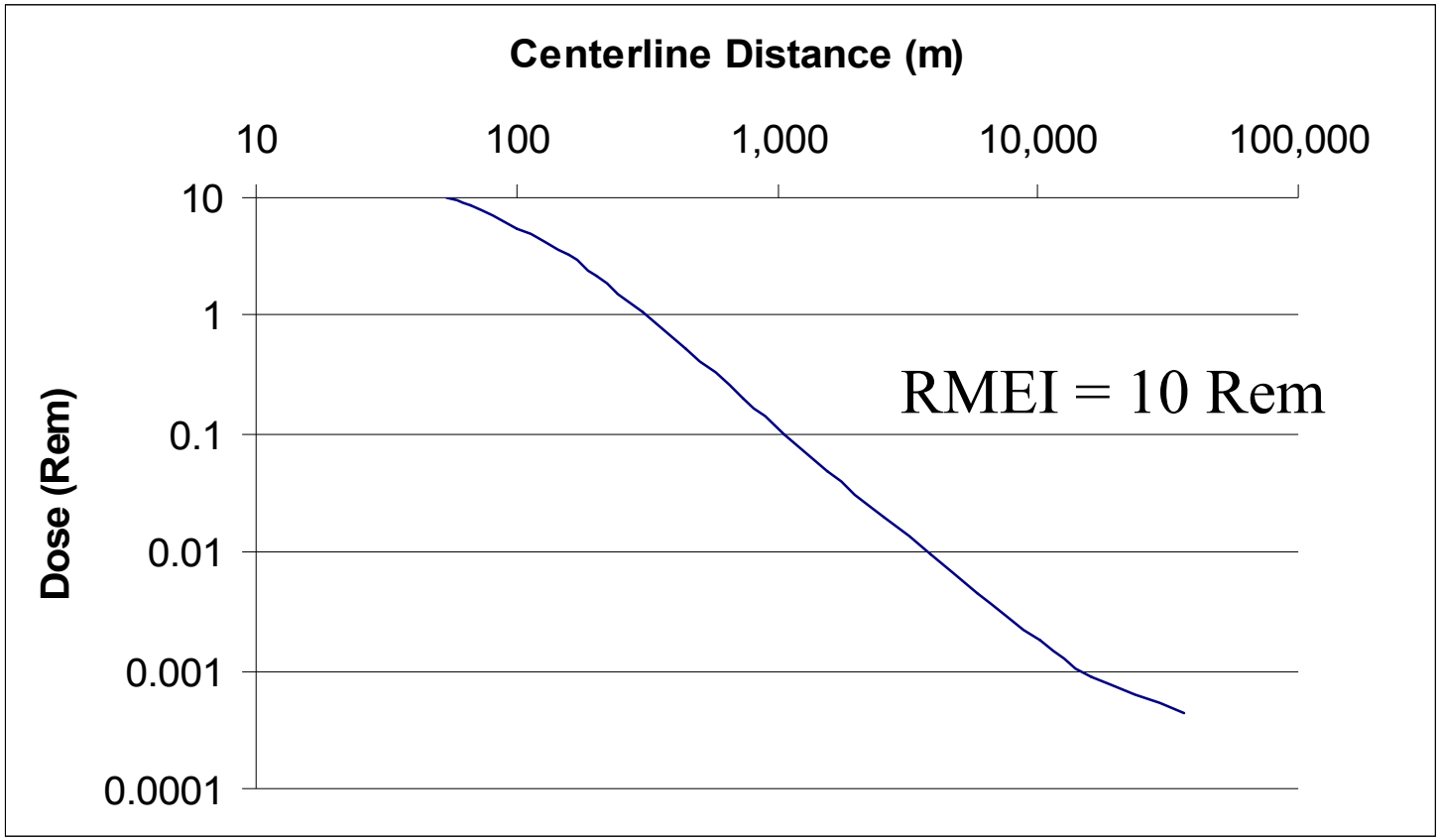
Urban Release RADTRAN Results

Maximum Individual Consequence (24 hour evacuation time)



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Urban Release RADTRAN Results

	Total Exposed Population under the Plume
Urban	62,800

Expected Values of Collective Dose (Person-Rem)

	Groundshine	Inhalation	Resuspension	Cloudshine
Urban	480	830	40	0.34

	Early Fatality	Early Morbidity
Urban	**0.00**	**0.00**

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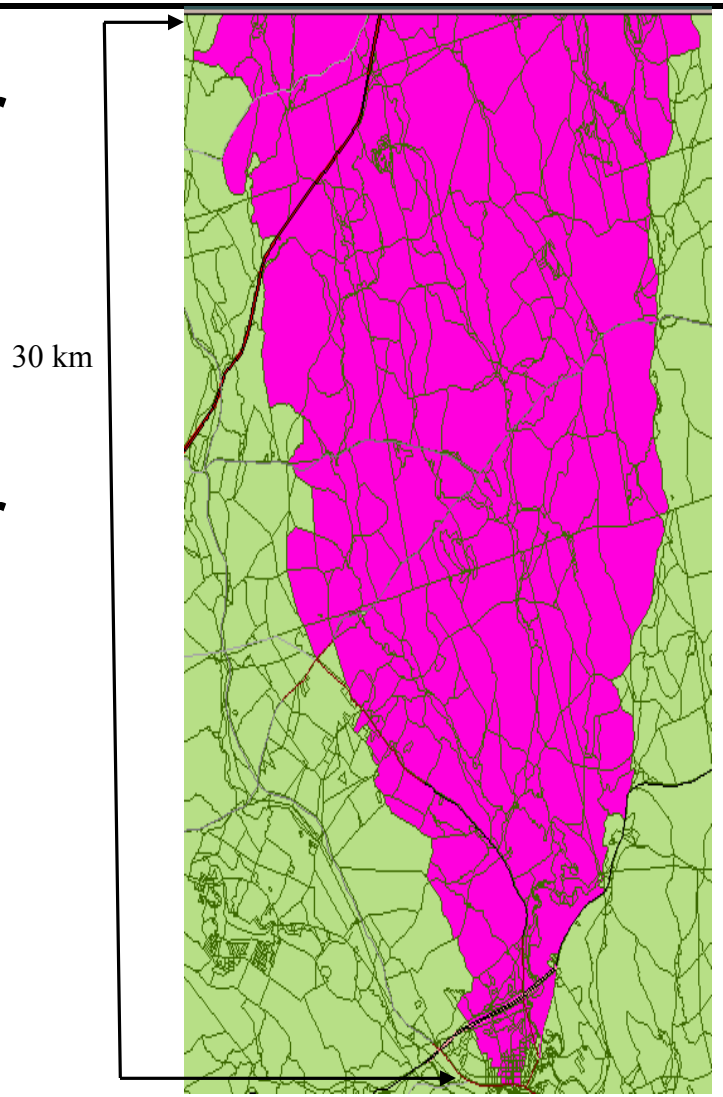
Small Town Release

Released near the center of a small town.

- **The plume was analyzed for 30 km**
- **Used user-defined weather with local weather patterns**
- **Population ~22,000**



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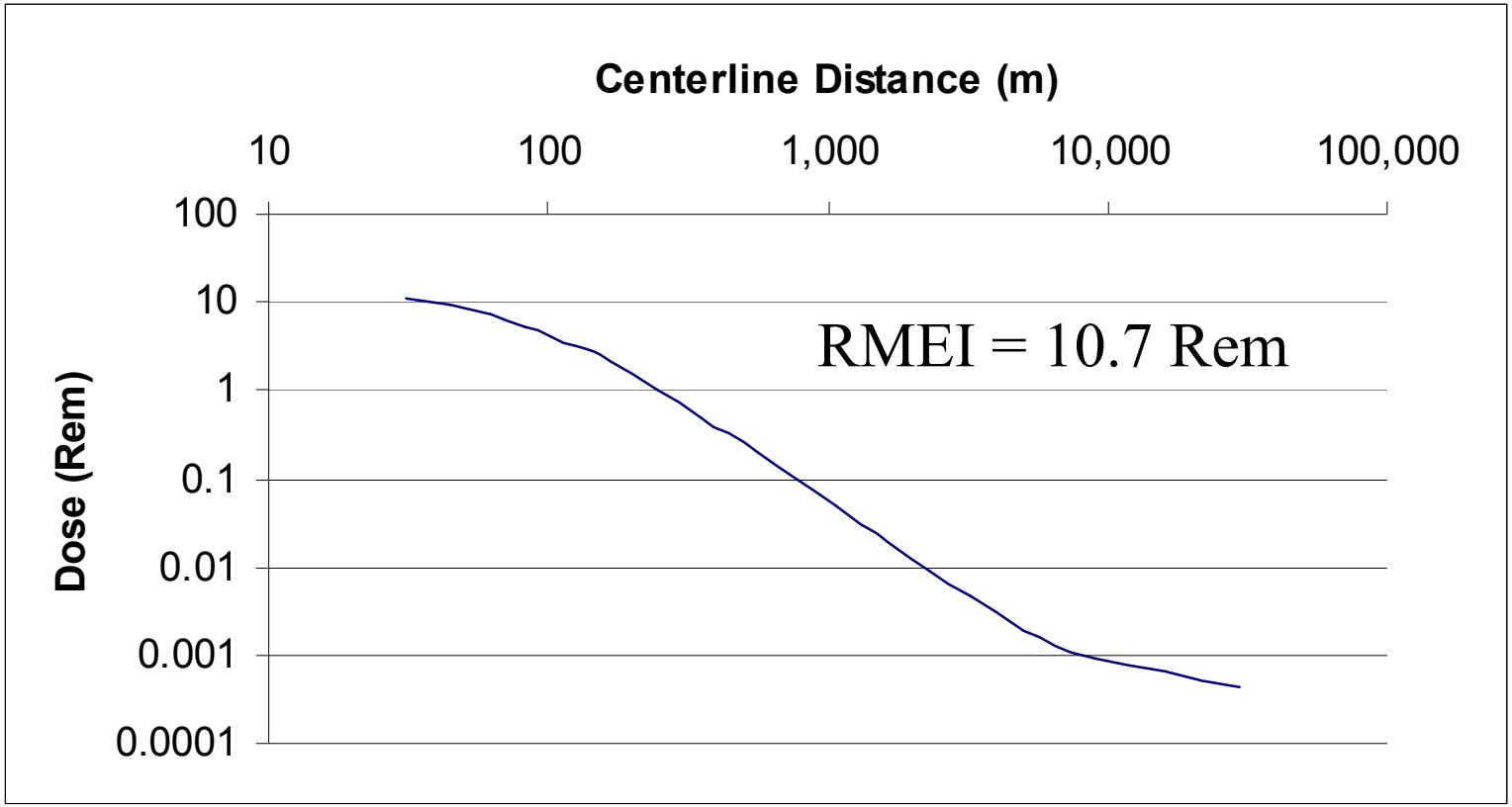
Small Town Release RADTRAN Results

Maximum Individual Consequence (24 hour evacuation time)



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Small Town Release RADTRAN Results

	Total Exposed Population under the Plume
Rural	5,270

Expected Values of Collective Dose (Person-Rem)

	Groundshine	Inhalation	Resuspension	Cloudshine
Rural	42	330	16	0.13

	Early Fatality	Early Morbidity
Rural	**0.00**	**0.00**

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Small Town Release RADTRAN Results

Societal Ingestion Dose (Person-Rem)		
	Gonads	Effective
Rural	5.45	16.2

Societal Ingestion Dose by Organ (Person-Rem)						
	Breast	Lungs	Red Bone Marrow	Bone Surface	Thyroid	Remainder
Rural	2	2	29	250	2	11

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RDD Consequence Analysis

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Input Sources

- Assume 100 kg of Co-60
  - 113,000,000 curies
- Assume 16” of lead as shielding surrounding source
  - Model exposure rate using Microshield v7.01
- Assume 10% of the Co-60 is released
- Assume 10% of the material released is aerosolized
- Assume 5% of the aerosolized material is respirable
- Assume 20% of all rural land is farmland

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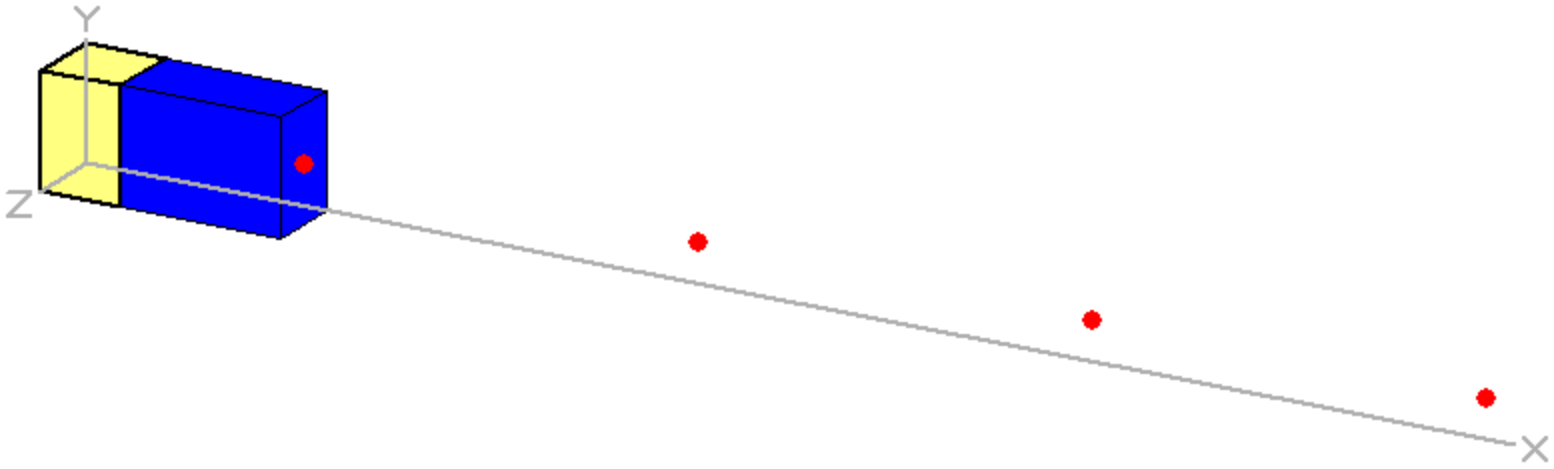
Microshield Version 7.01

Used to model exposure rates outside the lead shielding

- **Source Dimensions:**
  20 x 20 x 28.2 cm
- **On Contact reading = 2.8 mrem/hr**
- **1-meter reading = 0.44 mrem/hr**
- **2-meter reading = 0.16 mrem/hr**
- **3-meter reading = 0.08 mrem/hr**



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Urban Area Release

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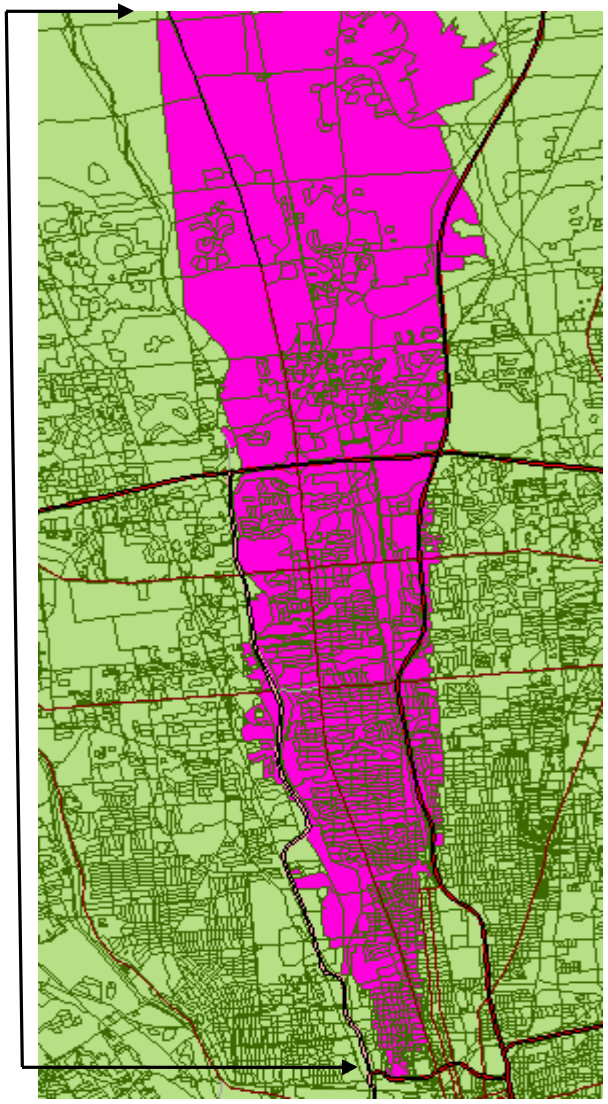
- **Population ~1.1 million**



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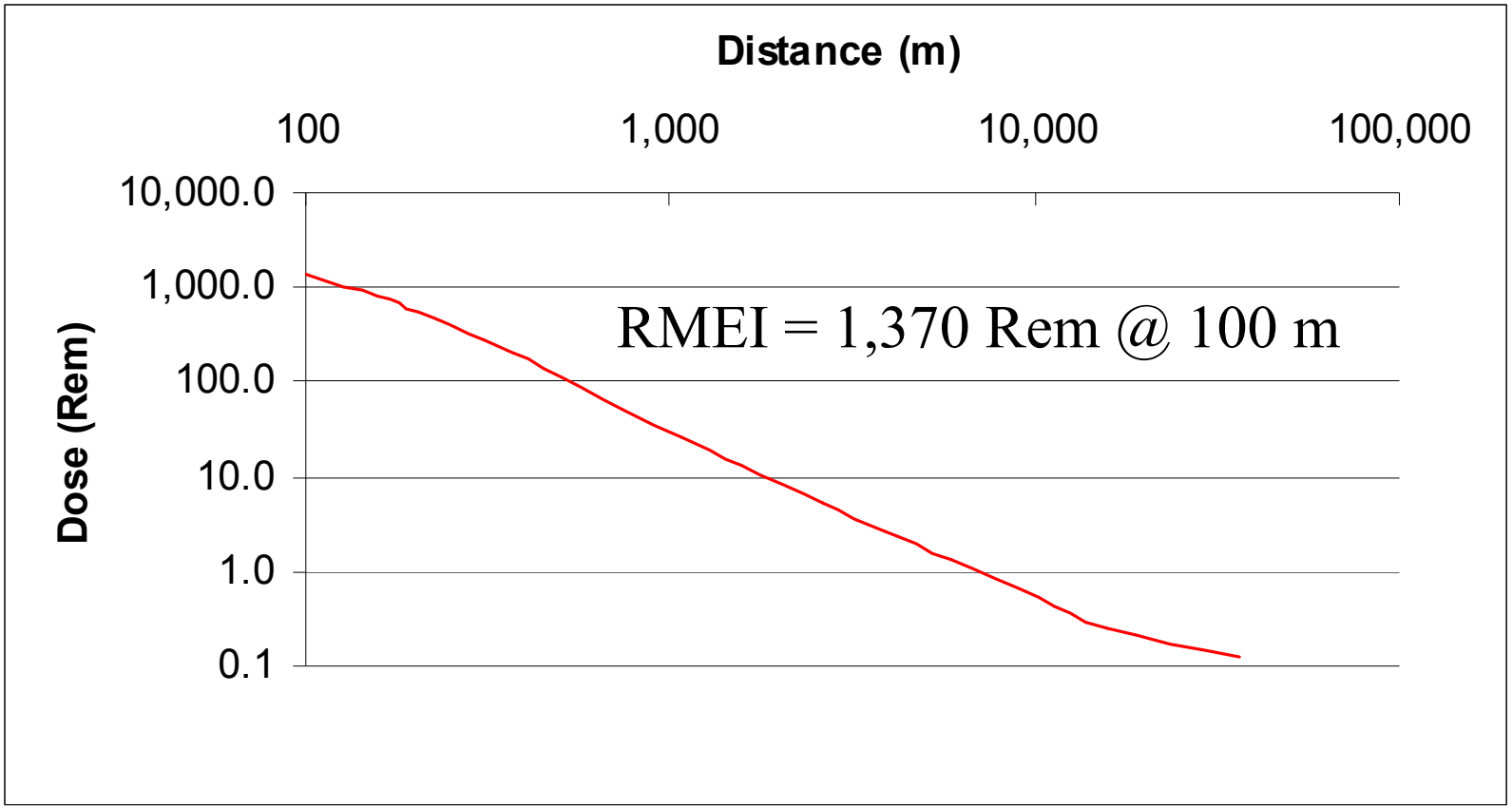
Urban Release RADTRAN Results

Maximum Individual Consequence (2 hour evacuation time)



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Urban Release RADTRAN Results

	Total Exposed Population under the Plume
Urban	62,800

Expected Values of Collective Dose (Person-Rem)

	Groundshine	Inhalation	Resuspension	Cloudshine
Urban	94,900	7,950	83.5	6,070

	Early Fatality	Early Morbidity
Urban	**0.0264**	**7.77**

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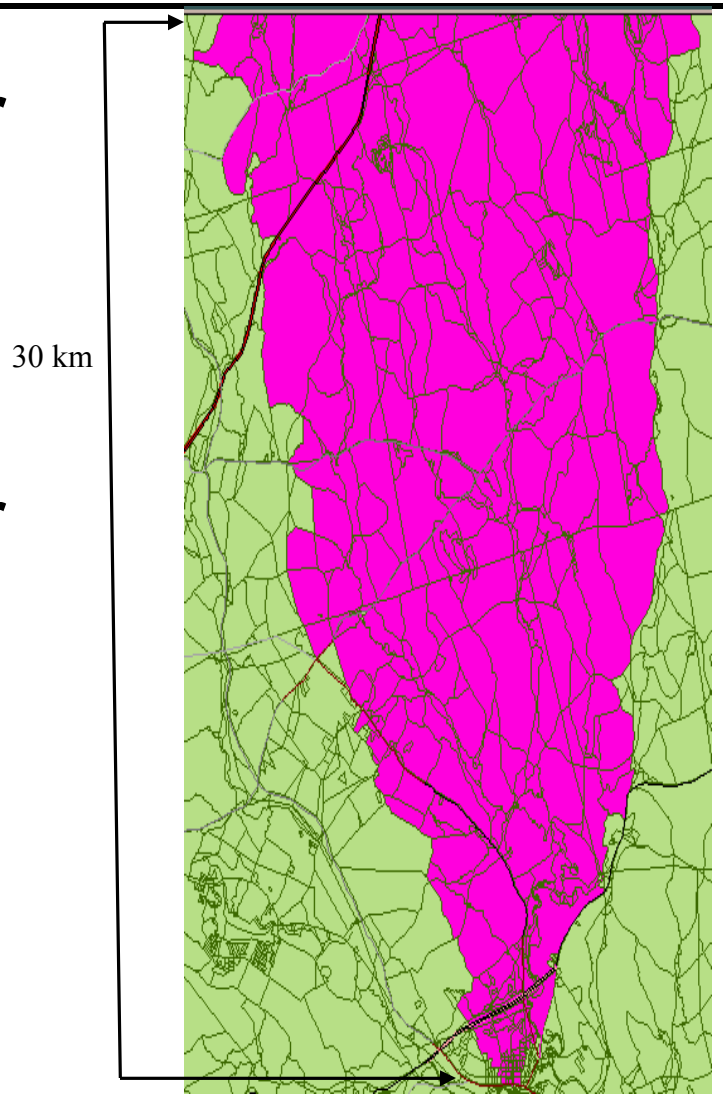
Small Town Release

Released near the center of a small town.

- **The plume was analyzed for 30 km**
- **Used user-defined weather with local weather patterns**
- **Population ~22,000**



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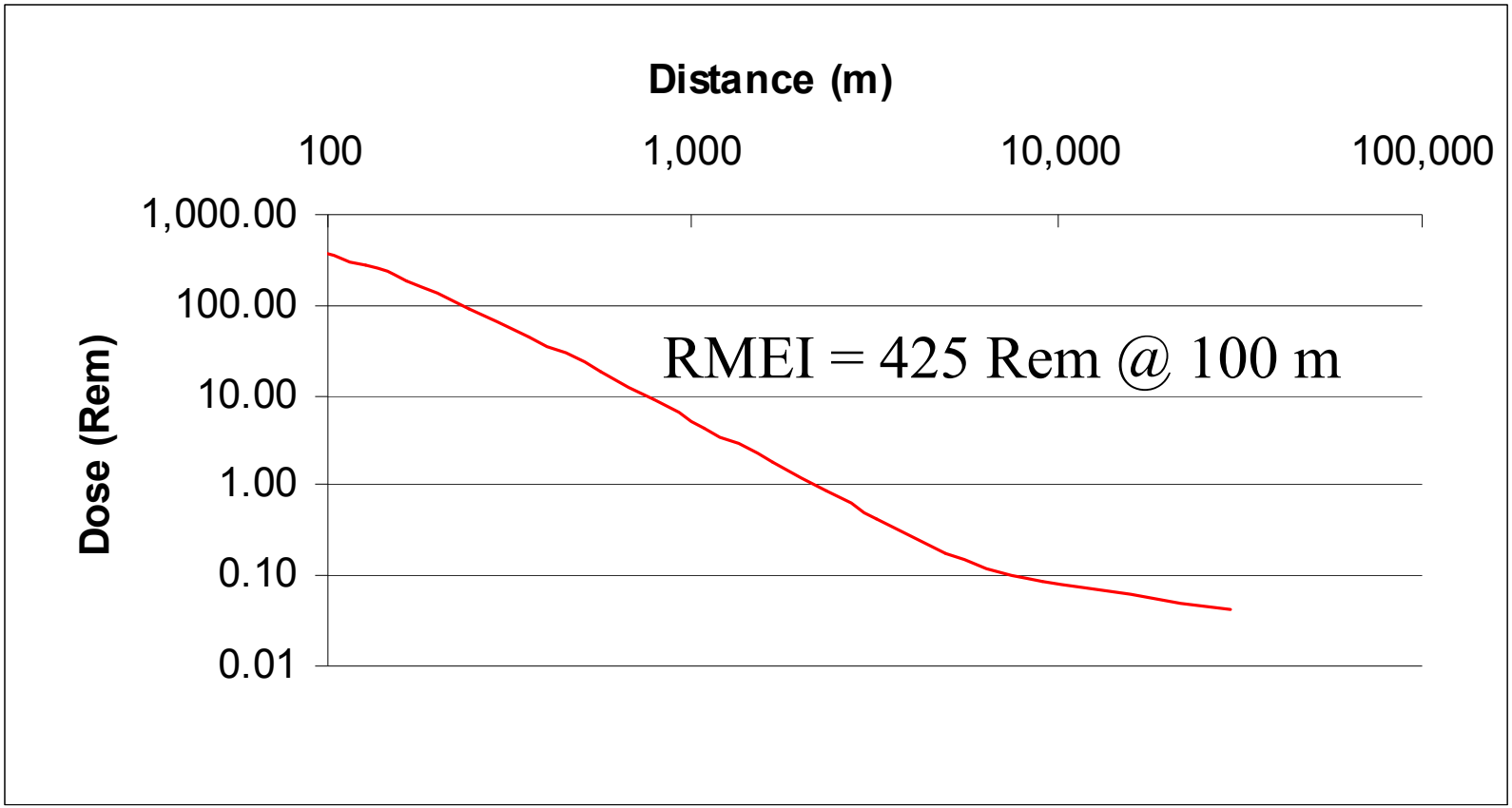
Small Town Release RADTRAN Results

Maximum Individual Consequence (2 hour evacuation time)



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Small Town Release RADTRAN Results

	Total Exposed Population under the Plume
Rural	5,810

Expected Values of Collective Dose (Person-Rem)

	Groundshine	Inhalation	Resuspension	Cloudshine
Rural	15,900	12,800	13.8	9,750

	Early Fatality	Early Morbidity
Rural	**0.00476**	**3.30**

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Small Town Release RADTRAN Results

Societal Ingestion Dose (Person-Rem)		
	Gonads	Effective
Rural	5.13	4.46

Societal Ingestion Dose by Organ (Person-Rem)						
	Breast	Lungs	Red Bone Marrow	Bone Surface	Thyroid	Remainder
Rural	1.77	1.41	2.12	1.51	1.27	8.00

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Consequence Modeling

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Radiological and Nuclear Source Models

- Explosive and non-explosive RDD aerosol size distribution
  - Source Term Encyclopedia – SNL
- Nuclear detonation clouds
  - AIRRAD – SNL
  - KDFOC – LLNL
- Buoyant explosive cloud rise model
  - ERAD – SNL
- Buoyant & momentum plume rise from fires or stack emission
  - LODI – LLNL
  - VENTSAR – SRS

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Prompt Effects

- Nuclear detonation effects
  - NUKE – SNL
  - HOTSPOT – LLNL
- Conventional explosive blast effects
  - BLAST – SNL

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Meteorological Data & Modeling

- National Atmospheric Release Advisory Center – LLNL
- Gaussian plume
- Monte-Carlo / Gaussian-puff
- Advanced Lagrangian Particle Dispersion Model

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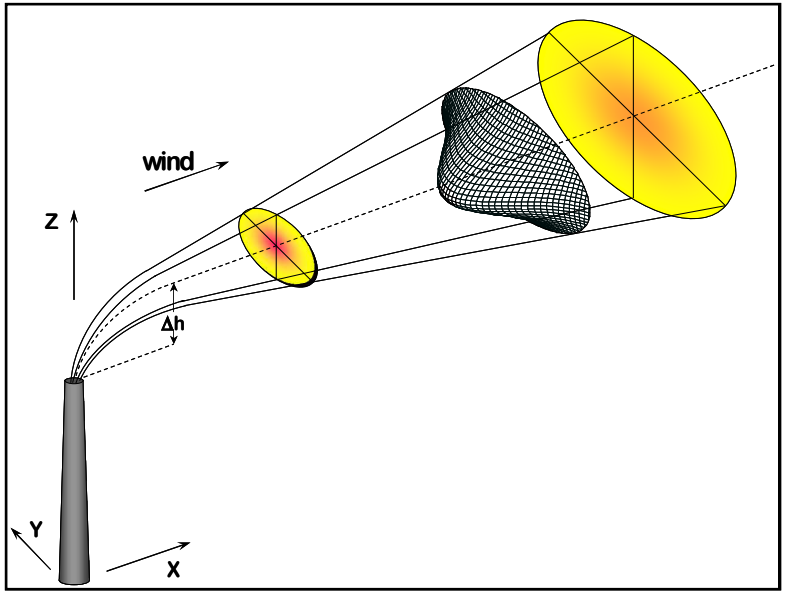
Standard Gaussian Dispersion Model

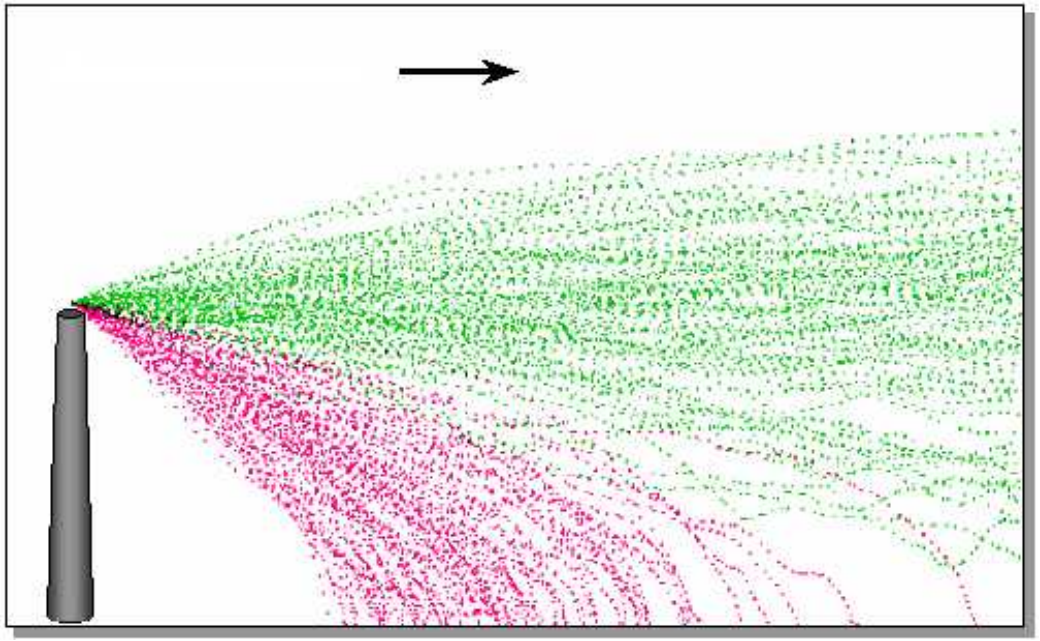
- Advantages of Gaussian plume model
  - easy to use
  - fast

- Limitations
  - flat terrain
  - high sources
  - continuous emissions
  - stationary meteorology
  - rough modeling of plume rise, settling, building effects
  - equation does not work for the near-field (σ_z and σ_y)



Advanced Lagrangian Particle Dispersion Model

- Advantages of Monte-Carlo Model
  - complex terrain
  - all source heights
  - all release durations
  - non-stationary conditions
  - sedimentation
  - washout
  - radioactive decay



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National Atmospheric Release Advisory Center (NARAC)

- Automated, real-time, global meteorological observation database.
- Continental-scale and global-scale grid meteorological analysis and forecast from NOAA and Navy.
- Regional scale 3-D meteorological models run at NARAC.

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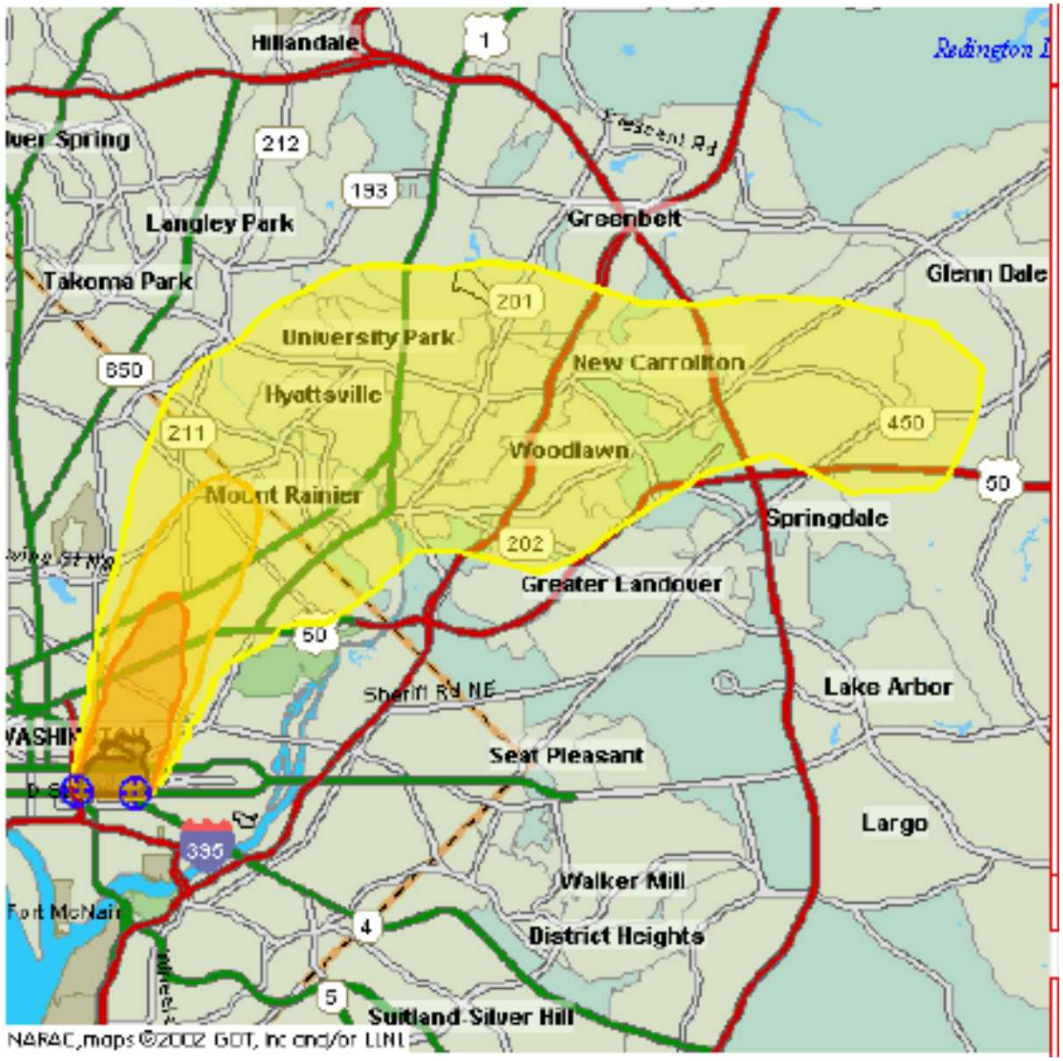
Mapping Output



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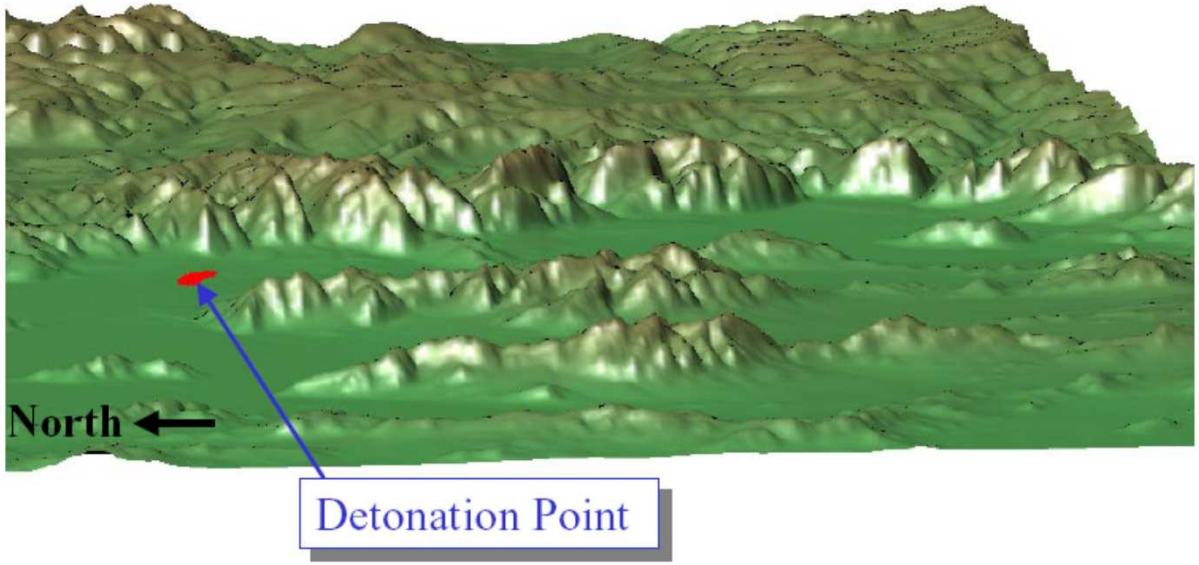
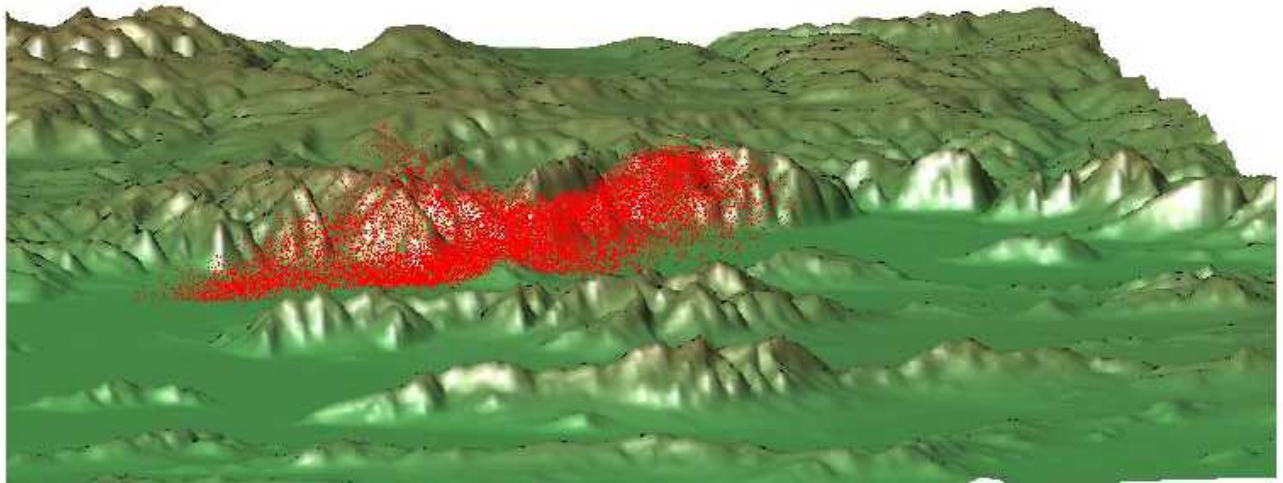
3-D Modeling





Dispersion and Fallout Models

- HOTSPOT – LLNL – Gaussian-plume
- ERAD – SNL – Monte-Carlo / Gaussian-puff
- LODI – LLNL – 3-D Monte Carlo (NARAC)
- AIRRAD – SNL – Nuclear fallout model
- KDFOC – LLNL – Nuclear fallout model

Hotspot

- Developed by LLNL
- www.llnl.gov/nai/technologies/hotspot
- Created to provide emergency response personnel and emergency planners with fast, field-portable set of software tools for evaluating incidents involving RAM.
- Designed for short-term release durations.

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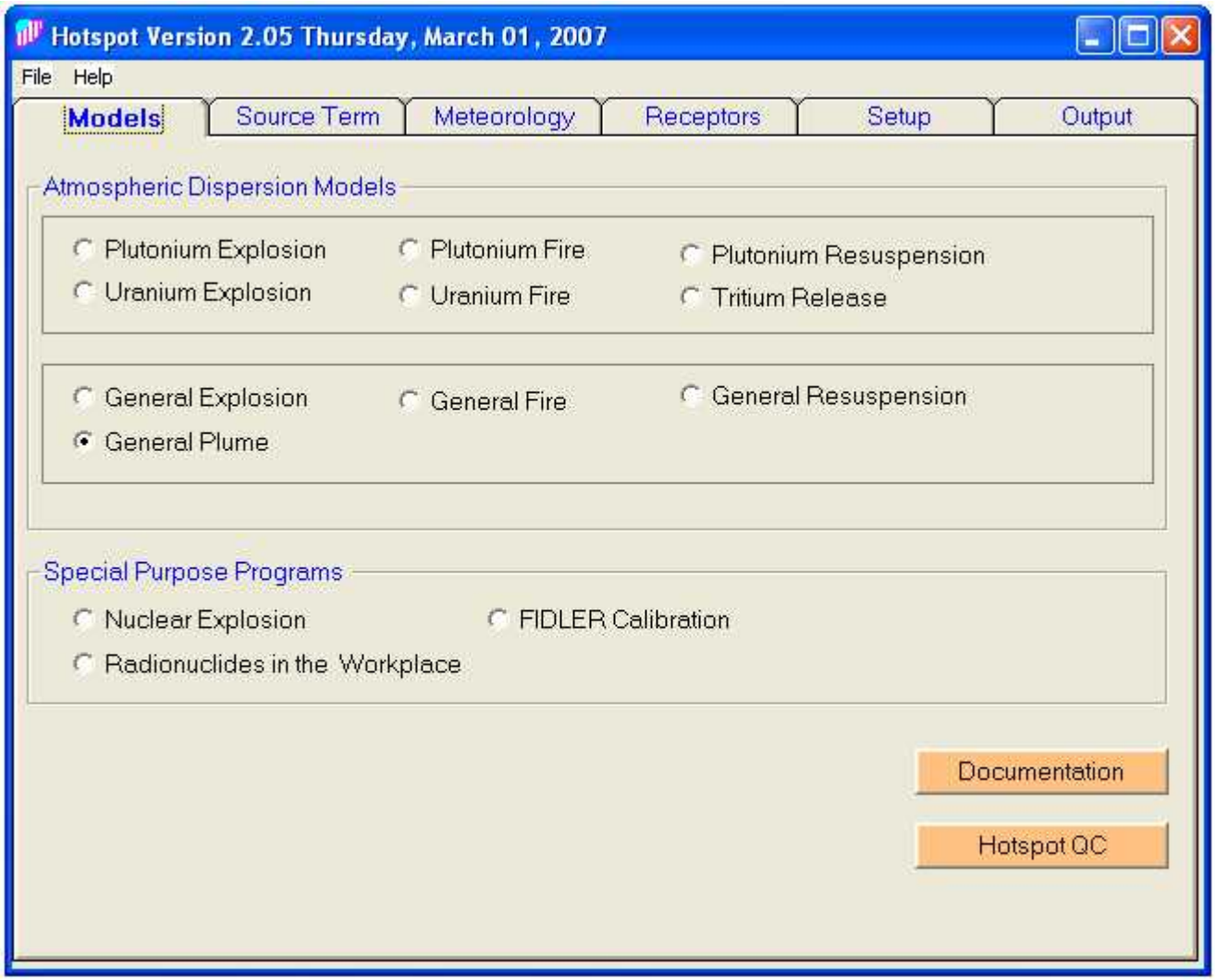

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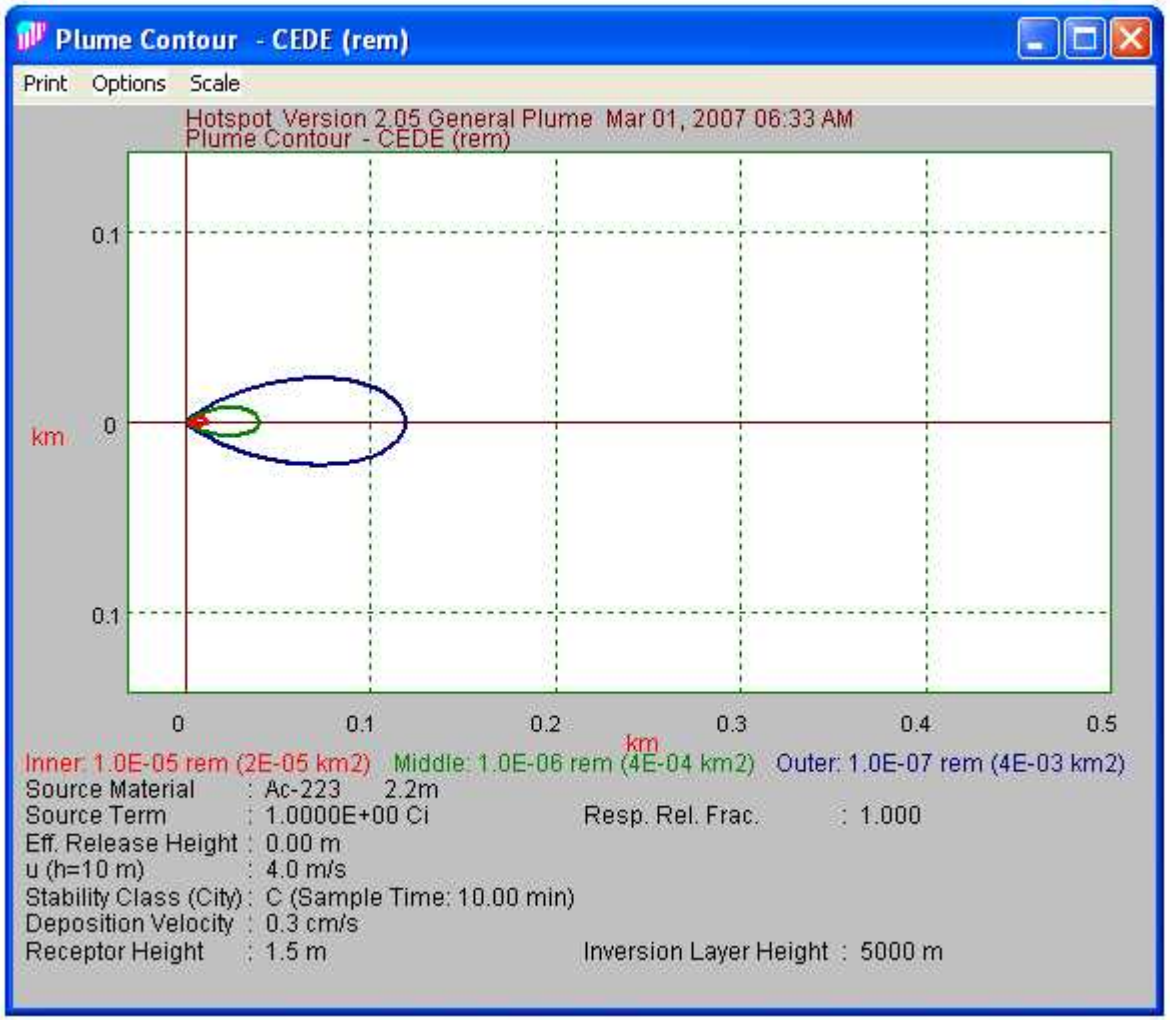
Mapping



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Adjustments

- As Radiological Technicians enter the contamination zone:
  - Radiation readings
  - Contamination readings
  - Modeling Adjustments
    - Weather
    - Release fractions
    - Time limiting
    - Communications

Experimentation vs. Modeling

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F-4 Test

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F-4 Test Slow Motion

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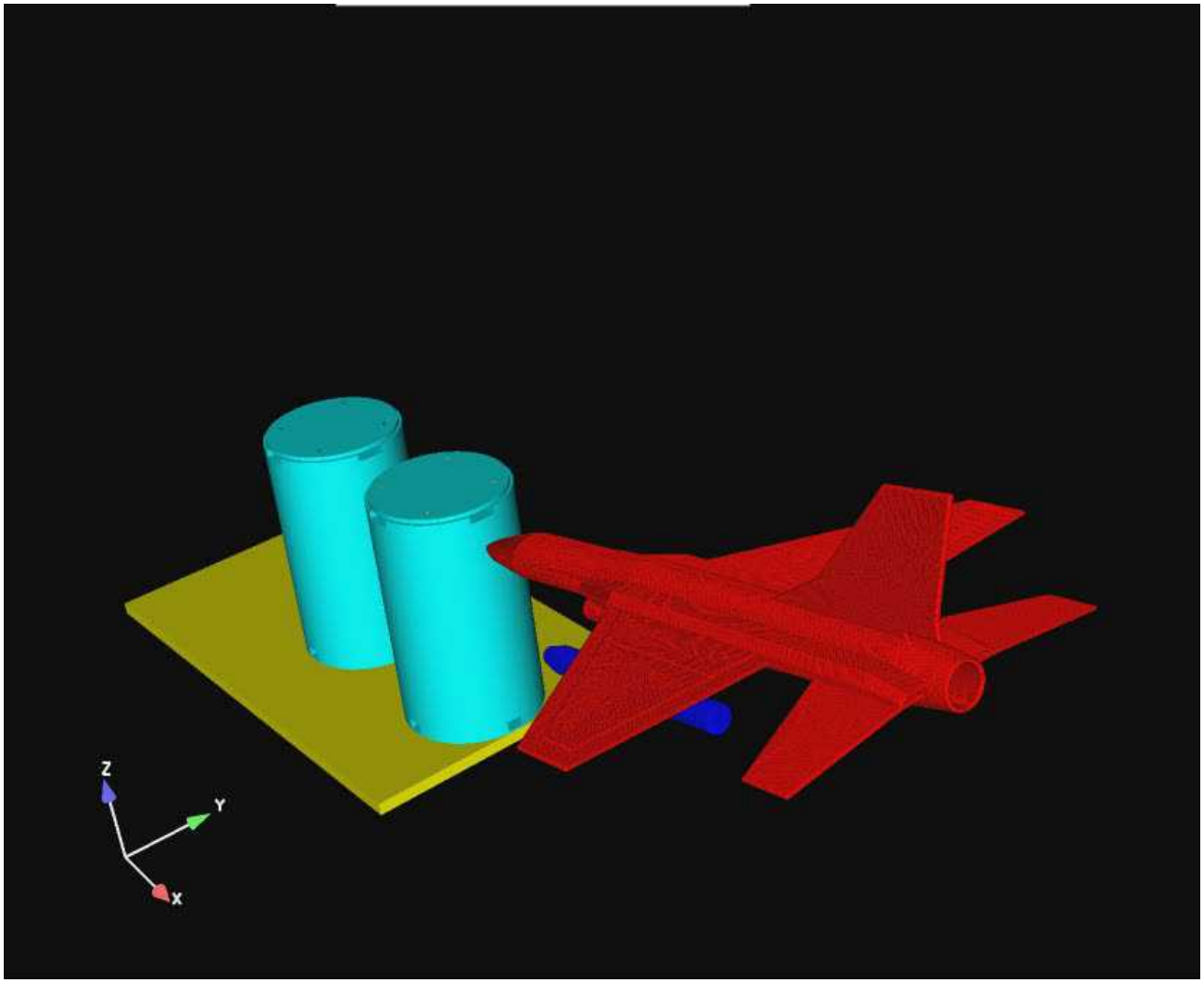
Computer Modeling



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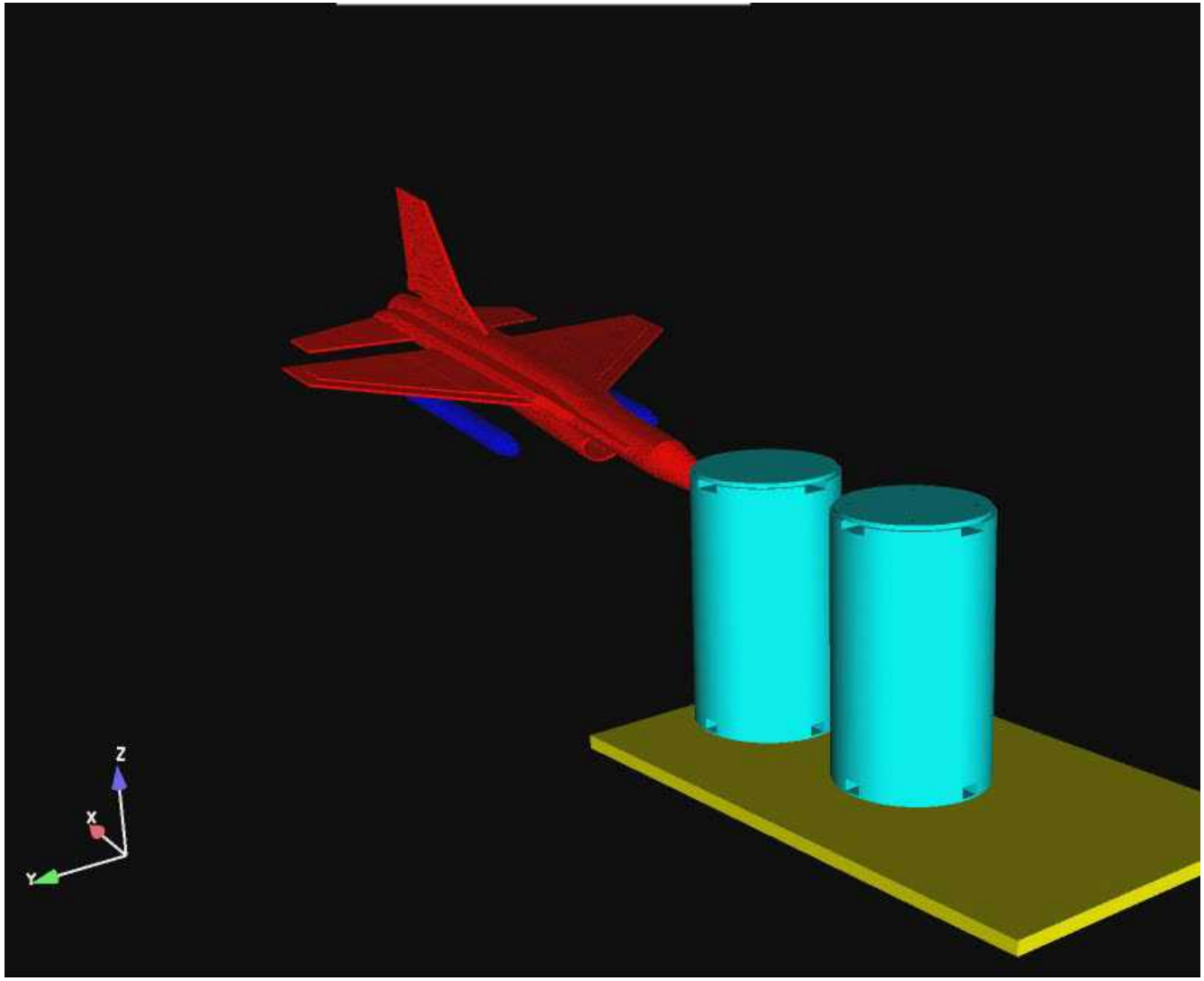
Computer Modeling Rear View



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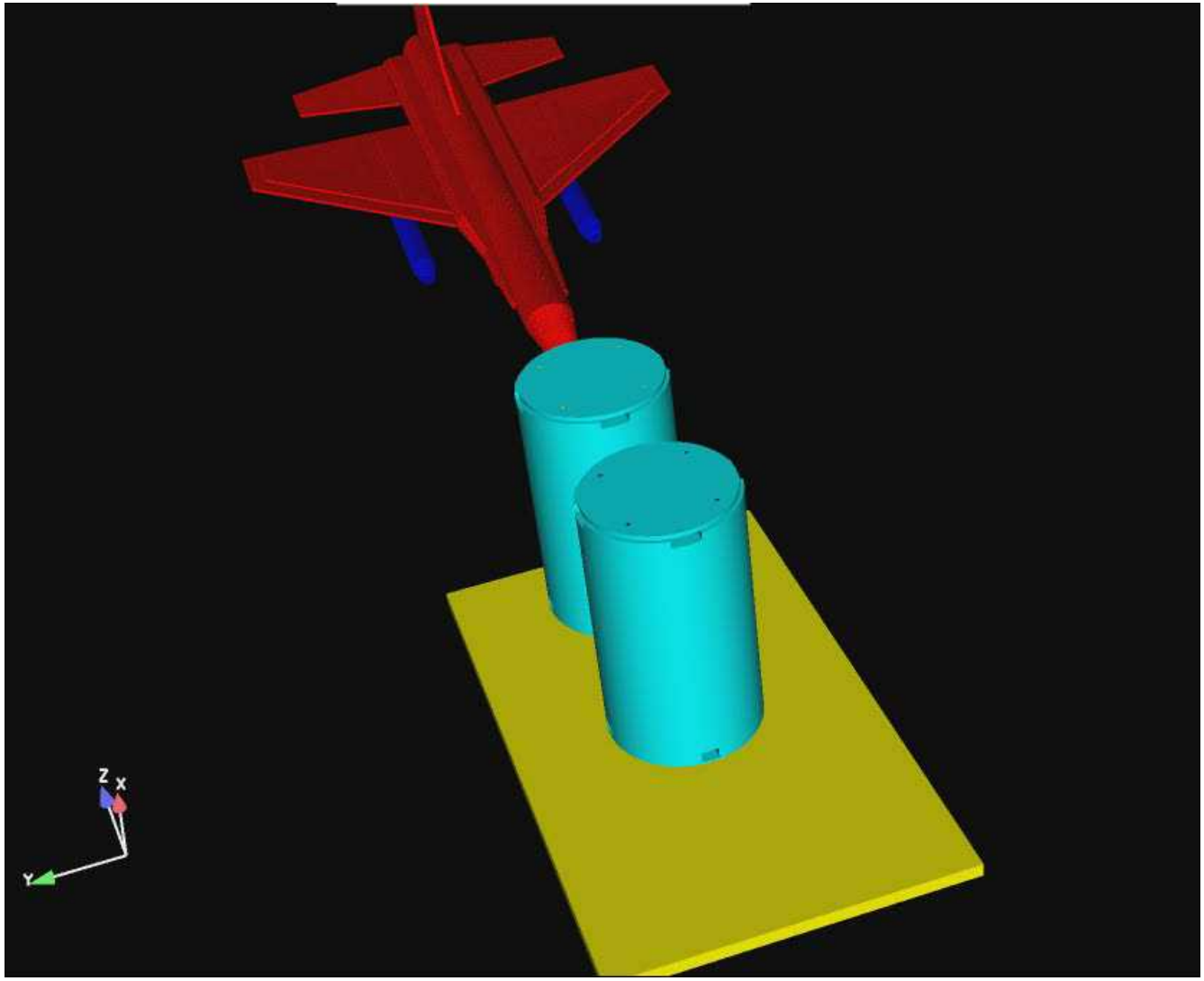
Computer Modeling Top View



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Sabotage Testing

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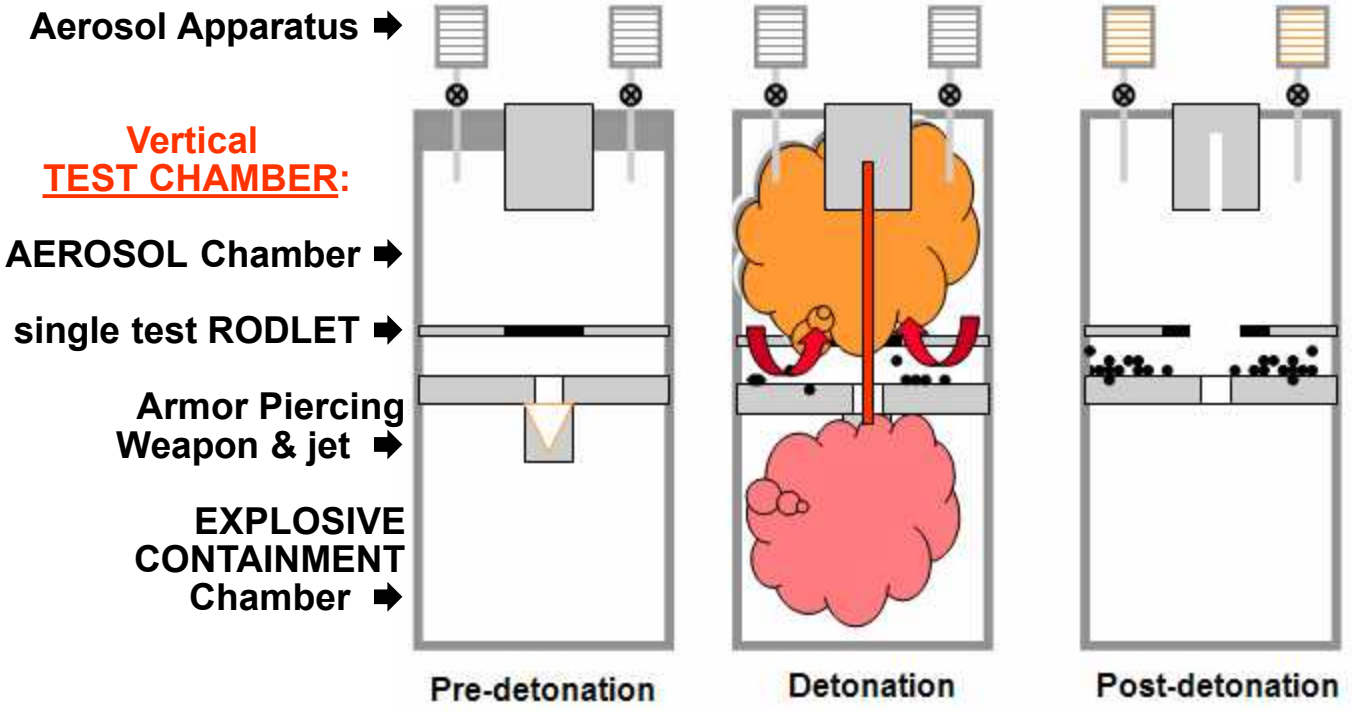
Spent Fuel Sabotage - Aerosol Test Program: Overview / Background

- SCENARIO: Terrorist attack on a nuclear transport / storage casks
- GOALS: measure aerosol particles produced from actual spent nuclear fuels and surrogates; source-term data/ modeling



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Sabotage Test

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