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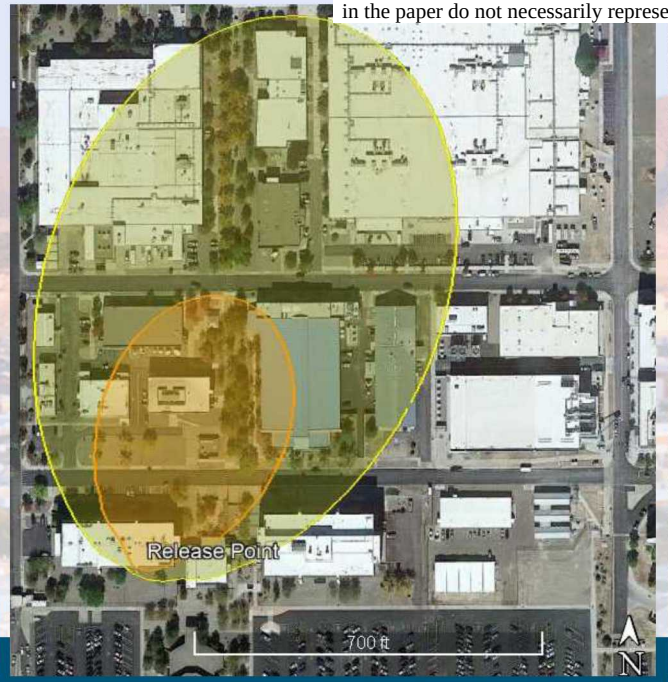

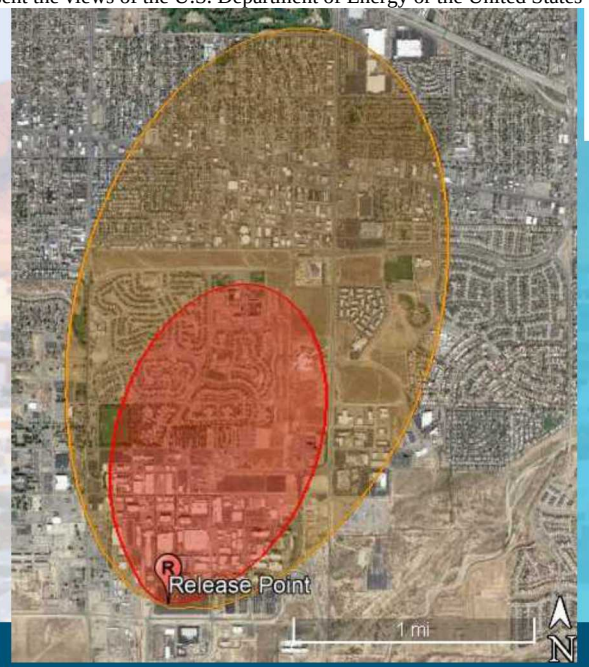

Radiological Dispersal and Prediction Models

April 2020

Heather M. Pennington

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Discussion

Time Scales for Explosive Aerosolization

Comparison of DOE Dispersal Models

Overview of Dispersion Models HotSpot and NARAC

In-depth Look at the SHARC Model

Mitigation Methods

Turbo FRMAC Overview

Briefing Products

Time Scales for Explosive Aerosolization/Fragmentation Phenomenology

μs

ms

< s

Microseconds (μs)

- Shock wave interaction with material
- Initial particle size distribution

Milliseconds (ms)

- Fireball dynamics
- Final particle size distribution

Milliseconds to seconds

- Plume rise

Seconds to minutes

- Late dispersal flow downwind

Models Based on Time Scale

Microseconds to Milliseconds: Computational Fluid Dynamics or Finite Element Analysis Codes:

- Energy deposition, initial particle size distribution
- Examples are:
  - Eulerian (Finite Volume, finite difference schemes)
  - Lagrangian (Finite Element Schemes)

Milliseconds to Seconds: Dispersal Models

- Plume rise, early dispersal, downwind dispersal
- Examples are:
  - HotSpot, SHARC[1] and NARAC[2]

1. Specialized Hazard Assessment Response Capability
2. National Atmospheric Release Advisory Center

Building a Source Term Database

Over the last 30 years Sandia has performed more than 1,000 characterization tests.

Finding: size of particulate released depends on explosive properties, device geometry, and material physical/chemical properties

MATERIAL	PHYSICAL FORM	DEVICE STRATEGIES TESTED
Ag	Metal	17
Al	Metal	5
Bi	Metal	3
Co	Metal	1
Cu	Metal	2
Mo	Metal	1
Pb	Metal	1
Ir	Metal	3
Stainless Steel	Metal	2
Ta	Metal	1
U	Metal	1
CeO2	Ceramic (2 densities per device)	7
$SrTiO_3$	Ceramic (3 densities per device)	8
Tb/Pd	Cermet	1
Various Materials	Liquid	8
BaSO4	Slurry	1
CeO2	Ceramic Powder	7
MnO2	Ceramic Powder	4
UO2	Ceramic Powder	1
CeO2	Pressed Powder	3
CsCl	Powdered Salt	7
BaSO4	Powdered Salt	2

DOE Dispersal Modeling Tools

The capabilities of different modeling tools – *HotSpot*, *SHARC,* and *NARAC* have different, complementary capabilities:

HotSpot's strengths are minimal input data requirements, very fast computations, and portability to run on computers at multiple locations.

SHARC's strengths are moderate input data requirements, vertical variation in meteorological conditions, fast computations for running a range of possible scenarios, population database and ability to run in a wide variety of locations and on different computer systems including a variety of different classified systems.

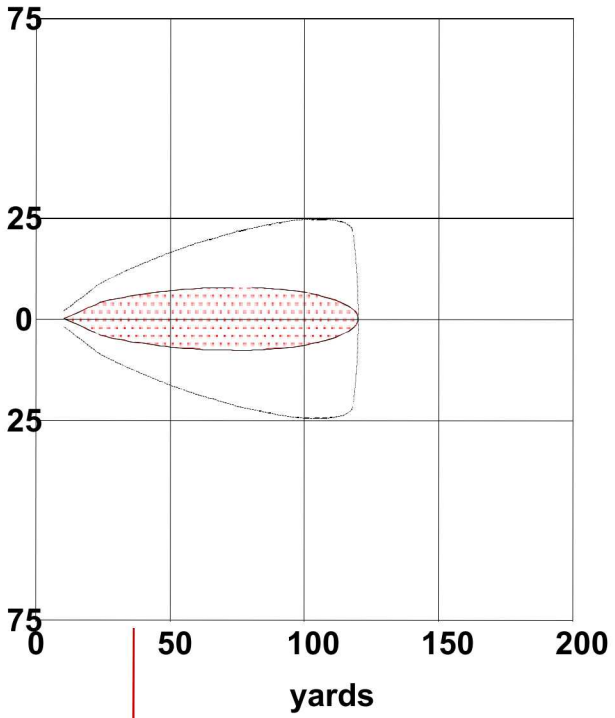
NARAC's strengths are 3-D time-varying weather conditions, complex terrain effects, the ability to predict longer distance and longer time impacts, population database, and the ability to update predictions using environmental measurement data.

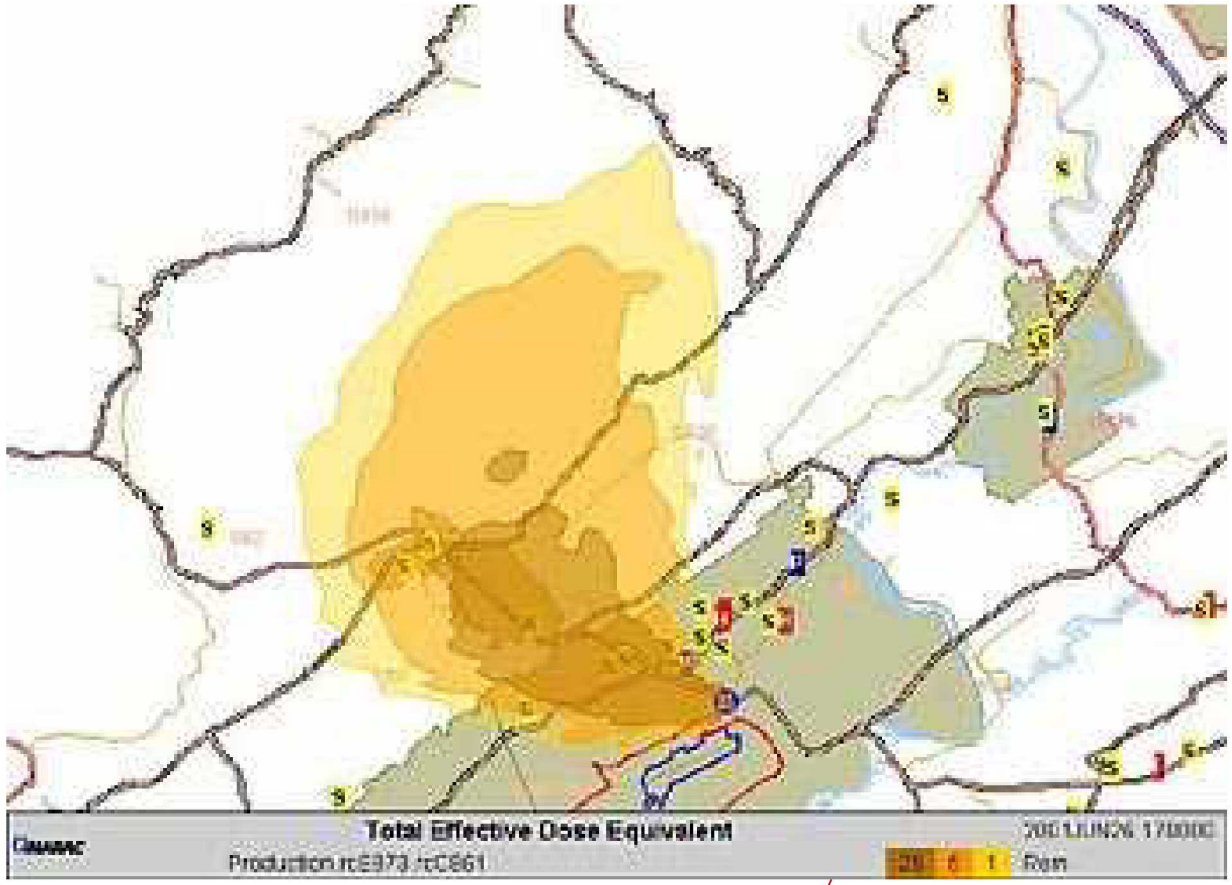
Comparison of Modeling Software Tools Capabilities

Model	HotSpot	SHARC	NARAC
Scenarios	• Nuclear detonation • Radiation dispersal device • Weapon accident explosion • General radiological release • Weapon accident fire • Facility fire • Stack venting	• Nuclear detonation • Radiation dispersal device • Weapon accident explosion • General radiological release	• Nuclear detonation • Radiation dispersal device • Weapon accident explosion • General radiological release • Weapon accident fire • Facility fire • Stack venting • Nuclear power plant accident

Heather Pennington, John Nasstrom. *DOE/NNSA Office of Nuclear Incident Response Atmospheric Dispersion, Fallout, and Effects Modeling Concept of Operations.* DC : NNSA, 2015.

Differing Levels of Complexity





Simple Model

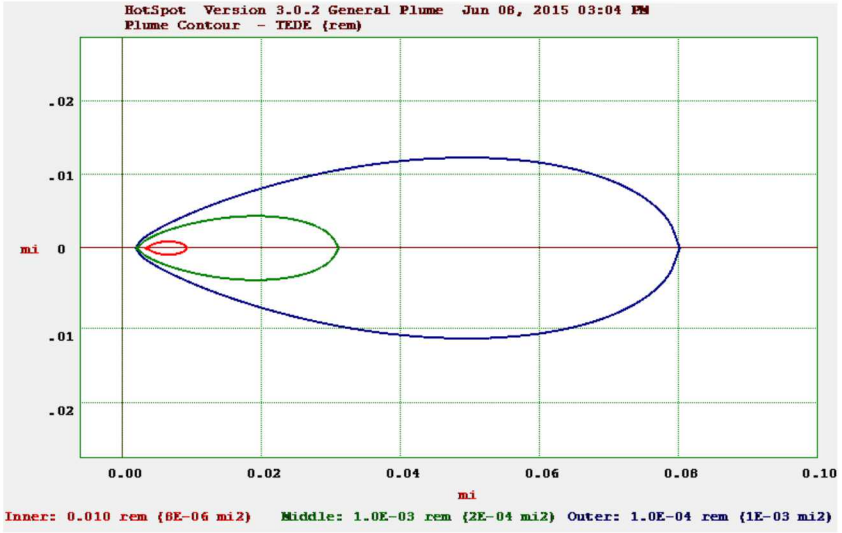
Sophisticated Model

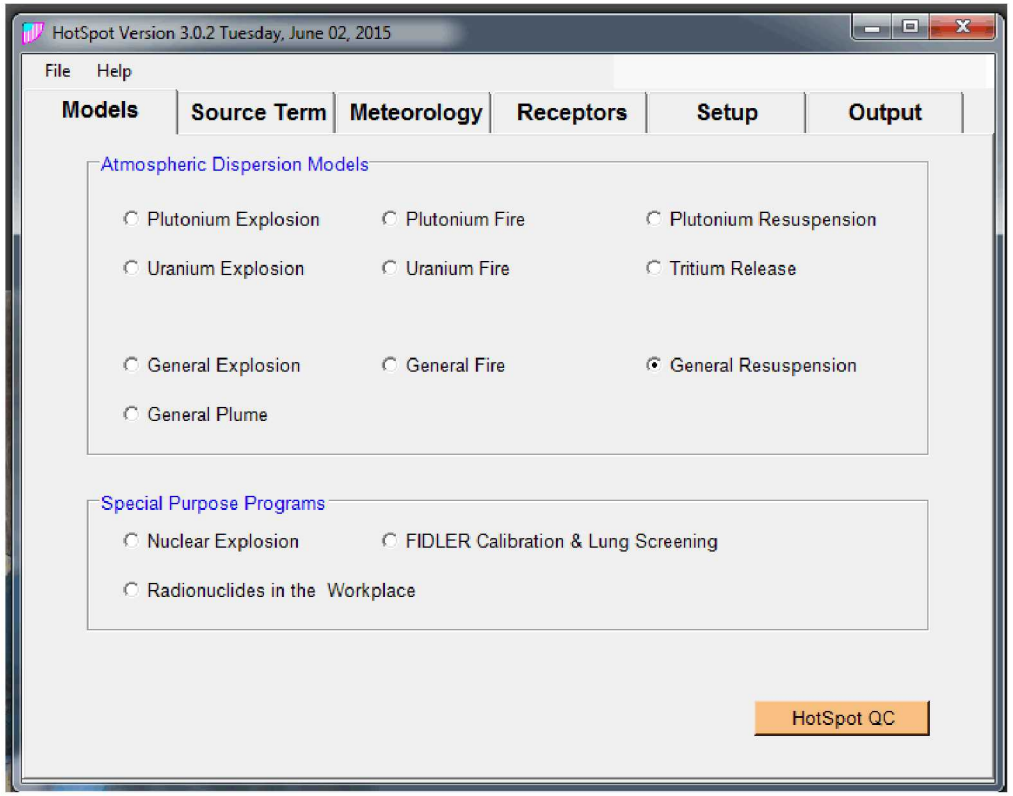
Run Time

HotSpot
(Developed by Steven Homann, Lawrence Livermore National Laboratory)

Simple Model

- Gaussian plume deposition
- Fast (results in a few minutes)
- Portable
- Easy to use





NARAC Provides Operational Services, Tools, and Expertise for Preparedness, Response and Recovery

Event Information

- Weather data
- Nuclear, radiological source information
- Terrain, land uses and population databases
- Measurement data and observations

National Atmospheric Advisory Center
NARAC

Operational Services and Expertise

- 24/7/365 expert scientific staff
- Detailed analysis, expert interpretation, quality assurance and training
- Event reconstruction

Actionable Information

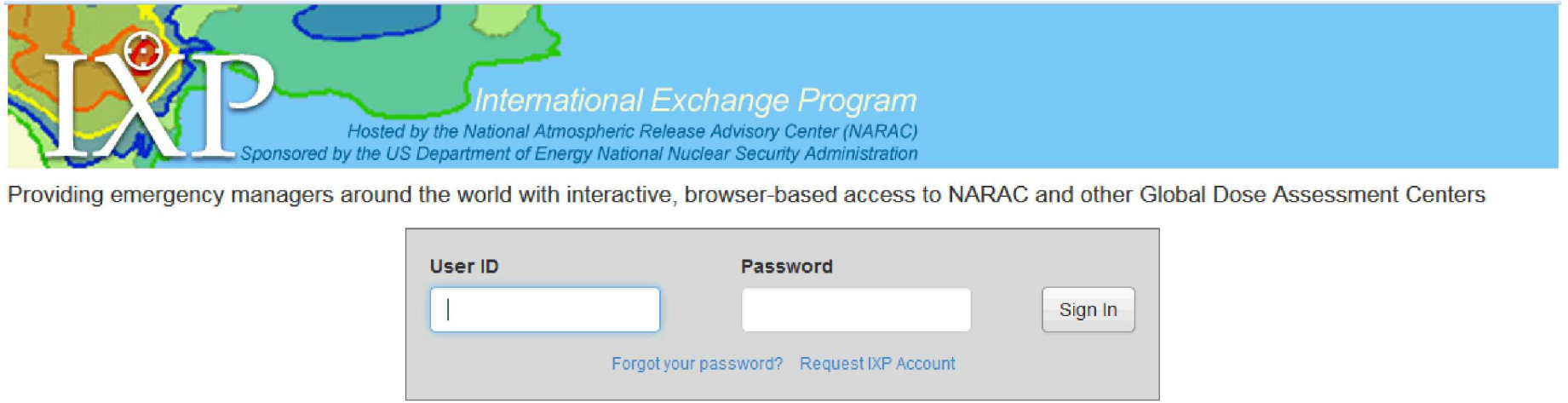
- Hazard areas and affected populations
- Health effect, public protective actions and worker protection levels based on federal guidelines
- Casualty, fatality and damage estimates
- Planning and consequence assessments

NARAC International Exchange Program

The IXP is available to all members states of the IAEA

Accounts can be requested by going to the IXP site and clicking “Request IXP Account”

https://ixp.llnl.gov



SNL Modeling Tool Set: SHARC[1]

Two scenarios available

- Nuclear Scenario
- RDD Scenario
  - Buoyant (explosively driven)
  - Non-buoyant

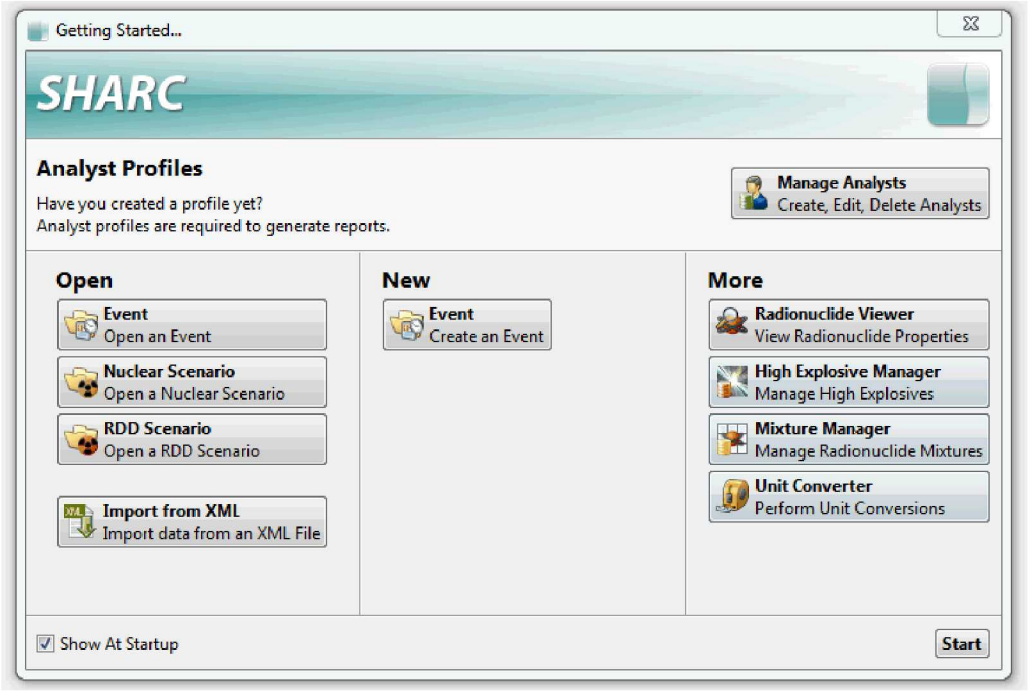
Automated calculation of fatality and casualty estimates using population databases

- Landscan / U.S. Census

Integrated with the FRMAC[2] health physics assessments

Automated briefing products and report generation

Designed to provide quick response (< 5 min)



[1]Specialized Hazard Assessment Response Capability
[2]Federal Radiological Monitoring and Assessment Center

SHARC RDD Scenario Capabilities

Blast Effects

- Physiological response
- Range of shattered glass

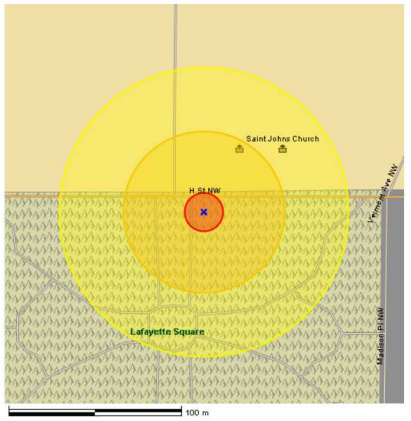
Radiation Protective Action Guides

- Predicted evacuation and sheltering areas based on EPA/DHS guides
- Worker protection areas based on exposure rate
- Predicted relocation areas based on EPA/DHS guides

Mitigation Considerations

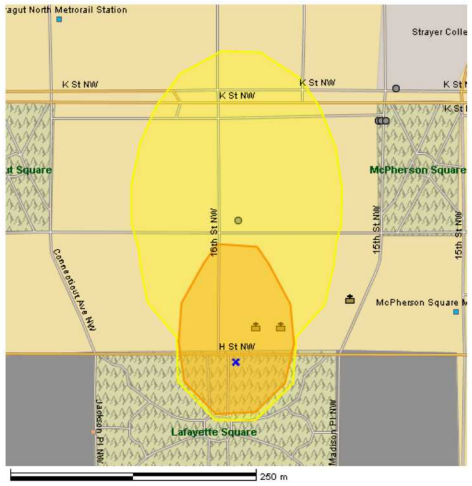
- Predicted effects when mitigation is used

Blast Effects



	Threshold for Fatalities (15 psi) Evacuate Personal Total Exposed Population: 17 Area: 402 m² Extent: 11.3 m
	Threshold for Injuries of Unsheltered Population (1.8 psi) Total Exposed Population: 199 Area: 6,865 m² Extent: 46.7 m
	Threshold for Glass Breakage (0.5 psi) Total Exposed Population: 557 Area: 22,232 m² Extent: 84.1 m

Radiation Protective Action Guides



	Evacuation of entire population warranted, unless additional unusually hazardous circumstances exist (exceeds 5 rem). Estimated Population: 410 Area: 26,300 m²
	Evacuation or sheltering normally initiated (1 to 5 rem). Estimated Population: 2,141 Area: 99,900 m²

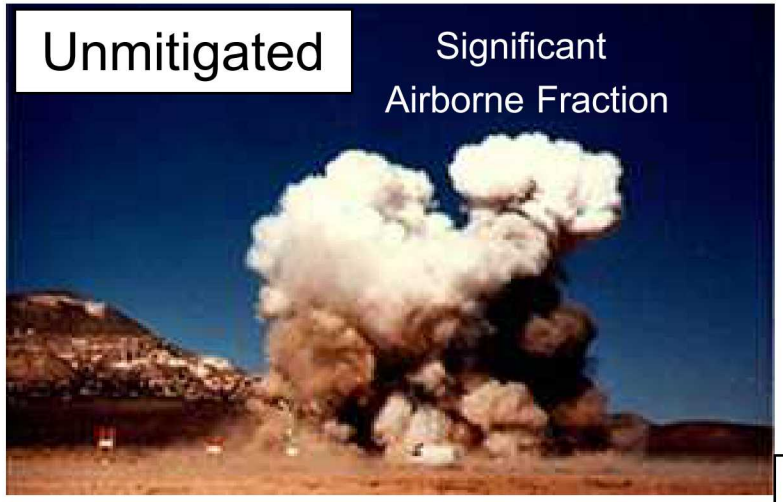
Aqueous Foam and Gelled Water Mitigation

Aqueous Foam

Gelled Water

Mitigation Benefits

Aqueous Foam



"Witness" vans at 30 feet from unmitigated and mitigated 100 lb detonations

Gelled Water

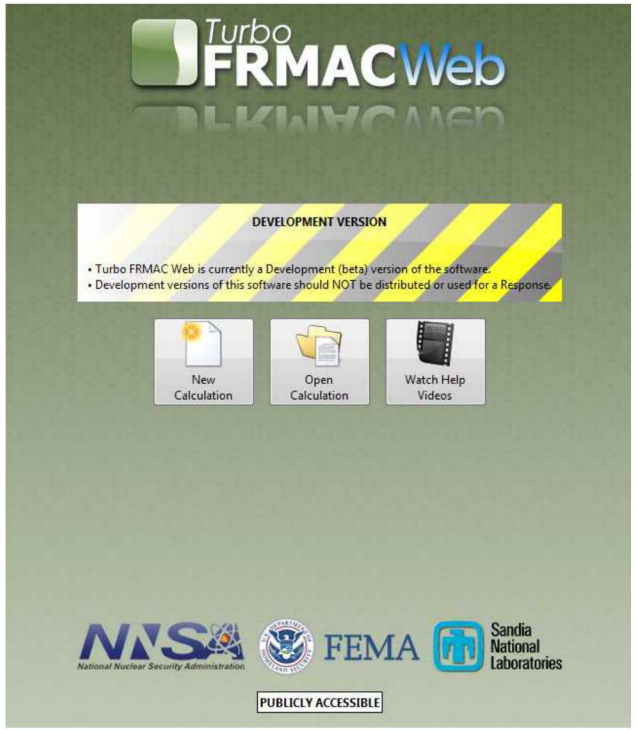
Turbo FRMAC

Performs complex calculations to quickly evaluate radiological hazards during an emergency response by assessing impacts to the public, workers, and the food supply.

Used to evaluate the hazard from a wide variety of radiological incidents to support Protective Action Decisions, such as:

- Should a population be sheltered, evacuated or relocated?
- When can a relocated population return home?
- Might a food in an area need to be considered for removal from commerce?
- How long can a worker remain in a contaminated area?

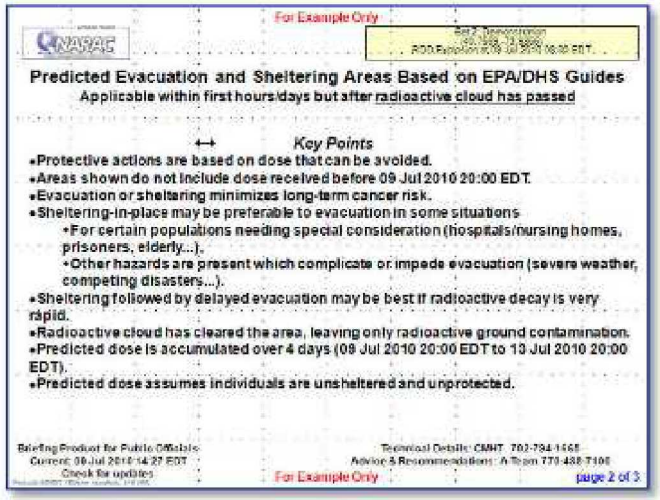
Calculations are based on methods established by the FRMAC and are based on U.S. Government interagency consensus.



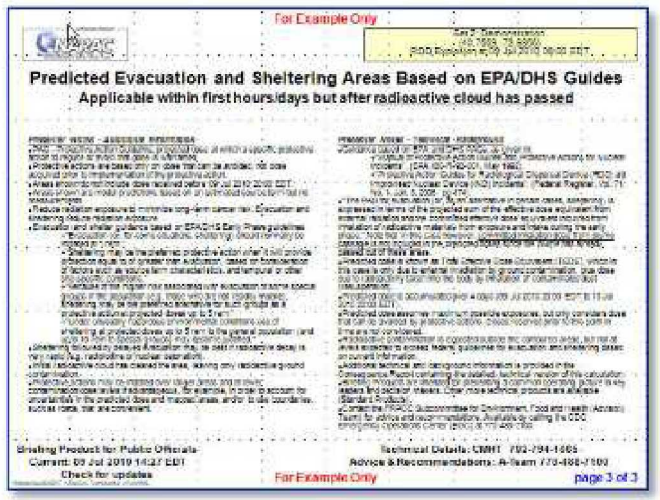
Briefing Products Were Tailored to Convey Key Information to Senior Officials and Federal, State, and Local Decision Makers

Communicate key information about the impacts of hazardous releases and possible actions in non-technical terms to decision makers

Slide 1. Plot:
Map with legend, notes on key briefing points, and assumptions



Slide 2. Key Points:
Expanded list of key information concerning the product and/or relevant actions for consideration



Slide 3. Presenter Notes:
Additional information and technical background (for use by the presenter, not intended to be shown)

Overview of Briefing Products Part1: Radiological/Nuclear, Kevin Foster, Kristen Yu, and Harvey Clark, Lawrence Livermore National Laboratory 2014 LLNL-PRES-665558 (RDD).

Questions ?

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