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# Radiological Dispersal and Prediction Models

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Nuclear Incident Response Programs, 06631

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# Discussion

- Time Scales for Explosive Aerosolization
- Discussion of Parameters that Matter in Plume Dispersal
- Comparison of DOE Dispersal Models
- Overview of dispersion models HotSpot and NARAC
- In-depth look at the SHARC Model
- Turbo FRMAC Overview
- SHARC Demo
- Briefing Products

# Time Scales for Explosive Aerosolization/Fragmentation Phenomenology



$\mu\text{s}$

- Microseconds ( $\mu\text{s}$ )
  - Shock wave interaction with material
    - Shock melting/vaporization
    - Shock Sintering
    - Failure in tension (strain rate, shear band melt)
  - Initial particle size distribution



$\text{ms}$

- Milliseconds ( $\text{ms}$ )
  - Fireball dynamics
    - Fireball/surface interaction
    - Ballistic release of some particles/frag
    - Agglomeration/Combustion
  - Final particle size distribution



$< \text{s}$

- Milliseconds to seconds
  - Plume rise
- Seconds to minutes
  - Late dispersal flow downwind

# Computational Fluid Dynamics Codes & Dispersal Models





- Computational Fluid Dynamics Codes: AUTODYN and CTH
  - Energy deposition, initial particle size distribution
  - Examples are:
    - Eulerian (Finite Volume, finite difference schemes)
    - Lagrangian (Finite Element Schemes)
  
- Dispersal Models: HotSpot, SHARC<sup>1</sup> and NARAC<sup>2</sup>
  - Fireball dynamics; early dispersal
  - Plume rise
  - Late dispersal

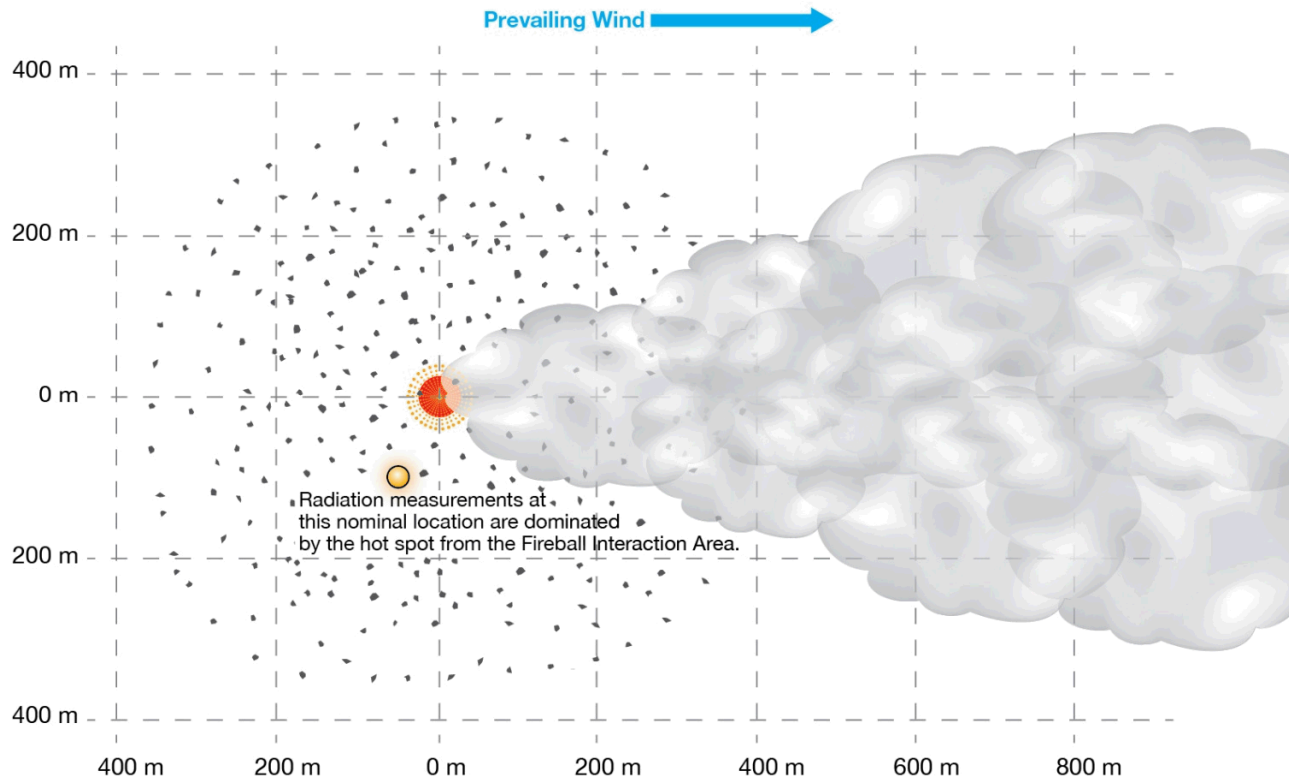
1. Specialized Hazard Assessment Response Capability
2. National Atmospheric Release Advisory Center

# Impact of particle/frag size on deposition

## Particle/Frag size, HE Amount/Location

## Determine Deposition Pattern – Size Matters

-  Fireball Interaction Area
-  Large Particles (~ 100-500  $\mu\text{m}$ )
-  Ballistic Fragments (> 1 cm)
-  Downwind Fallout (small particles)



Basis for all of this

More than  
1,000 RDD  
characterization  
tests have been  
performed at SNL  
in the last  
25 years

Have semi-empirical  
models for metals in  
different geometries,  
liquids, salts, ceramic  
powders, and preliminary  
models for ceramics.

Size of particulate released  
depends on device  
geometry material physical  
and 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
CeO <sub>2</sub>	Ceramic (2 densities per device)	7
SrTiO <sub>3</sub>	Ceramic (3 densities per device)	8
Tb/Pd	Cermet	1
Co	Liquid	2
CsCl	Liquid (several different relative humidity and temps)	6
BaSO <sub>4</sub>	Slurry	1
CeO <sub>2</sub>	Ceramic Powder	7
MnO <sub>2</sub>	Ceramic Powder	4
UO <sub>2</sub>	Ceramic Powder	1
CeO <sub>2</sub>	Pressed Powder	3
CsCl	Powdered Salt	7
BaSO <sub>4</sub>	Powdered Salt	2

# DOE Dispersal Modeling Tools

The capabilities of different modeling tools – *HotSpot*, Specialized Hazard Assessment Response Capability (*SHARC*), and *NARAC* have different, complementary capabilities:

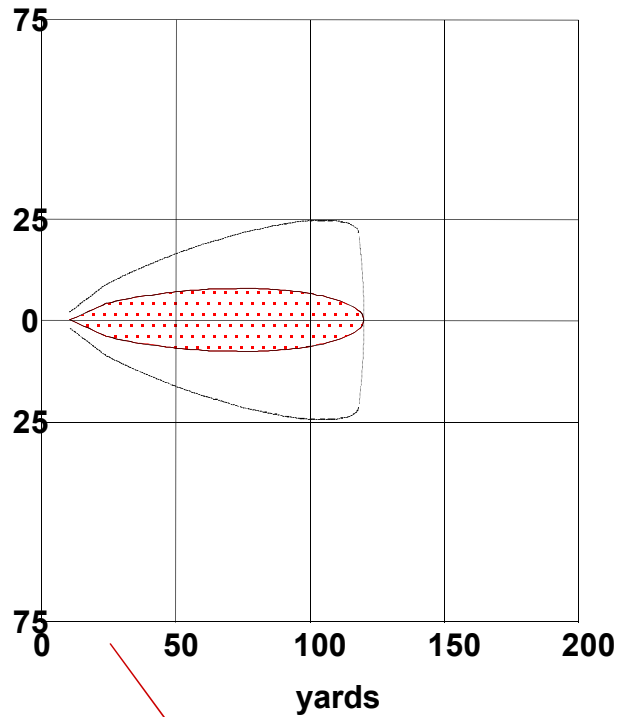
- **HotSpot's** strengths are minimal input data requirements, very fast computations, and portability to run on computers at multiple locations.
- **SHARC's** strengths are moderate input data requirements, vertical variation in meteorological conditions, fast computations for running a range of possible 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

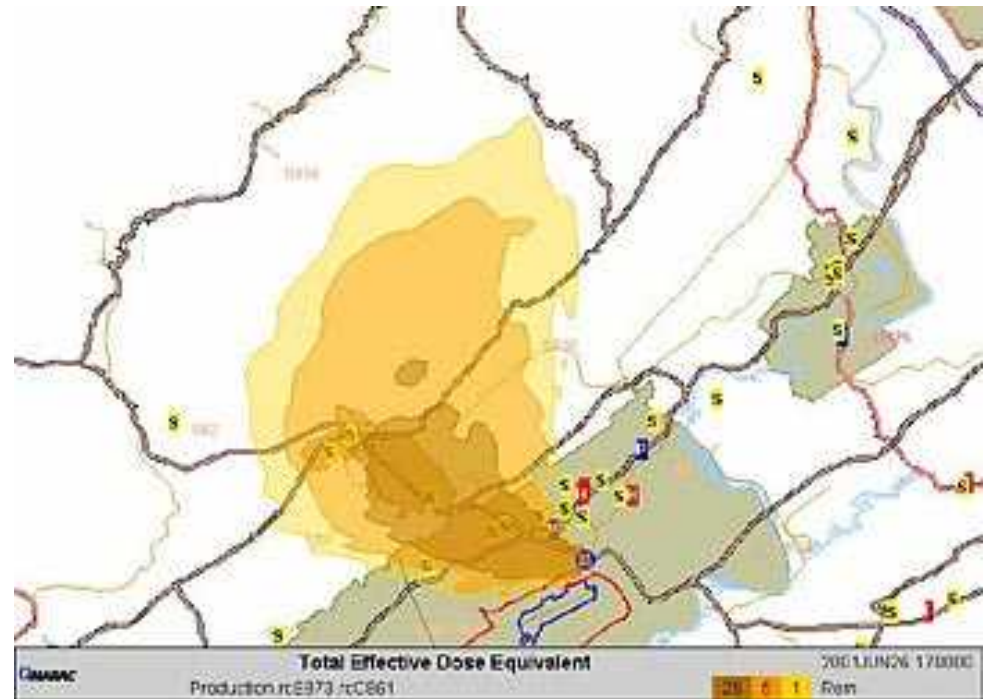


Model	HotSpot	SHARC	NARAC
<b>Scenarios</b>	<ul style="list-style-type: none"> <li>Nuclear detonation</li> <li>Radiation dispersal device</li> <li>Weapon accident explosion</li> <li>General radiological release</li> <li>Weapon accident fire</li> <li>Facility fire</li> <li>Stack venting</li> </ul>	<ul style="list-style-type: none"> <li>Nuclear detonation</li> <li>Radiation dispersal device</li> <li>Weapon accident explosion</li> <li>General radiological release</li> </ul>	<ul style="list-style-type: none"> <li>Nuclear detonation</li> <li>Radiation dispersal device</li> <li>Weapon accident explosion</li> <li>General radiological release</li> <li>Weapon accident fire</li> <li>Facility fire</li> <li>Stack venting</li> <li>Nuclear power plant accident</li> </ul>
<b>Meteorological data</b>	<ul style="list-style-type: none"> <li>Single point</li> <li>No time variation</li> </ul>	<ul style="list-style-type: none"> <li>1-D (vertical)</li> <li>No time variation</li> </ul>	<ul style="list-style-type: none"> <li>3-D</li> <li>Time-varying</li> </ul>
<b>Terrain</b>	Flat	Flat	Complex terrain
<b>Average run time</b>	1 min	5 min	10-30 min
<b>Population Database</b>	<ul style="list-style-type: none"> <li>No database available</li> </ul>	<ul style="list-style-type: none"> <li>LandScan</li> <li>U.S. Census</li> </ul>	<ul style="list-style-type: none"> <li>LandScan</li> <li>U.S. Census</li> </ul>
<b>Products</b>	<ul style="list-style-type: none"> <li>Prompt effects</li> <li>Fallout pattern and casualties</li> <li>Worker protection guides</li> <li>Sheltering/evacuation guides</li> </ul>	<ul style="list-style-type: none"> <li>Prompt effects</li> <li>Fallout pattern and casualties</li> <li>Worker protection guides</li> <li>Sheltering/evacuation guides</li> <li>Electromagnetic pulse (EMP) effects</li> <li>Shipping route options</li> <li>Containment and mitigation effects</li> </ul>	<ul style="list-style-type: none"> <li>Prompt effects</li> <li>Fallout pattern and casualties</li> <li>Worker protection guides</li> <li>Sheltering/evacuation guides</li> <li>Relocation guides</li> <li>Food/crop intervention guides</li> <li>Nuclide-specific fallout contamination levels with fractionation</li> <li>Monitoring mission planning</li> </ul>
<b>Information</b>	<a href="https://narc.llnl.gov/HotSpot/HotSpot.html">https://narc.llnl.gov/HotSpot/HotSpot.html</a>	<a href="http://nirp-irn.sandia.gov/">http://nirp-irn.sandia.gov/</a>	<a href="https://narc.llnl.gov">https://narc.llnl.gov</a>

# Differing Levels of Complexity



Simple Model



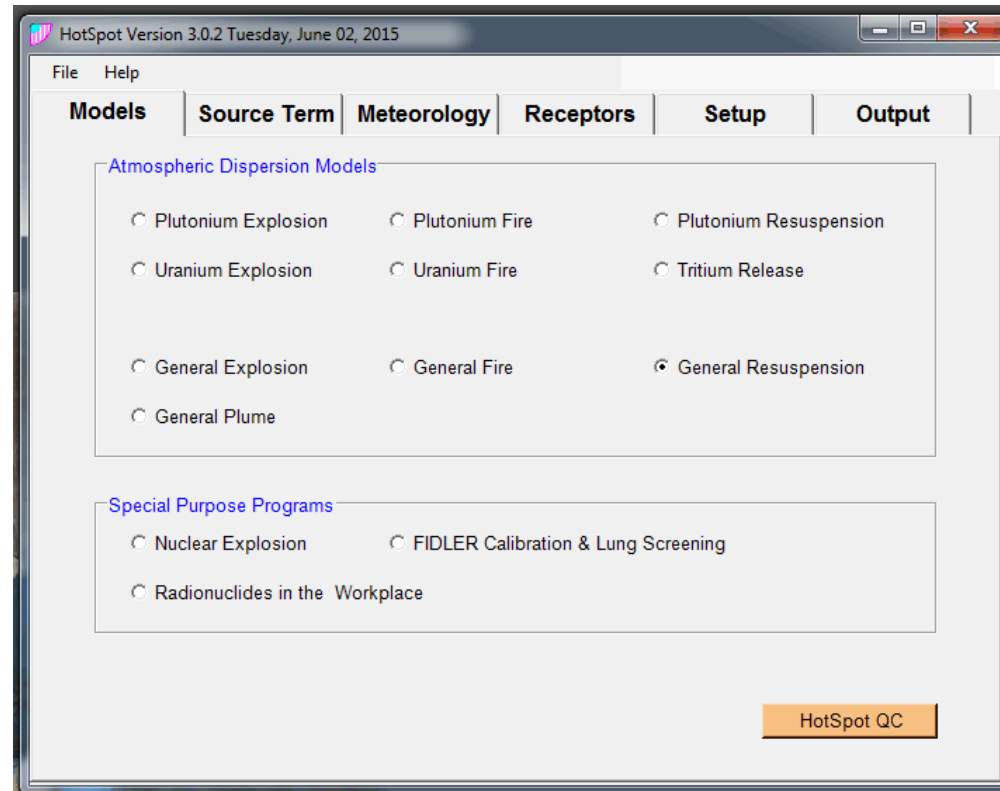
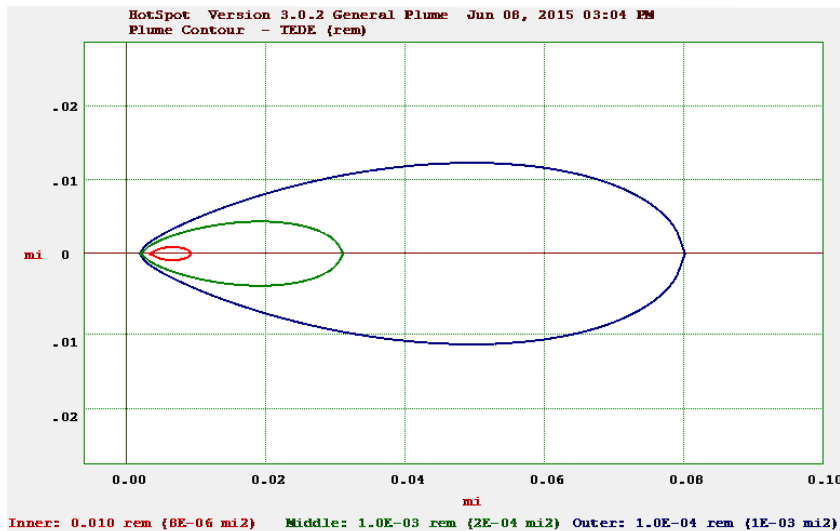
Sophisticated Model

# HotSpot

(Developed by Steven Homann, Lawrence Livermore National Laboratory)

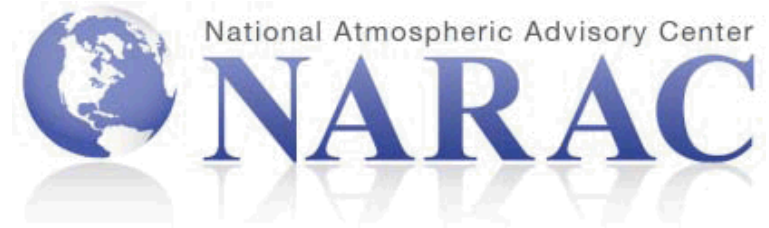
## Simple Model

- 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
- 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>

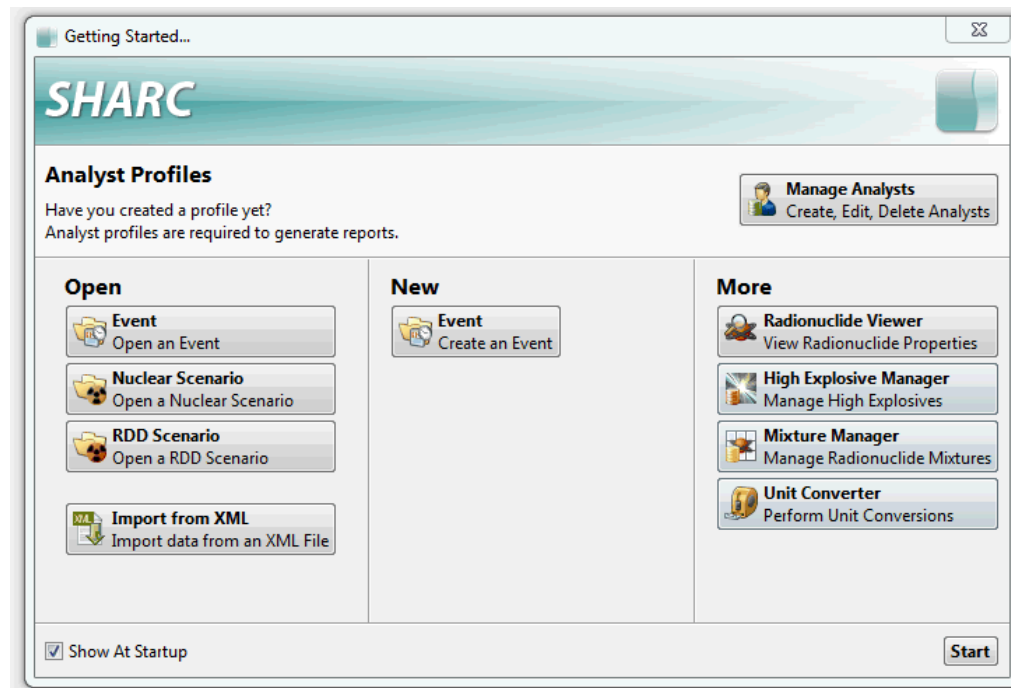


Providing emergency managers around the world with interactive, browser-based access to NARAC and other Global Dose Assessment Centers

<b>User ID</b>	<b>Password</b>	
<input type="text"/>	<input type="password"/>	<input type="button" value="Sign In"/>
<a href="#">Forgot your password?</a> <a href="#">Request IXP Account</a>		

# SNL Modeling Tool Set: SHARC<sup>1</sup>

- Two scenarios available
  - Nuclear Scenario
  - RDD Scenario
    - Buoyant (explosively driven)
    - Non-buoyant
- Automated calculation of fatality and casualty estimates using population databases
  - Landscan 2008
  - U.S. Census 2010
- Integrated with Turbo FRMAC<sup>2</sup> for health physics assessments
- Automated briefing products and report generation



<sup>1</sup>Specialized Hazard Assessment Response Capability

<sup>2</sup>Federal Radiological Monitoring and Assessment Center

# RDD Scenario Capabilities

## ■ Blast Effects

- Physiological response
- Range of shattered glass

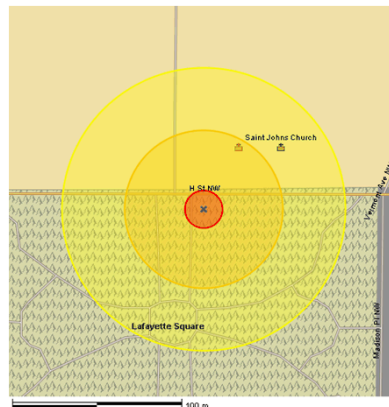
## ■ Radiation Protective Action Guides

- 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

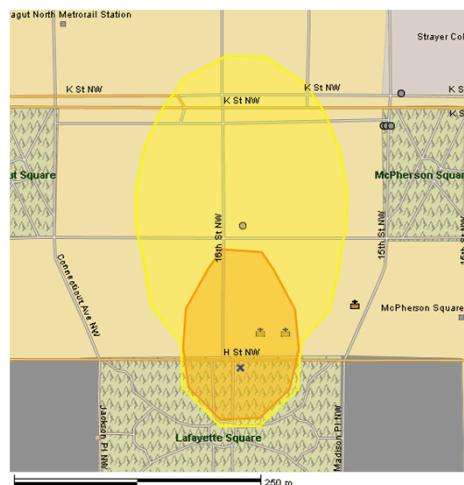
- Predicted effects when mitigation is used

### Blast Effects



	Threshold for Fatalities (15 psi) Evacuate Personal Total Exposed Population: 17 Area: 402 m <sup>2</sup> Extent: 11.3 m
	Threshold for Injuries of Unsheltered Population (1.8 psi) Total Exposed Population: 199 Area: 6,865 m <sup>2</sup> Extent: 46.7 m
	Threshold for Glass Breakage (0.5 psi) Total Exposed Population: 557 Area: 22,232 m <sup>2</sup> Extent: 84.1 m

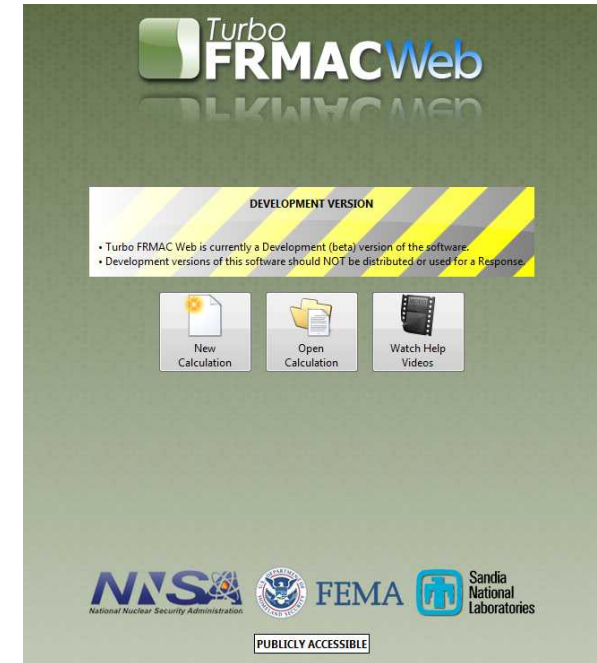
### Radiation Protective Action Guides



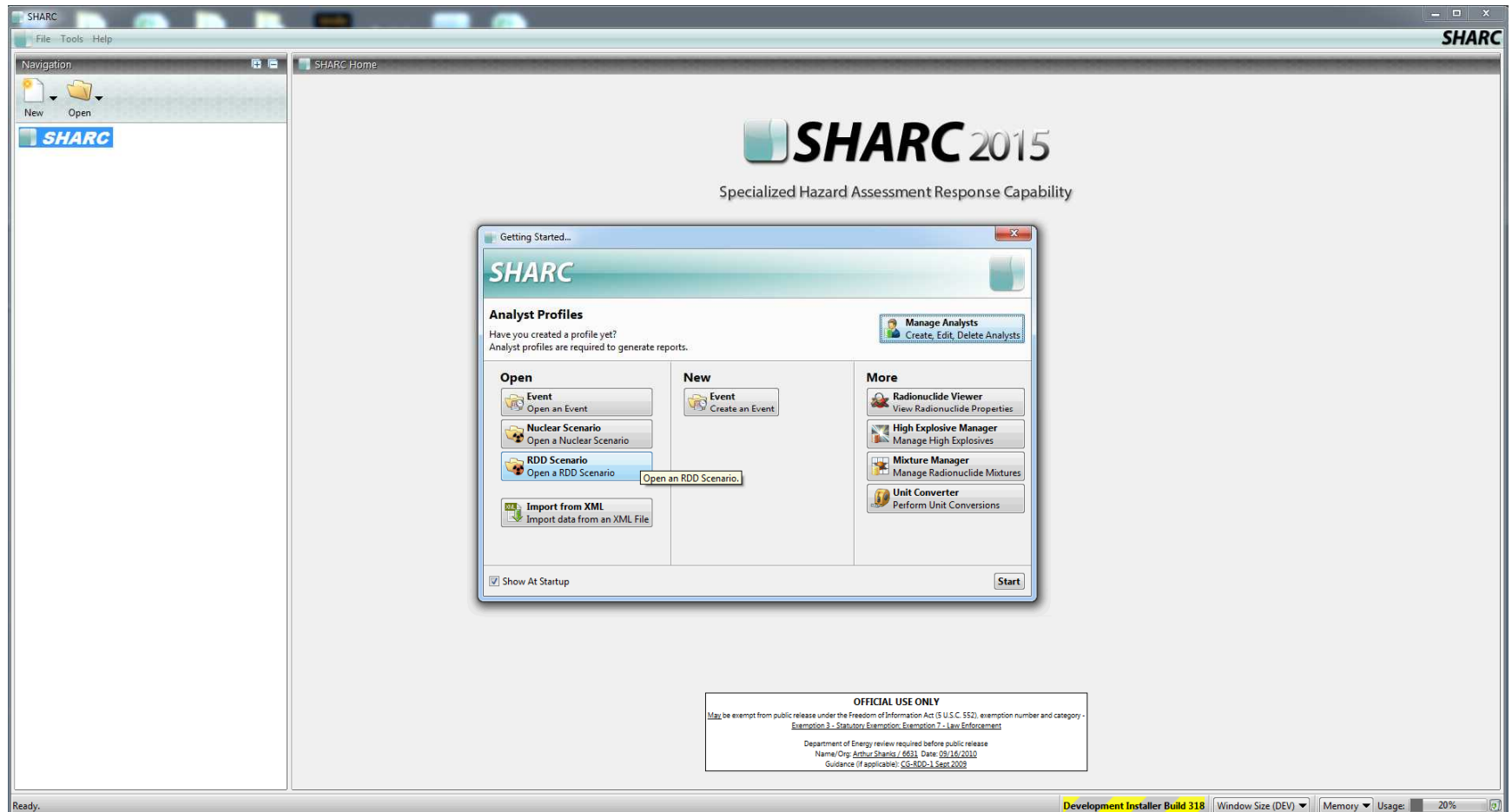
	Evacuation of entire population warranted, unless additional unusually hazardous circumstances exist (exceeds 5 rem). Estimated Population: 410 Area: 26,300 m <sup>2</sup>
	Evacuation or sheltering normally initiated (1 to 5 rem). Estimated Population: 2,141 Area: 99,900 m <sup>2</sup>

# 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. Turbo FRMAC can be used to evaluate the hazard from a wide variety of radiological incidents, including:
  - Radiological Dispersal Devices (RDDs)
  - Nuclear Power Plant Emergencies
  - Fuel Handling Accidents
  - Transportation Accidents
  - Nuclear Detonations
- These evaluations can be used 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?
  - When can a new crop be planted to minimize potential for contaminated food?
  - Should livestock be placed on stored feed?
  - How long can a worker remain in a contaminated area?
- Turbo FRMAC calculations are based on methods established by the Federal Radiological Monitoring and Assessment Center (FRMAC) in the FRMAC Assessment Manual. FRMAC-developed methods are based on U.S. Government interagency consensus.



# Live Demo SHARC



The screenshot displays the SHARC 2015 software interface. The main window title is "SHARC" and the menu bar includes "File", "Tools", and "Help". A "Navigation" pane on the left shows "New" and "Open" options, with a "SHARC" button below. The main content area features the "SHARC 2015" logo and the tagline "Specialized Hazard Assessment Response Capability".

A "Getting Started..." dialog box is open, containing the following sections:

- Analyst Profiles:** A message asks "Have you created a profile yet? Analyst profiles are required to generate reports." A "Manage Analysts" button is available for "Create, Edit, Delete Analysts".
- Open:** Includes buttons for "Event" (Open an Event), "Nuclear Scenario" (Open a Nuclear Scenario), "RDD Scenario" (Open a RDD Scenario), and "Import from XML" (Import data from an XML File).
- New:** Includes a button for "Event" (Create an Event).
- More:** Includes buttons for "Radionuclide Viewer" (View Radionuclide Properties), "High Explosive Manager" (Manage High Explosives), "Mixture Manager" (Manage Radionuclide Mixtures), and "Unit Converter" (Perform Unit Conversions).

At the bottom of the dialog, there is a "Show At Startup" checkbox and a "Start" button.

At the bottom of the main window, a "Ready." status bar is visible on the left, and a system tray on the right shows "Development Installer Build 318", "Window Size (DEV)", "Memory", and "Usage: 20%".

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[Exemption 3 - Statutory Exemption, Exemption 7 - Law Enforcement](#)  
Department of Energy review required before public release  
Name/Orig: Arthur Shanias / 6683 Date: 09/16/2010  
Guidance (if applicable): CG-RDD-1 Sept 2009



# QUESTIONS



# Backup Slides

# IMAAC Provides Critical Information to Protect the Public and the Environment

“The IMAAC provides a single point for the coordination and dissemination of Federal dispersion modeling and hazard prediction products that represent the Federal position” during actual or potential incidents involving hazardous atmospheric releases (National Response Framework)



**IMAAC**

**Interagency Modeling and  
Atmospheric Assessment Center**

