U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

RASCAL & RTT

RADIOLOGICAL ASSESSMENT SYSTEM FOR CONSEQUENCE ANALYSIS & RESPONSE TECHNICAL TOOLS

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Office of Nuclear Security & Incident Response

US Nuclear Regulatory Commission

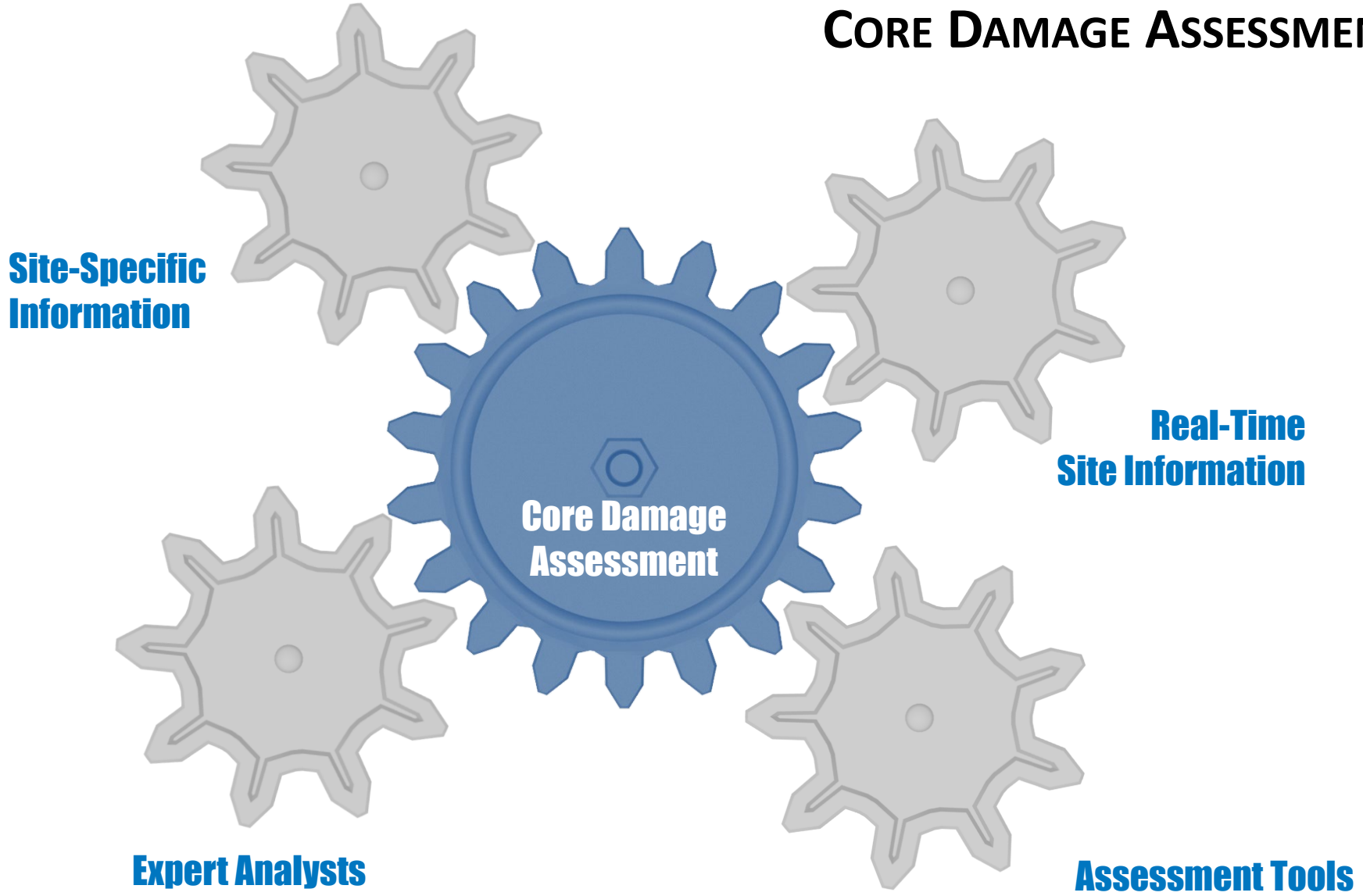
USNRC Incident Response Program

- Established after TMI
- Mission Areas
  - Oversight of licensee actions and recommendations
  - Support State/Local government with technical information
  - Support larger Federal response efforts

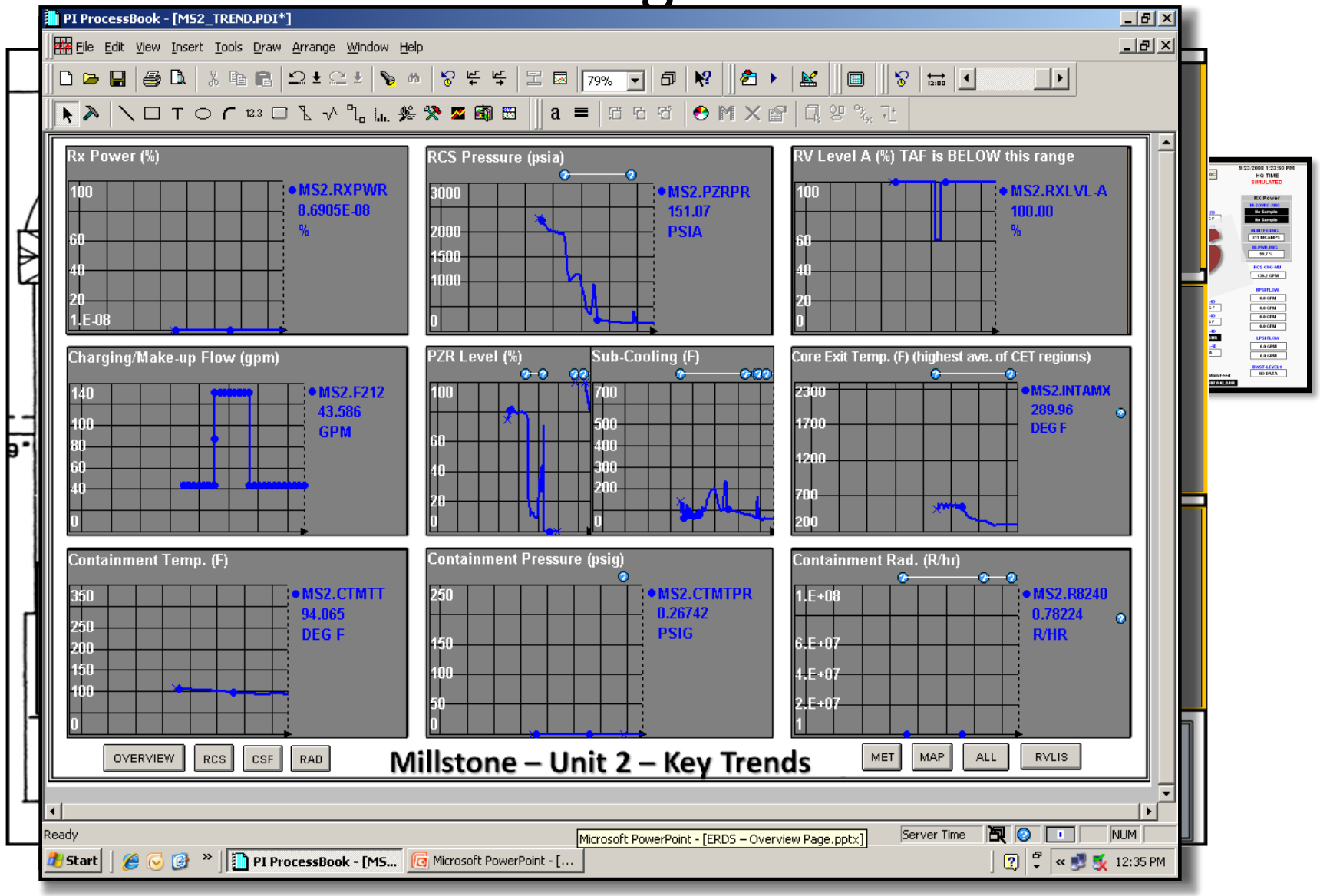
Response Technical Tools

- Used by NRC Incident Response Program's Reactor Safety Team:
  - Predict future conditions
  - Assess event classification
  - Assess licensee plans/priorities
  - Assess licensee capabilities
  - Advise and support
- Computerized version of Response Technical Manual 96

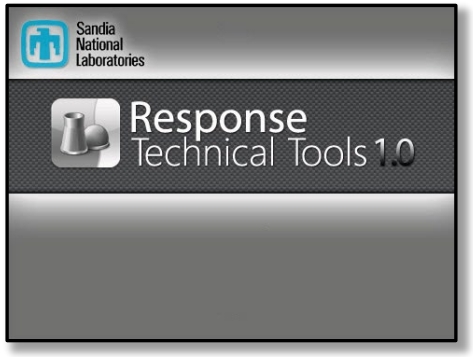
Core Damage Assessment

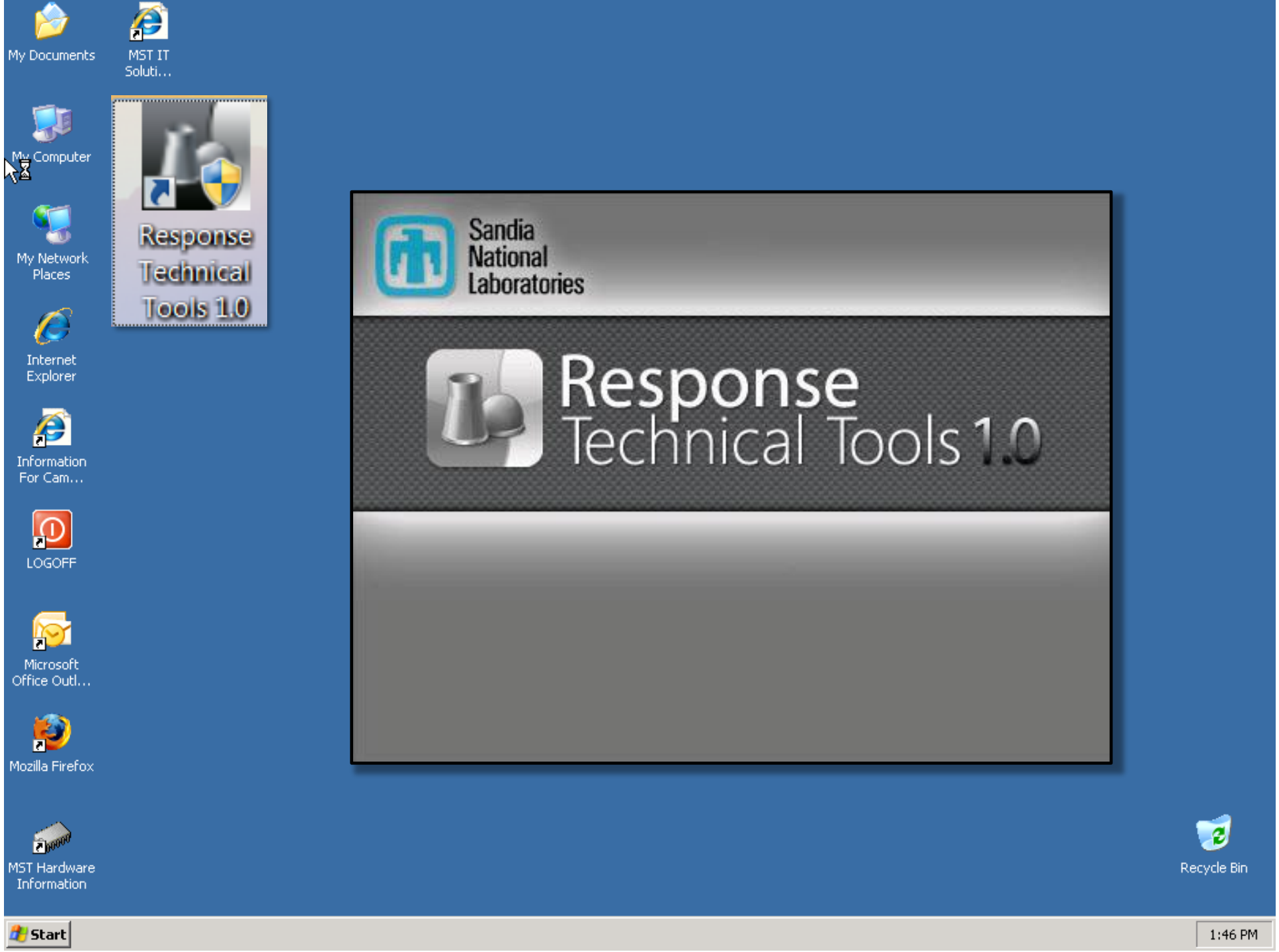


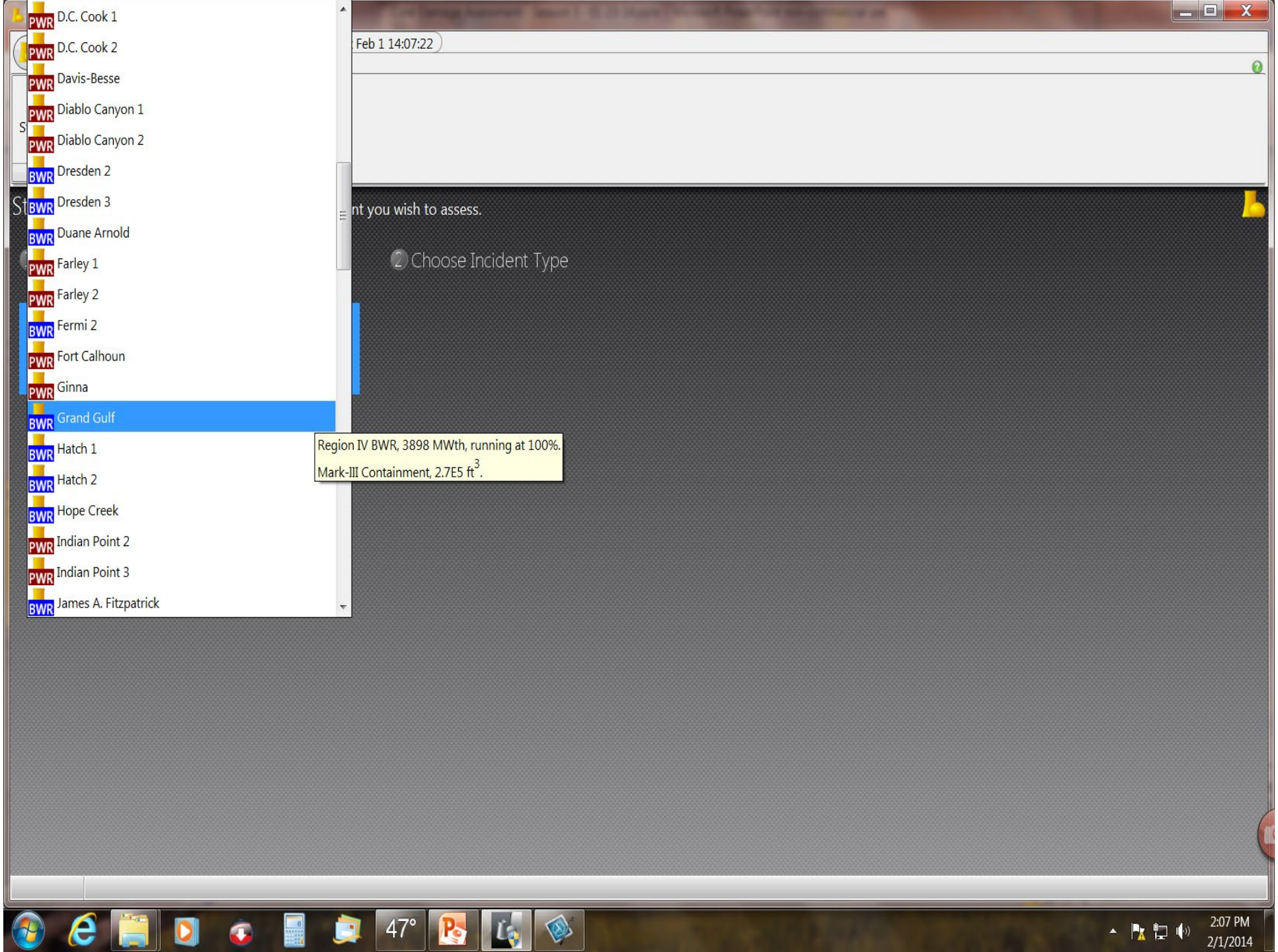
Core Damage Assessment - ERDS



Response Technical Tools




My Documents
MST IT Soluti...
My Computer
Response Technical Tools 1.0
My Network Places
Internet Explorer
Information For Cam...
LOGOFF
Microsoft Office Outl...
Mozilla Firefox
MST Hardware Information
Sandia National Laboratories
Response Technical Tools 1.0
Recycle Bin
Start
1:46 PM


D.C. Cook 1
D.C. Cook 2
Davis-Besse
Diablo Canyon 1
Diablo Canyon 2
Dresden 2
Dresden 3
Duane Arnold
Farley 1
Farley 2
Fermi 2
Fort Calhoun
Ginna
Grand Gulf
Hatch 1
Hatch 2
Hope Creek
Indian Point 2
Indian Point 3
James A. Fitzpatrick
Feb 1 14:07:22
nt you wish to assess.
2 Choose Incident Type
Region IV BWR, 3898 MWth, running at 100%.
Mark-III Containment, 2.7E5 ft3.
47°
2:07 PM
2/1/2014

*New Reactor Incident - Response Technical Tools

Local Time: Tue Feb 18 14:53:16

Home | Tools

Plant
Plant Settings
Quad Cities 1
Region III BWR, 2957 MWth, running at 100.0%.
Mark-I Containment, 1.582E5 ft^3.

Shutdown Time
Set Time
Tuesday
Feb 18, 2014
10:20 EDT
Elapsed: 4:33:16

Damage Assessment
1 Assess Critical Safety Systems
2 Core Uncovery Determination
3 Estimate Timing of Core Damage
4 Assess Core Damage State
5 Deflagration
Show All Steps

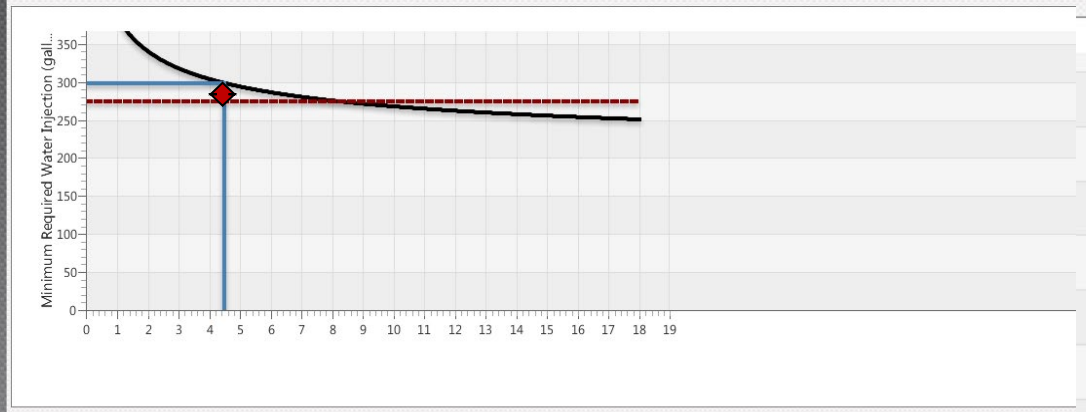
Window
Switch Incidents

1 ⚠ *Step 1->Water Injection*: Sufficient water is not being injected to remove decay heat.

- Subcritical State
- Core Coverage
- Water Injection
- Decay Heat

Water Injection Recommendation

Time Since Shutdown:	4.50	hr	
	[0.0, 8.77E3]		
Known Leak Rate:	1.50E2	gal	/ min
	[0.0, 1.00E6]		
Minimun Required Water Injection*:	2.98E2	gal	/ min
Actual Water Injection:	275.0	gal	/ min
	[0.0, 1.00E6]		

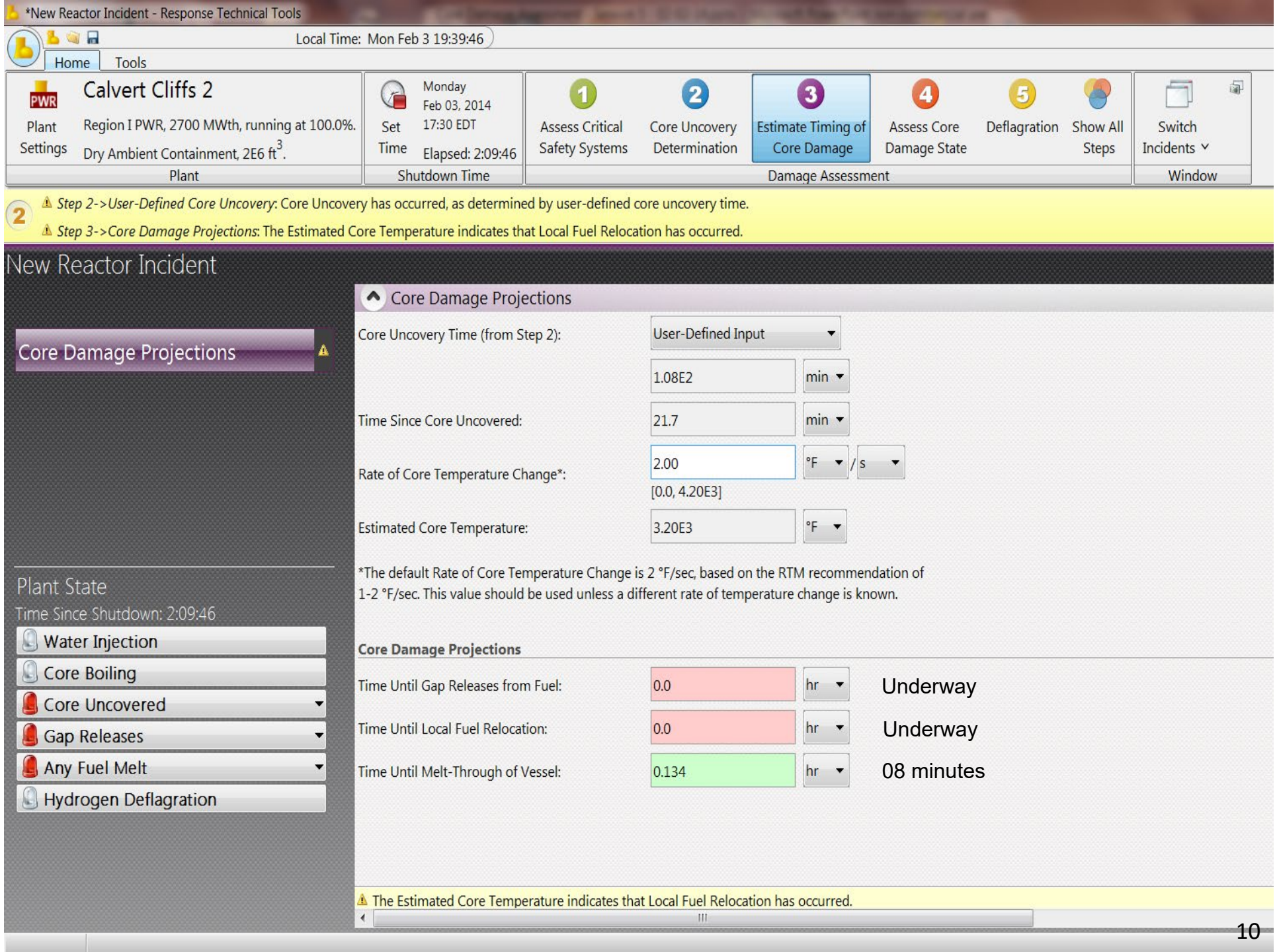


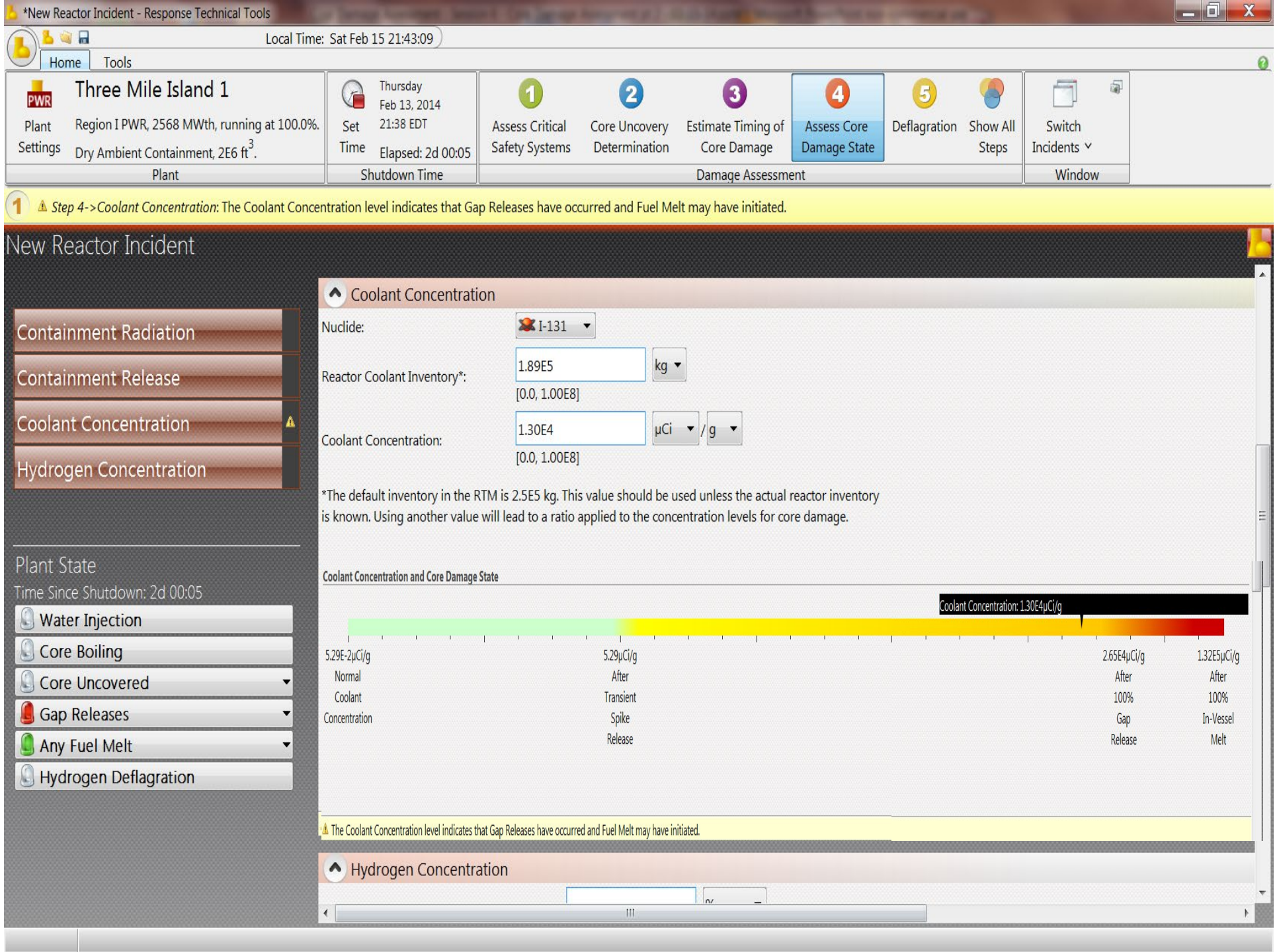
Plant State
Time Since Shutdown: 4:33:16

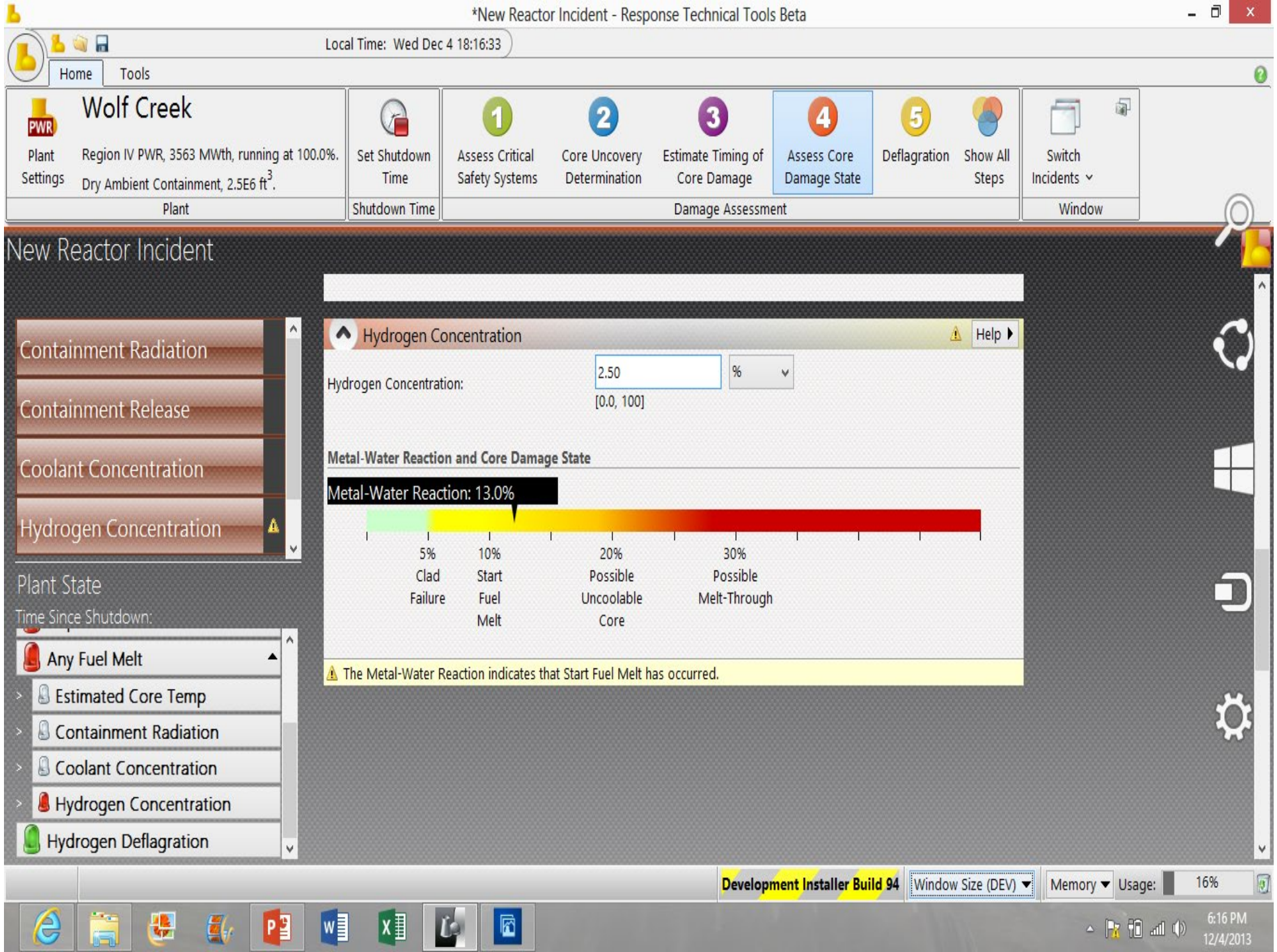
- Water Injection
- Core Uncovered
- Gap Releases
- Any Fuel Melt
- Hydrogen Deflagration

*Recommendation is based on this 3026 MWth plant, recently running at 100.0%.
If the core has been uncovered for 15-30 minutes or longer,
increase the Minimum Required Water by a factor of 2 to 3.

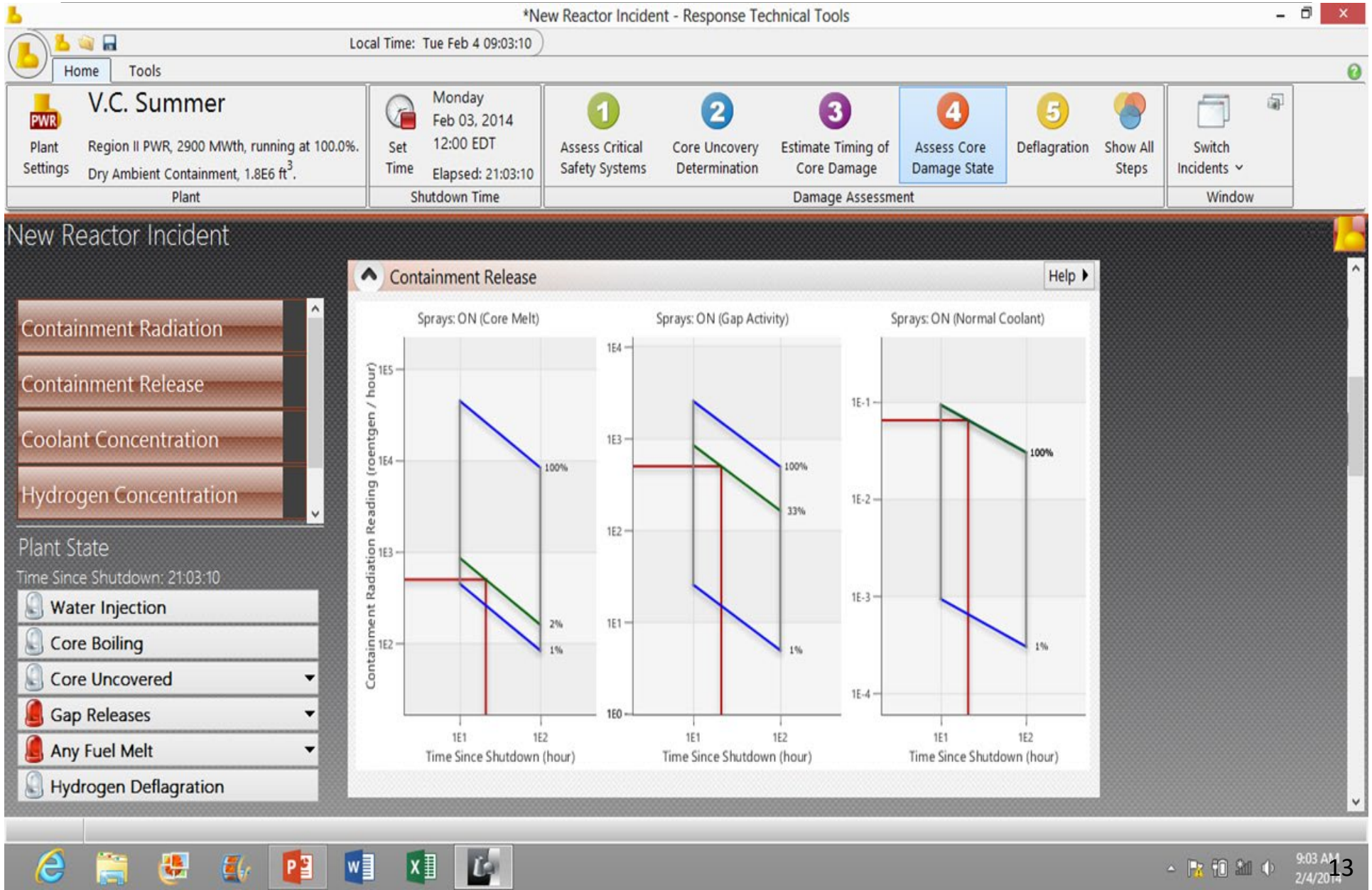
⚠ Sufficient water is not being injected to remove decay heat.


*New Reactor Incident - Response Technical Tools
Local Time: Mon Feb 3 19:39:46
Home
Tools
Calvert Cliffs 2
Plant Settings
Region I PWR, 2700 MWth, running at 100.0%.
Dry Ambient Containment, 2E6 ft3.
Plant
Monday
Feb 03, 2014
17:30 EDT
Set Time
Elapsed: 2:09:46
Shutdown Time
1 Assess Critical Safety Systems
2 Core Uncovery Determination
3 Estimate Timing of Core Damage
4 Assess Core Damage State
5 Deflagration
Show All Steps
Damage Assessment
Switch Incidents
Window
2
Step 2->User-Defined Core Uncovery: Core Uncovery has occurred, as determined by user-defined core uncovery time.
Step 3->Core Damage Projections: The Estimated Core Temperature indicates that Local Fuel Relocation has occurred.
New Reactor Incident
Core Damage Projections
Plant State
Time Since Shutdown: 2:09:46
Water Injection
Core Boiling
Core Uncovered
Gap Releases
Any Fuel Melt
Hydrogen Deflagration
Core Damage Projections
Core Uncovery Time (from Step 2):
User-Defined Input
1.08E2
min
Time Since Core Uncovered:
21.7
min
Rate of Core Temperature Change*:
2.00
°F
/ s
[0.0, 4.20E3]
Estimated Core Temperature:
3.20E3
°F
*The default Rate of Core Temperature Change is 2 °F/sec, based on the RTM recommendation of 1-2 °F/sec. This value should be used unless a different rate of temperature change is known.
Core Damage Projections
Time Until Gap Releases from Fuel:
0.0
hr
Underway
Time Until Local Fuel Relocation:
0.0
hr
Underway
Time Until Melt-Through of Vessel:
0.134
hr
08 minutes
The Estimated Core Temperature indicates that Local Fuel Relocation has occurred.


*New Reactor Incident - Response Technical Tools
Local Time: Sat Feb 15 21:43:09
Home
Tools
Three Mile Island 1
Region I PWR, 2568 MWth, running at 100.0%.
Dry Ambient Containment, 2E6 ft3.
Plant Settings
Plant
Thursday
Feb 13, 2014
21:38 EDT
Set Time
Elapsed: 2d 00:05
Shutdown Time
1 Assess Critical Safety Systems
2 Core Uncovery Determination
3 Estimate Timing of Core Damage
4 Assess Core Damage State
5 Deflagration
Show All Steps
Damage Assessment
Switch Incidents
Window
1 Step 4->Coolant Concentration: The Coolant Concentration level indicates that Gap Releases have occurred and Fuel Melt may have initiated.
New Reactor Incident
Containment Radiation
Containment Release
Coolant Concentration
Hydrogen Concentration
Plant State
Time Since Shutdown: 2d 00:05
Water Injection
Core Boiling
Core Uncovered
Gap Releases
Any Fuel Melt
Hydrogen Deflagration
Coolant Concentration
Nuclide:
I-131
Reactor Coolant Inventory*:
1.89E5
kg
[0.0, 1.00E8]
Coolant Concentration:
1.30E4
µCi
/ g
[0.0, 1.00E8]
*The default inventory in the RTM is 2.5E5 kg. This value should be used unless the actual reactor inventory is known. Using another value will lead to a ratio applied to the concentration levels for core damage.
Coolant Concentration and Core Damage State
Coolant Concentration: 1.30E4µCi/g
5.29E-2µCi/g Normal Coolant Concentration
5.29µCi/g After Transient Spike Release
2.65E4µCi/g After 100% Gap Release
1.32E5µCi/g After 100% In-Vessel Melt
The Coolant Concentration level indicates that Gap Releases have occurred and Fuel Melt may have initiated.
Hydrogen Concentration


*New Reactor Incident - Response Technical Tools Beta
Local Time: Wed Dec 4 18:16:33
Home
Tools
Wolf Creek
Plant Settings
Region IV PWR, 3563 MWth, running at 100.0%.
Dry Ambient Containment, 2.5E6 ft3.
Plant
Set Shutdown Time
Shutdown Time
1 Assess Critical Safety Systems
2 Core Uncovery Determination
3 Estimate Timing of Core Damage
4 Assess Core Damage State
5 Deflagration
Show All Steps
Damage Assessment
Switch Incidents
Window
New Reactor Incident
Containment Radiation
Containment Release
Coolant Concentration
Hydrogen Concentration
Plant State
Time Since Shutdown:
Any Fuel Melt
Estimated Core Temp
Containment Radiation
Coolant Concentration
Hydrogen Concentration
Hydrogen Deflagration
Hydrogen Concentration
Help
Hydrogen Concentration:
2.50
%
[0.0, 100]
Metal-Water Reaction and Core Damage State
Metal-Water Reaction: 13.0%
5% Clad Failure
10% Start Fuel Melt
20% Possible Uncoolable Core
30% Possible Melt-Through
The Metal-Water Reaction indicates that Start Fuel Melt has occurred.
Development Installer Build 94
Window Size (DEV)
Memory
Usage:
16%
6:16 PM
12/4/2013

CONTAINMENT RADIATION

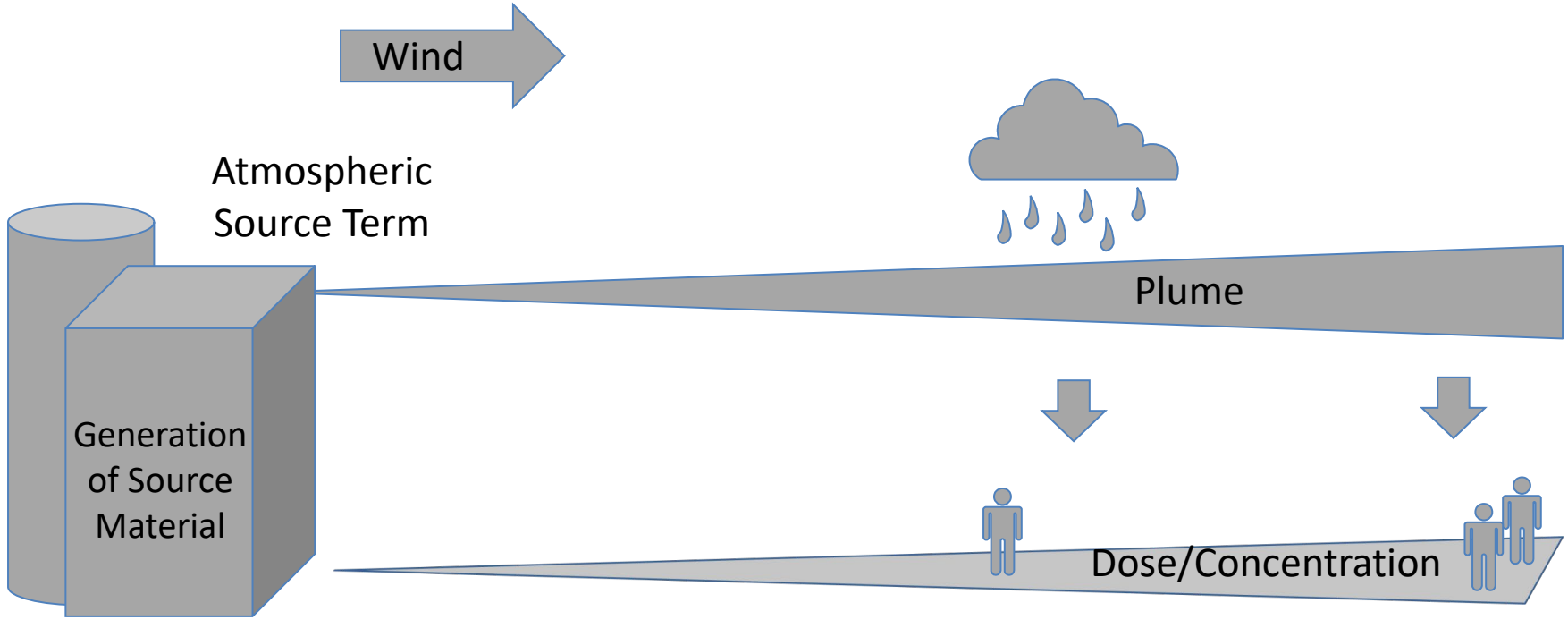


Radiological System for Consequence Analysis (RASCAL)

- Used by NRC Incident Response Program
  - Independent dose and consequence projections during radiological incidents and emergencies
- Fast-running code that estimates doses for potential or ongoing releases from:
  - nuclear power plants (light-water reactors),
  - spent fuel storage pools and casks,
  - fuel cycle facilities, and
  - radioactive material handling facilities
- Also estimates deposition, field measurements, and intermediate phase doses

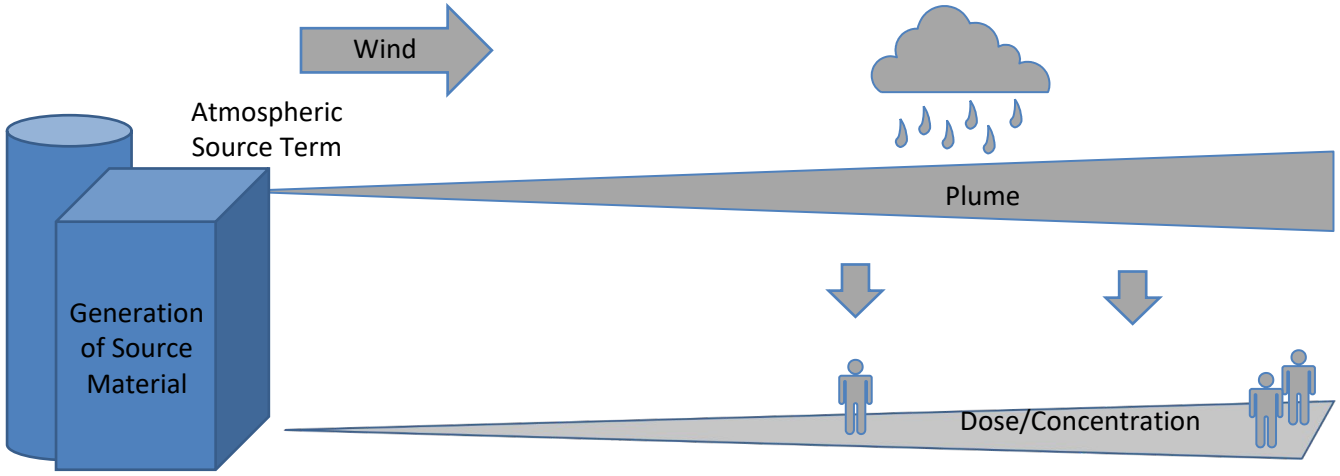
How RASCAL works

RASCAL creates an atmospheric source term, processes weather data, and calculates doses



RASCAL Defines Atmospheric Source Term

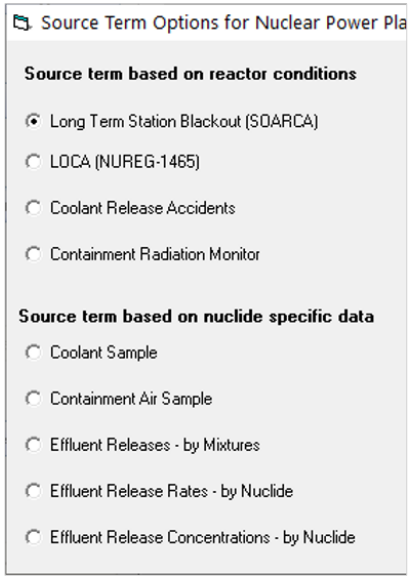
- Models or measurements determine radionuclides available for release
  - Unit-specific data for NPPs, spent fuel, and fuel facilities
  - Models/measurements based on accident scenario studies
- Source material may be filtered, reduced, or decayed
  - Filtering and release height; NPP unit-specific pathways



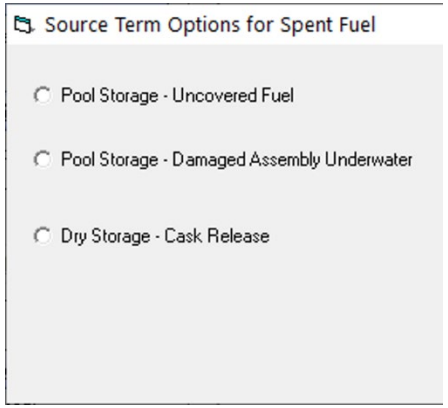
Source Term

- Source term models calculate material that can be released
- Pick the best model; may have multiple options
- Available choices depend on Event Type

Nuclear Power Plant

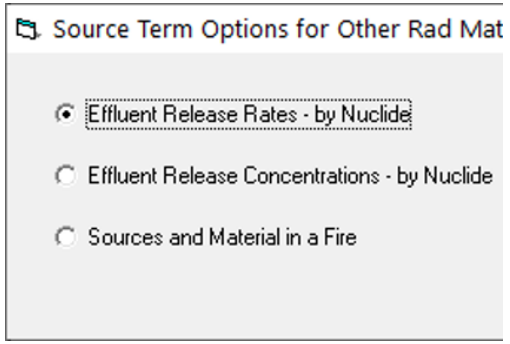


Spent Fuel

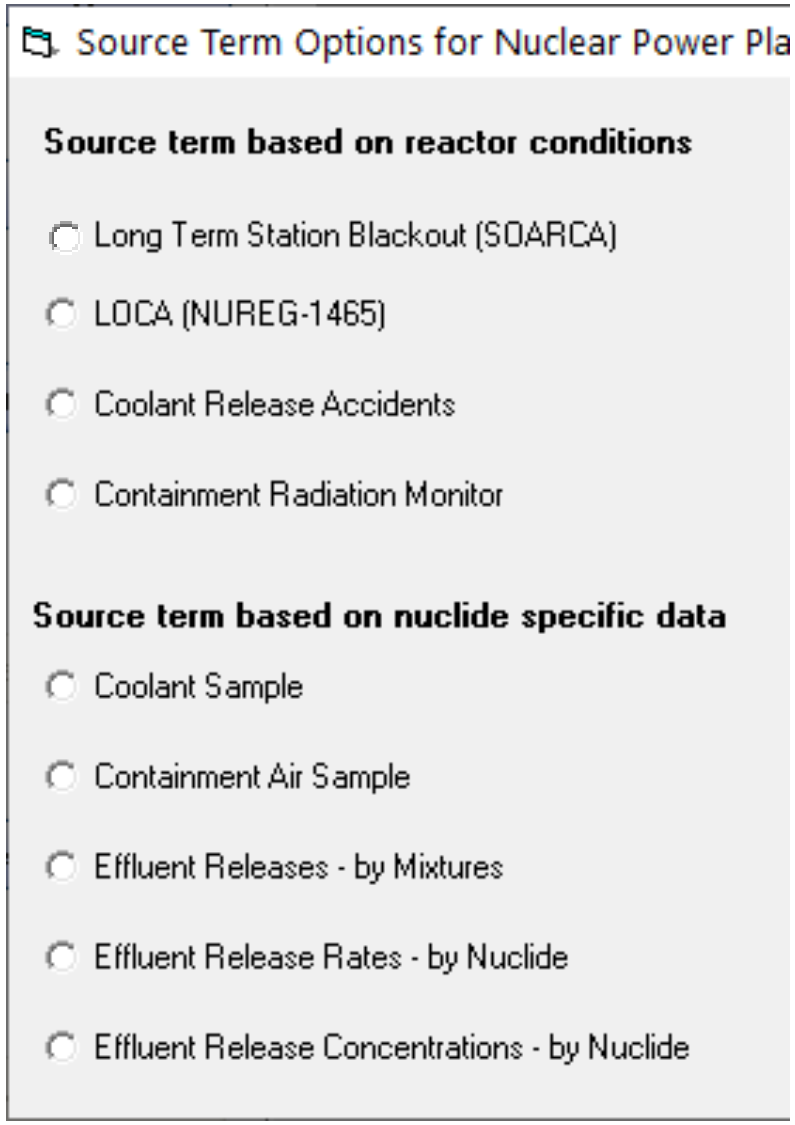


Fuel Cycle

Other Materials

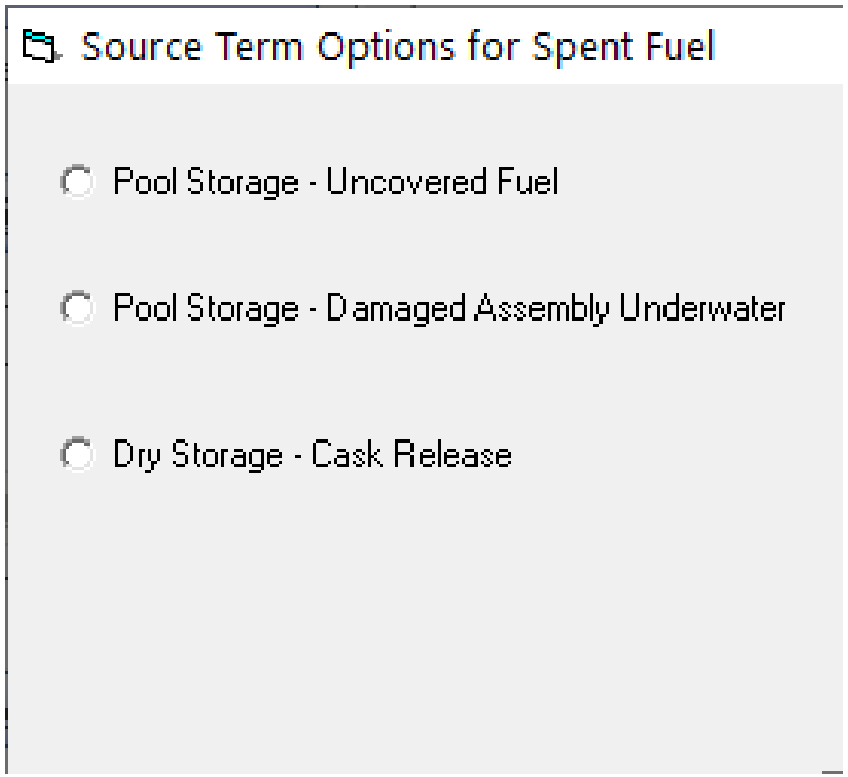


Nuclear Power Plant



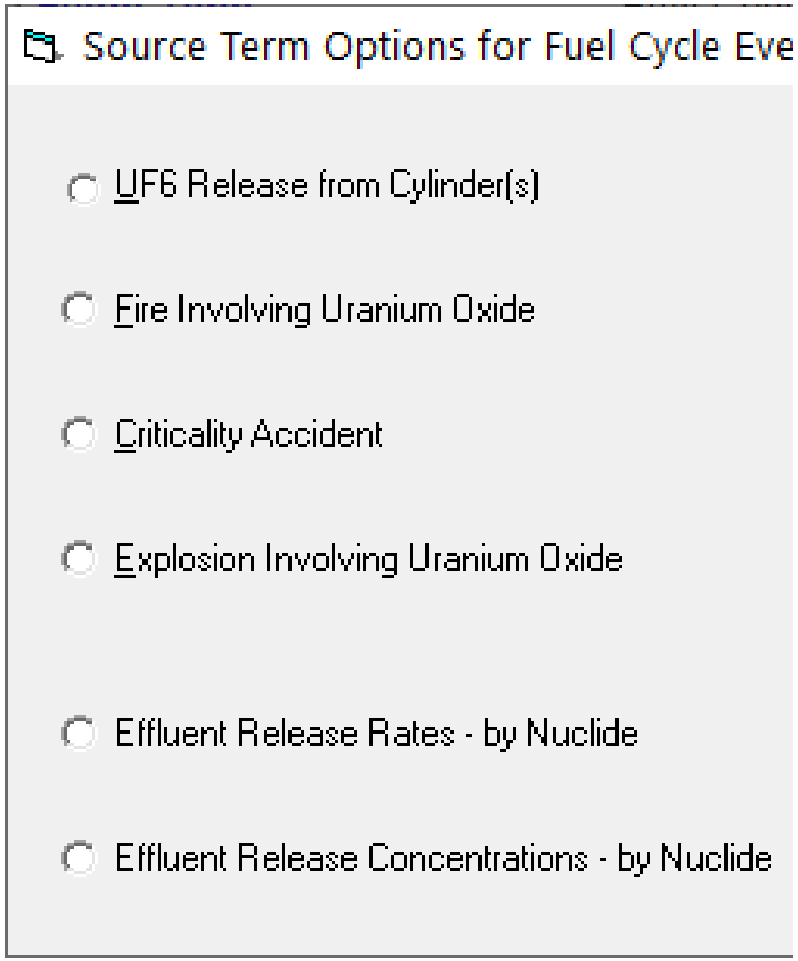
- RASCAL has 9 nuclear power plant source term options:
- 4 based on reactor condition models
- 5 based on nuclide measurements

Spent Fuel



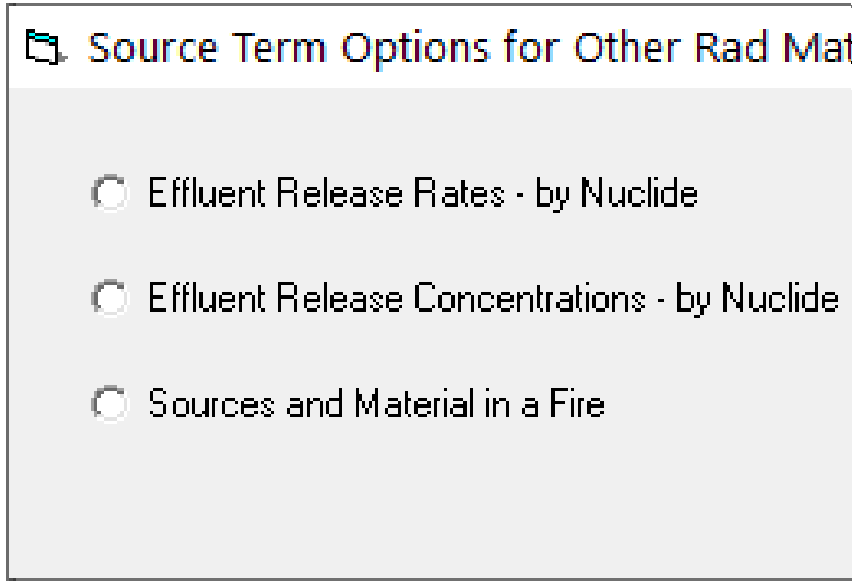
- For Spent Fuel, RASCAL has 3 source term options
- Includes both pool and dry storage
- Sites are collocated with NPPs

FUEL CYCLE



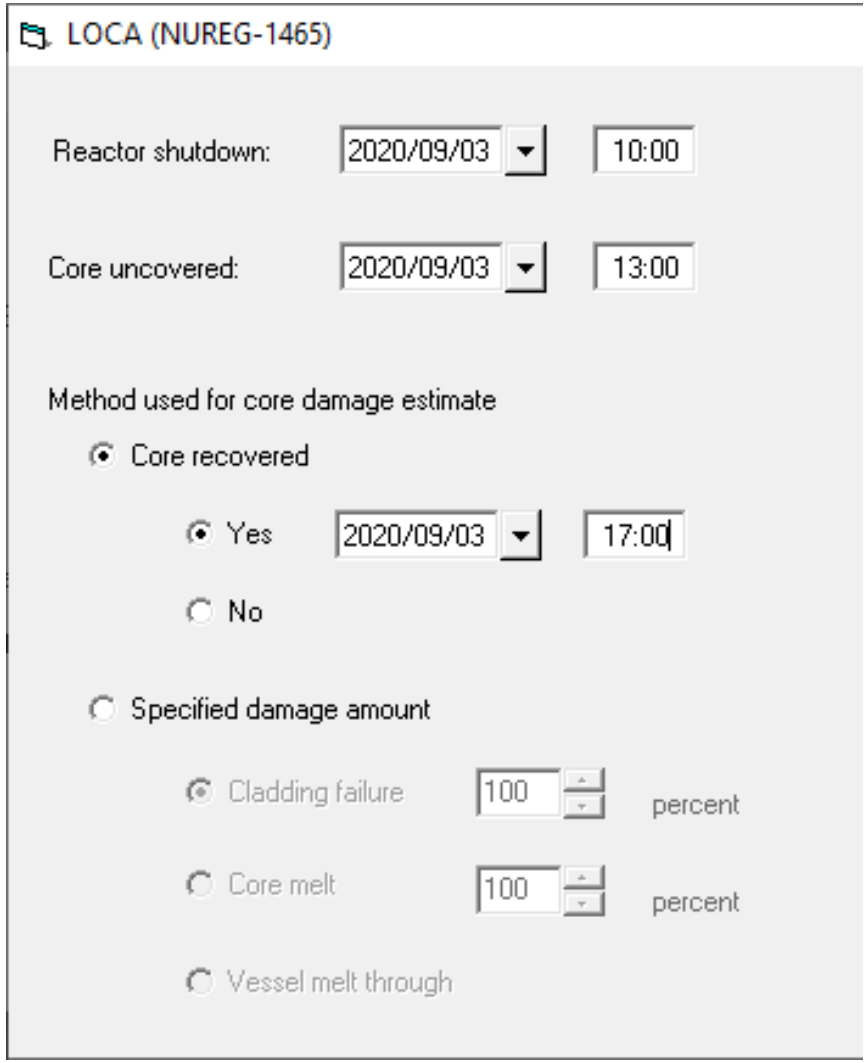
- RASCAL can model certain events from fuel fabrication facilities
- UF6 release – special plume model with chemical HF hazard
- Criticality – plume model for activation but includes prompt shine

Other Materials Locations



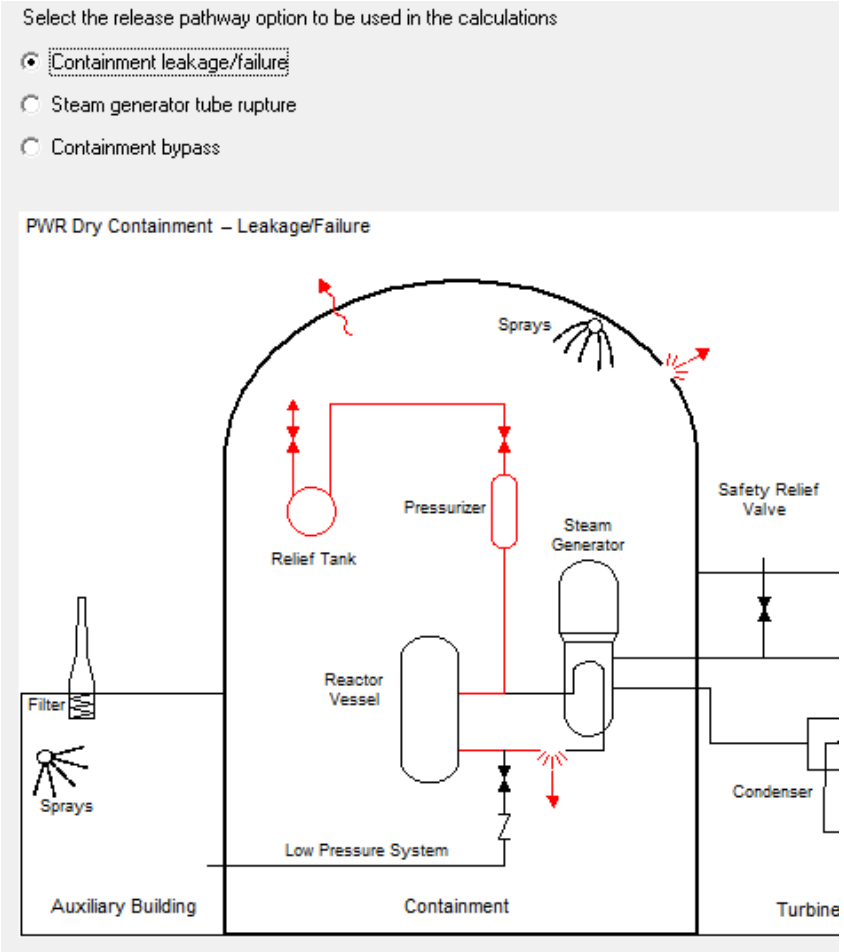
- RASCAL also has 3 “other” materials options
- Useful for modeling transportation accidents, lab accidents, etc.
- All models still focus on atmospheric releases
  - Liquid releases (like spills and leaks) are not modeled in RASCAL

Source Term Details



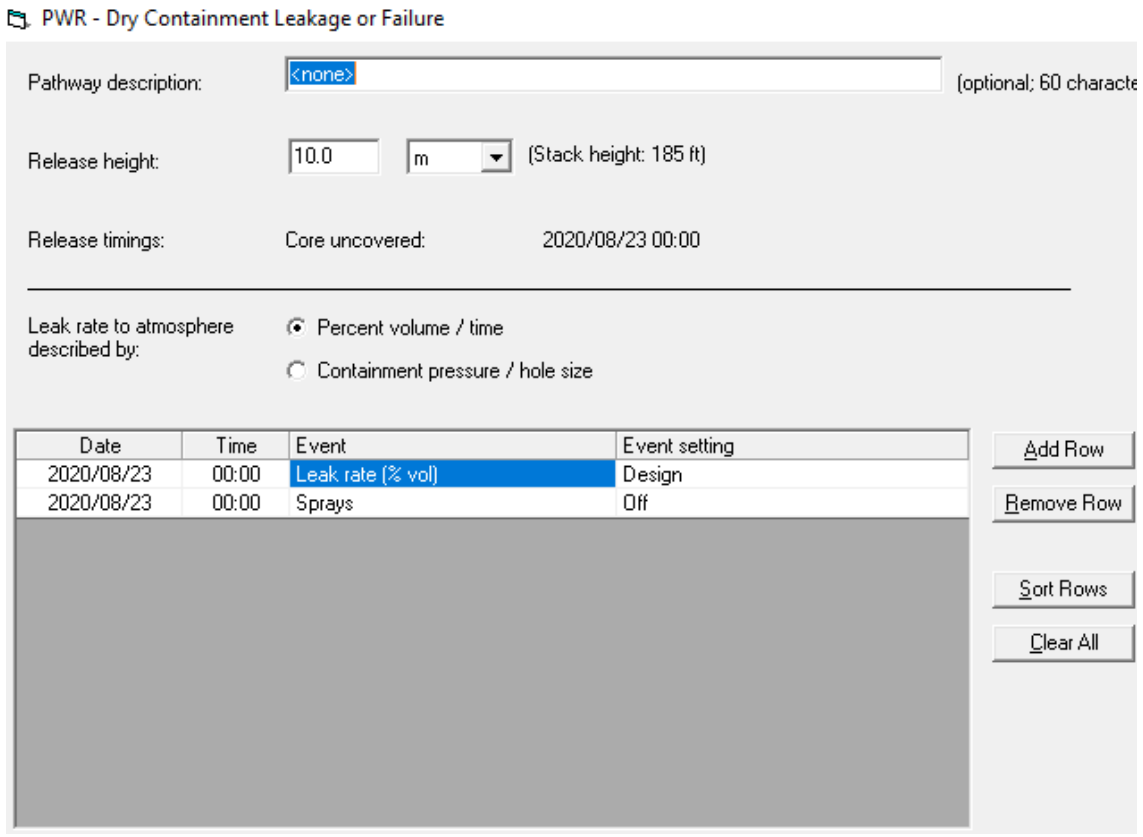
- Each model requires additional details like timing or measurements
- For example, in the LOCA model:
  - Time of reactor shutdown
    - Starts the decay of all nuclides in the core (they're in equilibrium before)
  - Time core was uncovered
    - When NUREG-1465 models start, starting with 30 min of gap activity, then fuel melt
  - Is the core recovered?
    - Additional material stops being generated after the core becomes recovered

Release Pathway



- RASCAL needs information on how generated material is released to the atmosphere
  - Pathway
  - Height
    - Wind speeds change with height
  - Reduction
    - Amount of material reduced by decay, holdup, filter, sprays
  - Timing
    - Release rates, start and stop

Release Pathway Details



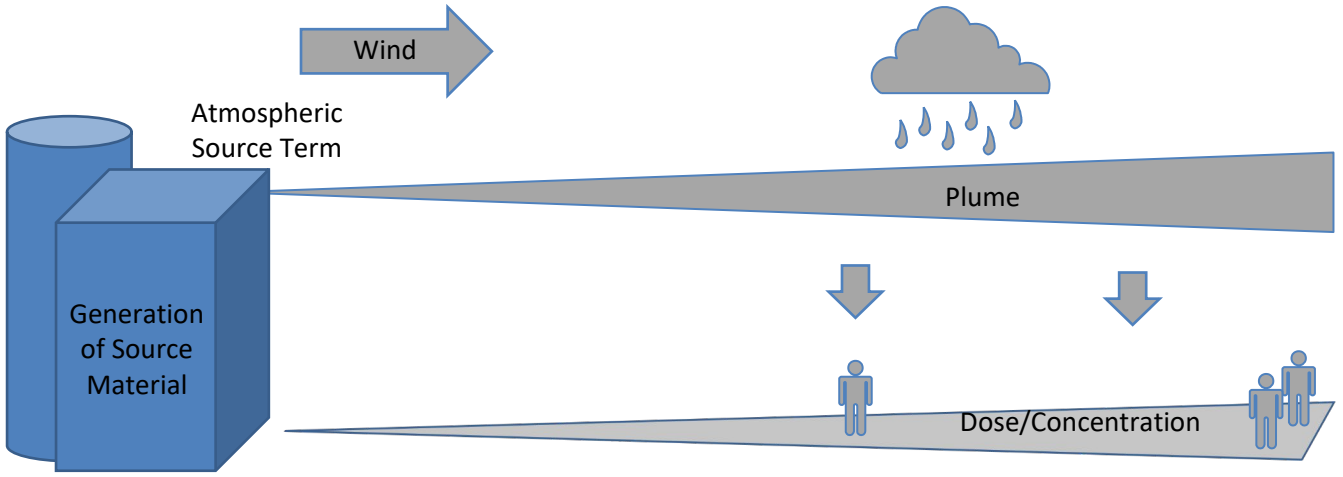
- Release Height
  - 10m is minimum height allowed (ground release)
- Select leak rate type
  - Percent Volume / Time (e.g., 3%/hour)
  - Containment pressure / Hole Size (e.g., 30 psi/2 cm^2)
- Define release timeline
  - Used for leak rate and additional conditions
  - Need to review/set initial conditions, then can add rows as needed

RASCAL Defines Atmospheric Source Term

- **Atmospheric Source Term**
  - **May be single nuclide or complex core damage**
  - **Isotopic activity over time (15 min)**

...ity (Ci) released to atmosphere (by nuclide and time step)

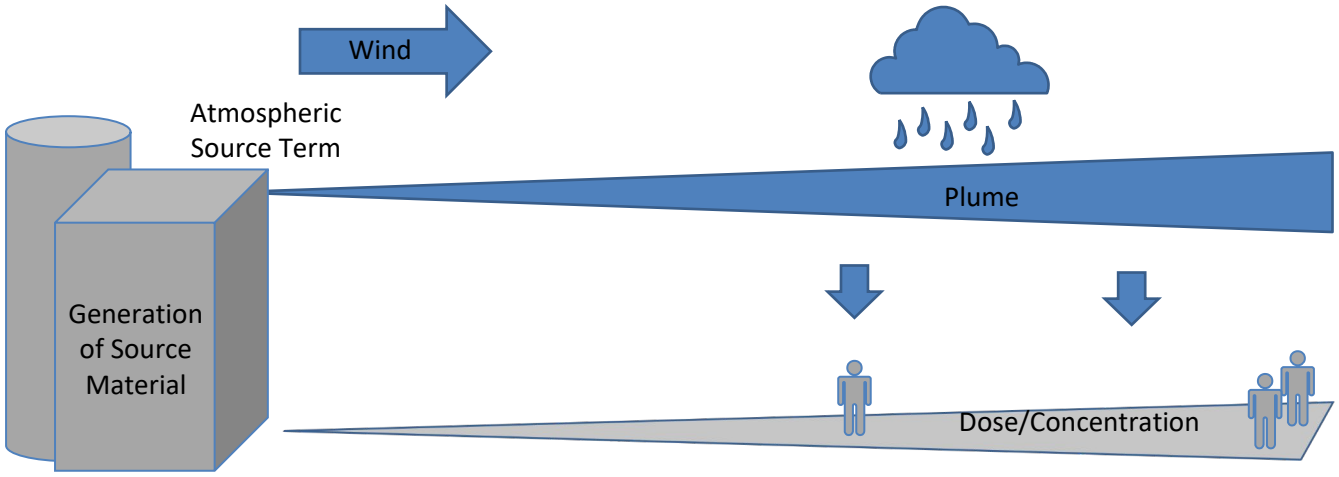
Interval	2016/02/02	2016/02/02	2016/02/02	2016/02/02	2016/02/02	2016/02/02	2016/02/02	20
Start	00:00	00:15	00:30	00:45	01:00	01:15	01:30	01:
Am-241	0.00E+00	0.00E+00	4.62E-10	1.46E-09	2.75E-09	4.17E-09	5.63E-09	
Ba-139	0.00E+00	0.00E+00	5.62E+00	8.62E+00	9.99E+00	1.04E+01	1.02E+01	1
Ba-140	0.00E+00	0.00E+00	7.25E+00	1.26E+01	1.66E+01	1.95E+01	2.17E+01	3
Ce-141	0.00E+00	0.00E+00	1.67E-01	2.92E-01	3.83E-01	4.51E-01	5.01E-01	1
Ce-143	0.00E+00	0.00E+00	1.51E-01	2.61E-01	3.42E-01	4.01E-01	4.43E-01	1
Ce-144*	0.00E+00	0.00E+00	1.35E-01	2.35E-01	3.09E-01	3.64E-01	4.04E-01	1
Cm-242	0.00E+00	0.00E+00	1.71E-03	2.97E-03	3.91E-03	4.60E-03	5.11E-03	
Cs-134	3.62E+00	6.30E+00	1.16E+01	1.56E+01	1.85E+01	2.07E+01	2.23E+01	2
Cs-136	1.48E+00	2.57E+00	4.73E+00	6.35E+00	7.53E+00	8.41E+00	9.09E+00	9
Cs-137*	2.50E+00	4.36E+00	8.05E+00	1.08E+01	1.28E+01	1.43E+01	1.54E+01	1
Cs-138	0.00E+00	1.73E+01	3.76E+01	5.65E+01	6.04E+01	5.41E+01	4.37E+01	3
I-131	2.65E+01	4.60E+01	1.05E+02	1.49E+02	1.81E+02	2.05E+02	2.23E+02	2
I-132	3.84E+01	6.49E+01	1.49E+02	2.07E+02	2.49E+02	2.81E+02	3.05E+02	2
I-133	5.37E+01	9.27E+01	2.11E+02	2.95E+02	3.57E+02	4.01E+02	4.32E+02	4
I-134	5.92E+01	8.46E+01	1.58E+02	1.85E+02	1.85E+02	1.72E+02	1.53E+02	1
I-135	5.13E+01	8.70E+01	1.94E+02	2.67E+02	3.18E+02	3.50E+02	3.71E+02	3
Kr-83m	4.08E+00	7.43E+00	3.14E+01	5.10E+01	6.69E+01	7.94E+01	8.91E+01	8
Kr-85	2.89E-01	5.78E-01	2.69E+00	4.81E+00	6.91E+00	9.00E+00	1.12E+01	
...5m	8.25E+00	1.58E+01	7.11E+01	1.22E+02	1.69E+02	2.12E+02	2.52E+02	



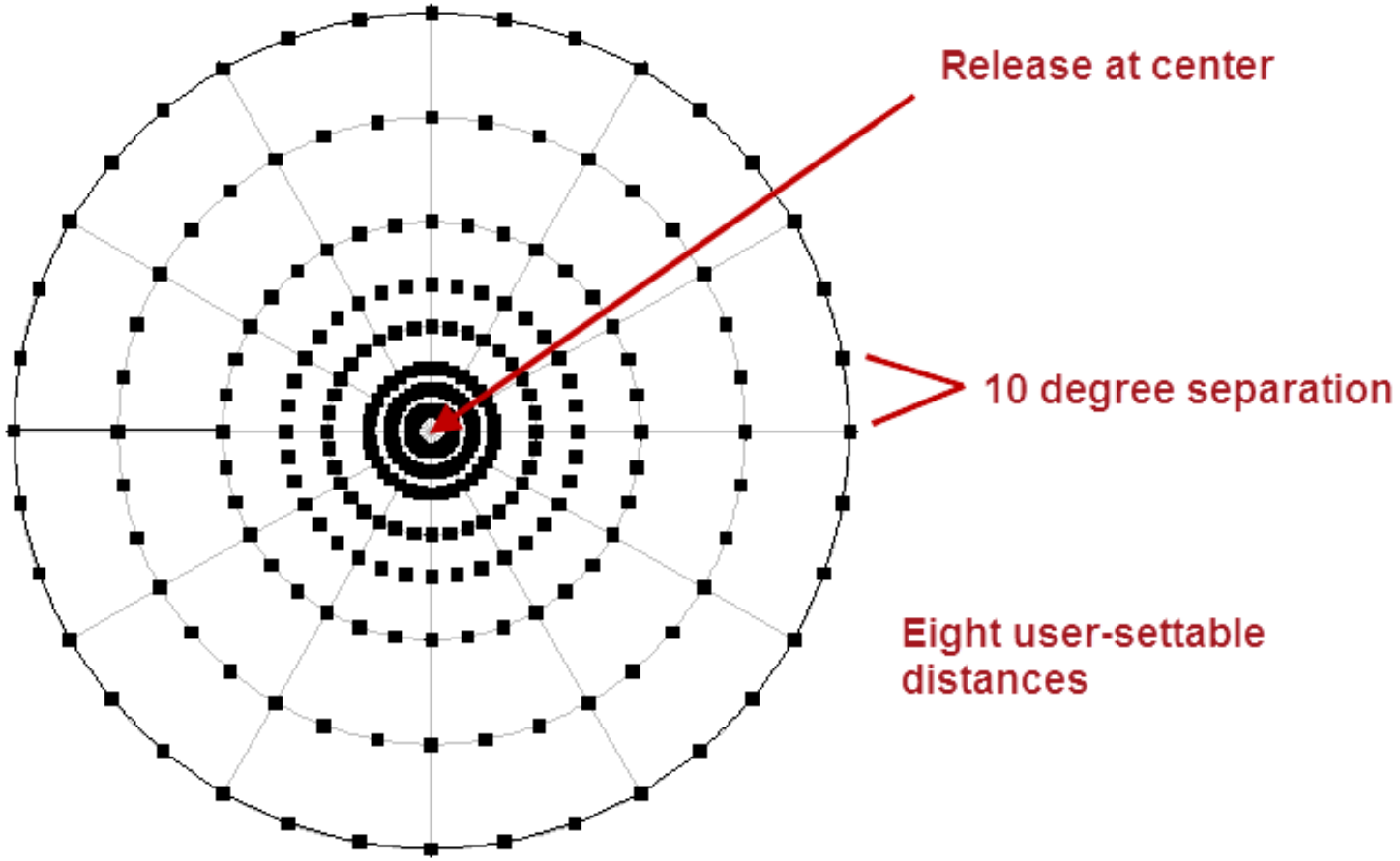
Atmospheric Source Term is Moved using ATD Models

Atmospheric Transport and Dispersion Models

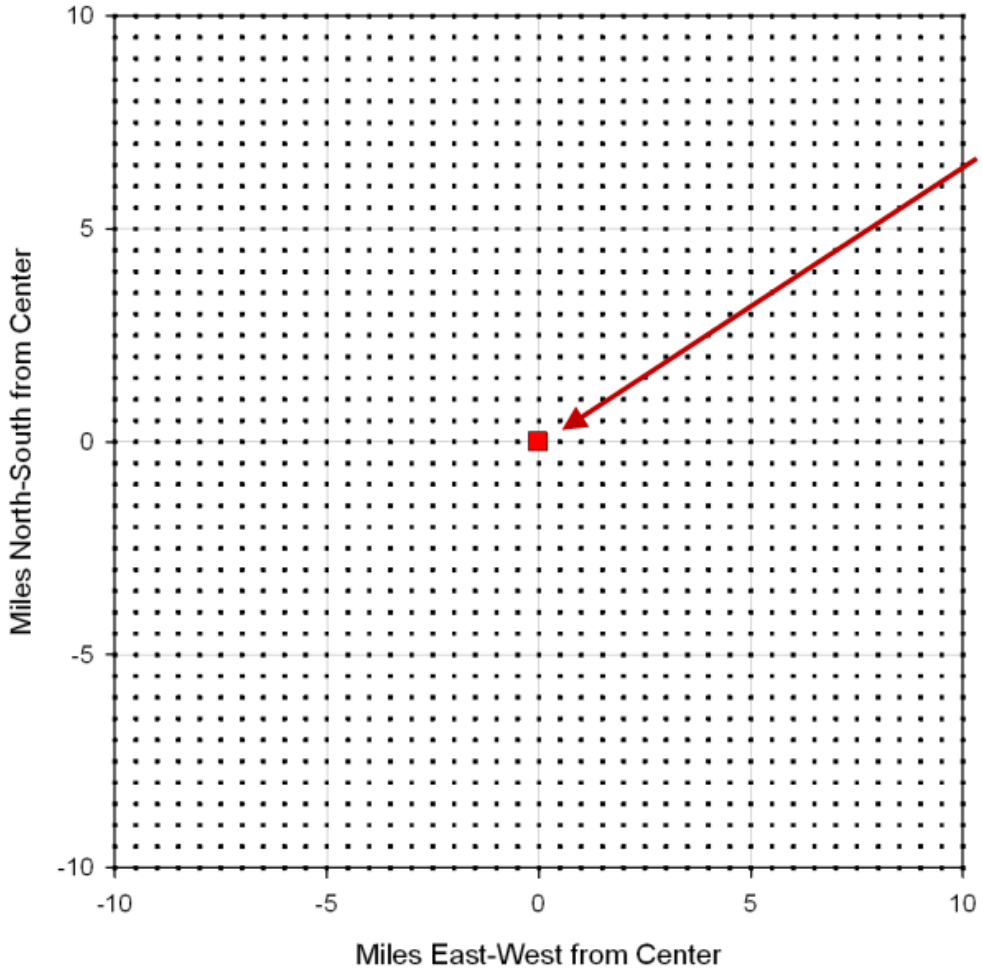
- **Transport material based on weather conditions**
- **Track material to where it falls/washes on ground**
- **Accounts for dry/wet processes and particle size**



A STRAIGHT-LINE GAUSSIAN PLUME MODEL ON A POLAR GRID IS USED TO MODEL DISTANCES CLOSE TO THE RELEASE POINT



A PUFF MODEL ON A CARTESIAN GRID IS USED TO MODEL AT LONGER DISTANCES

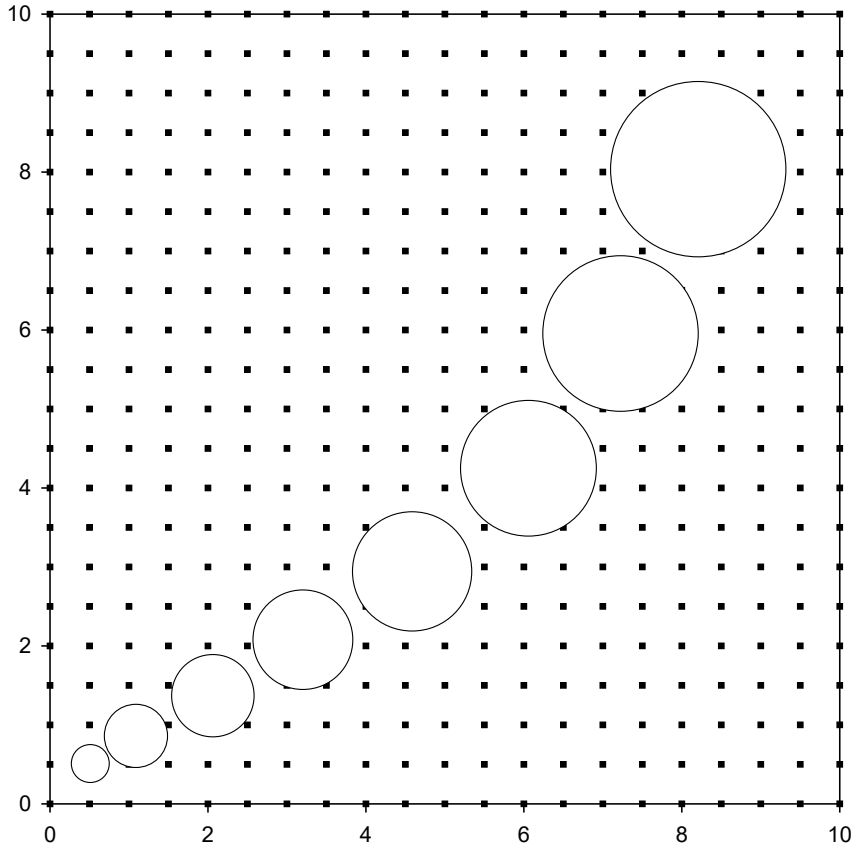


Release at center

41x41 grid of evenly spaced points

Spacing between grid points set by user selected calculation distance

A SEQUENCE OF DISCRETE PUFFS IS USED TO MODEL THE PLUME



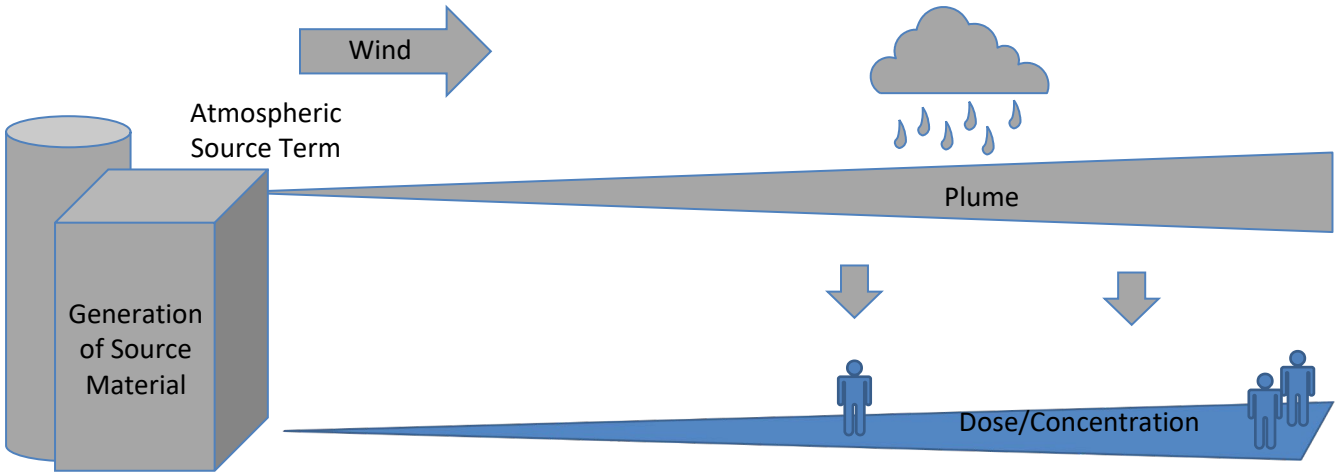
Puff centers move with the wind.

Puffs grow larger as time passes.

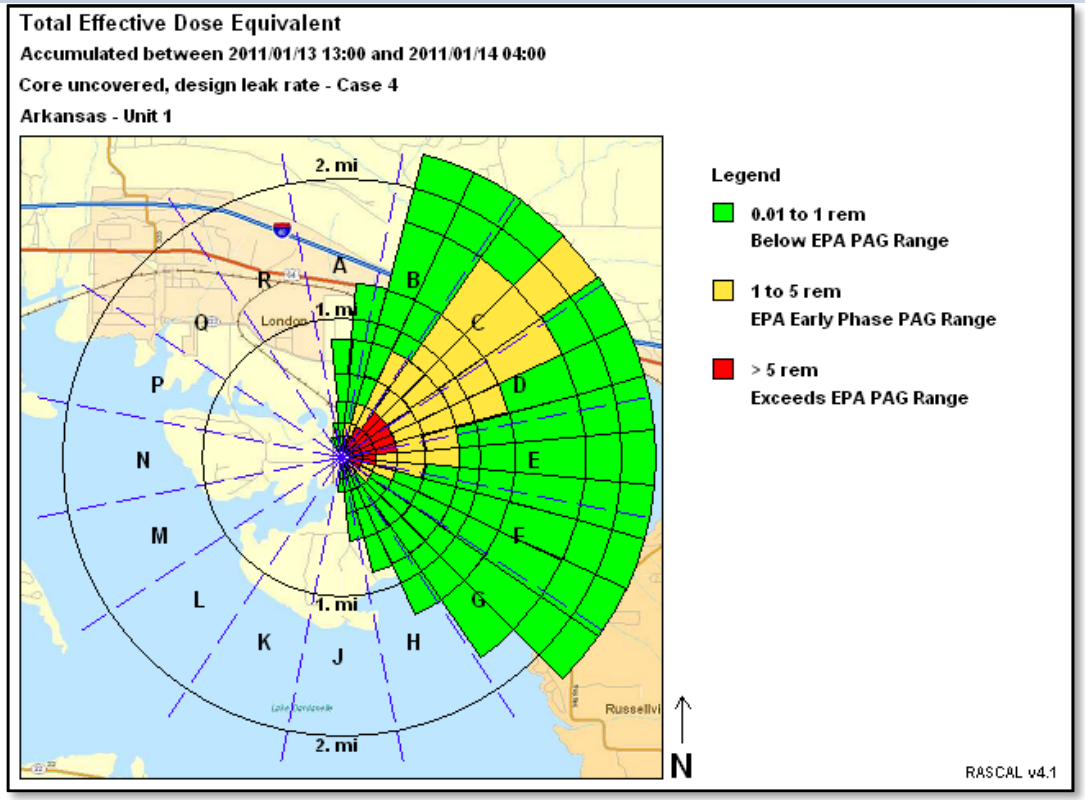
Each puff represents 15 minutes of release.

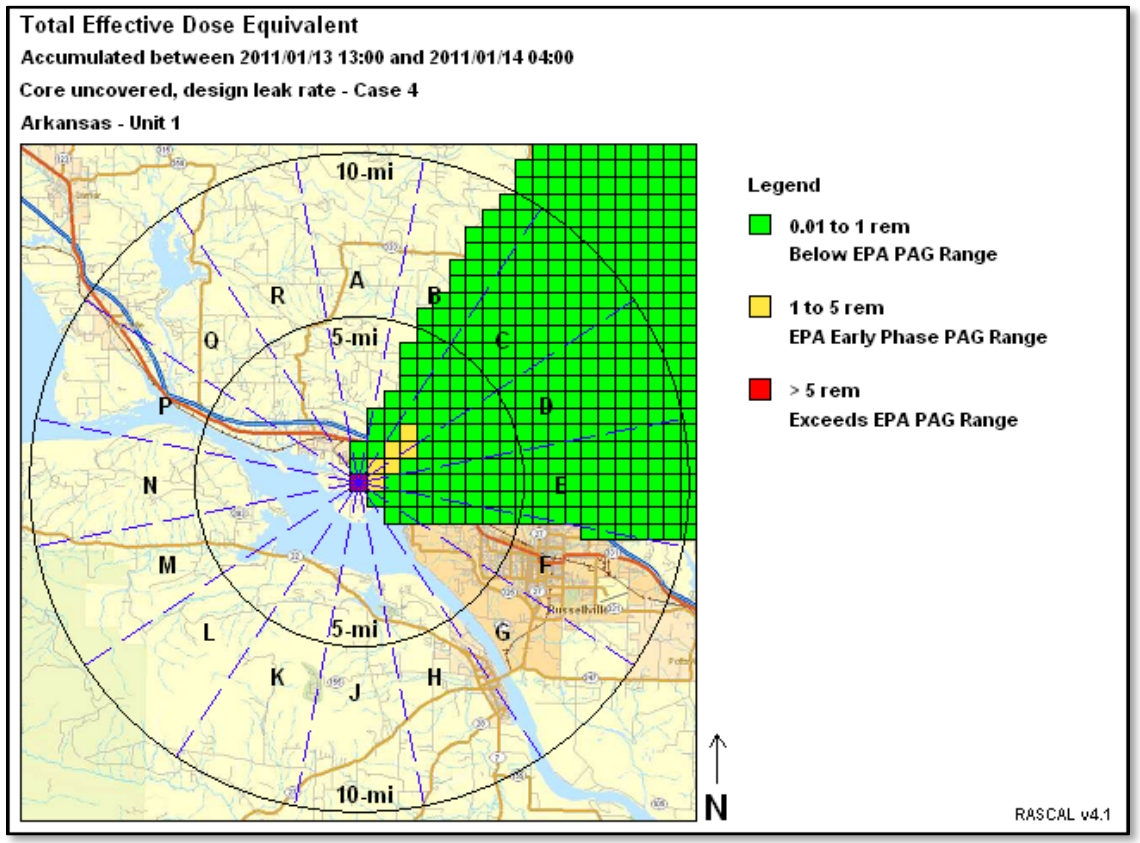
Final Calculations Provide Doses and Concentrations

- Dose calculation accounts for multiple pathways
  - External (Groundshine + cloudshine)
  - Internal (Inhalation + ~~ingestion)~~
- Results includes other display/calculation options



RASCAL Outputs





QUESTIONS?