



What's in the Black Box Known as EMERGENCY DOSE ASSESSMENT

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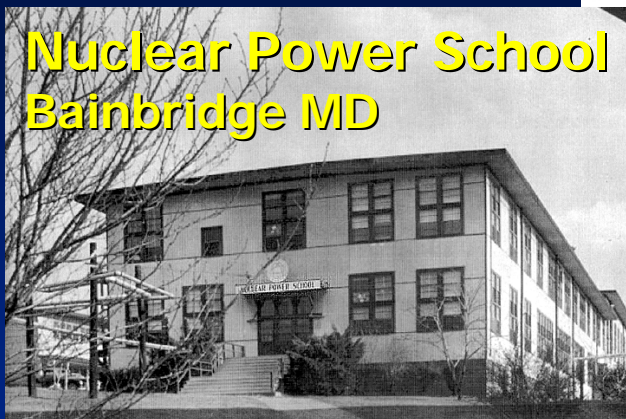
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Abstract

In this workshop, we are going to pry open the black box which is dose assessment. We'll:

- **Discuss the role of dose assessments in an emergency response**
- **Identify the three steps in performing a dose assessment**
- **Look at each of these three steps in some detail**
- **Look at the major methods, principles and assumptions involved in each step**
- **Consider how these assumptions affect the usefulness and uncertainty of the dose assessment outputs**

Non-Objectives

In this workshop, my goal is not that you can leave here this morning and be able to write your own dose assessment program; nor that you become a dose assessment wizard on a particular dose assessment program.

Objective

Instead, I hope that by discussing the dose assessment internals, you will gain a fuller understanding of the capabilities, limitations, and uncertainties of dose assessment, and be a better consumer of the data our dose assessors prepare.

Purpose of Dose Assessment

- The NRC places strong emphasis on the use of plant condition assessments as a basis for emergency classifications and protective action recommendations (PARs)
- This emphasis was developed as a result of insights from severe accident assessments performed in the 1980's. These insights showed that:
 - Timely protective actions, preferably prior to the start of the release, were necessary for protecting the public
 - Data necessary for meaningful dose assessments may not be readily available and that such assessments could be uncertain
- As such, dose assessments could not fully support anticipatory decision-making associated with initial protective actions

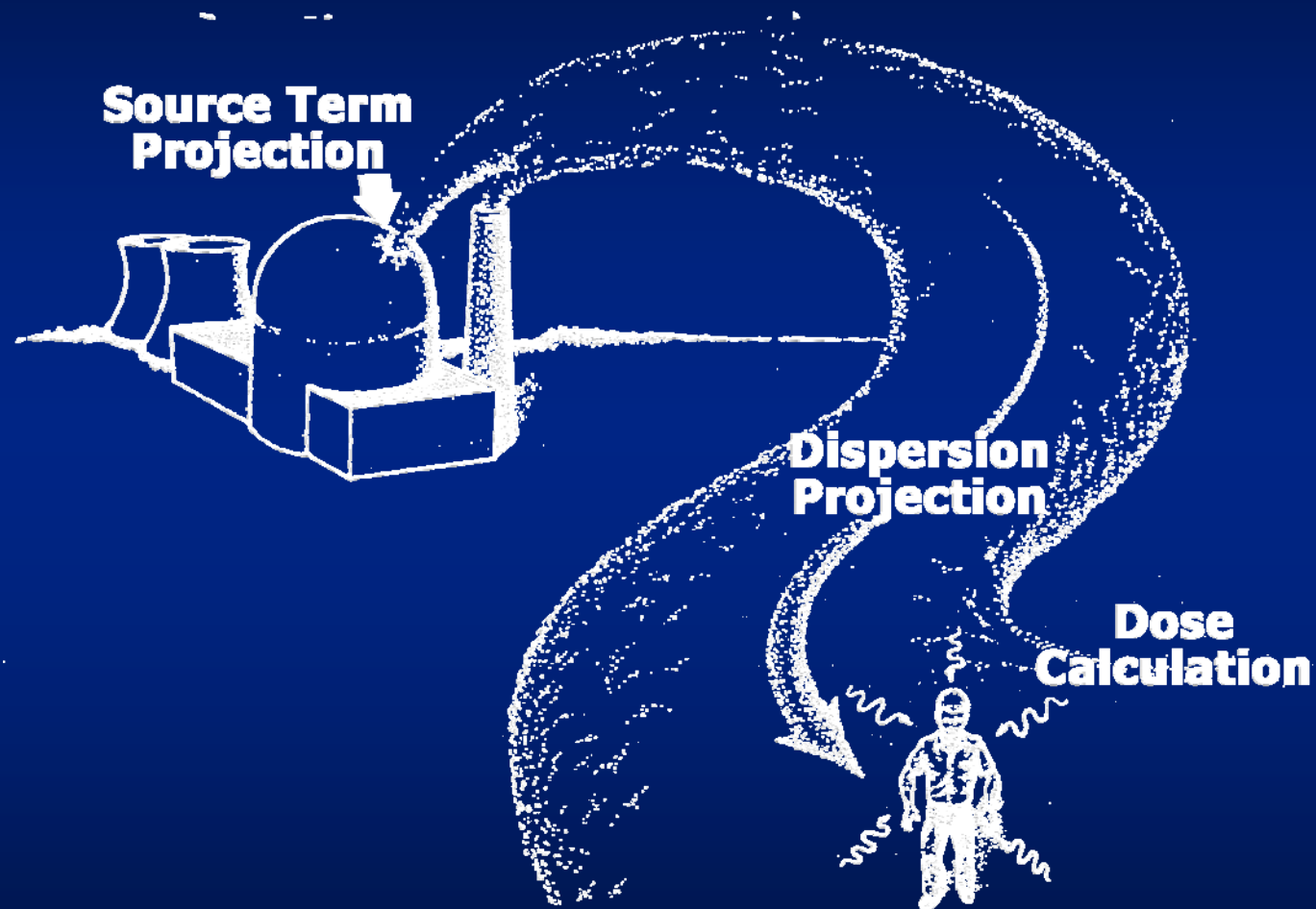
Purpose of Dose Assessment (Con't)

- That said, offsite dose assessment is conducted during emergency response to assess the radiological impact of accidental releases of radionuclides in order to provide appropriate protective actions for the workers and the public
 - For rapidly evolving events, verify adequacy of plant condition-based initial PARs
 - For slowly evolving, less severe events, provide dose input to PAR decision
 - Provide dose input for emergency classification decisions for monitored releases
 - Provide a basis for extending or upgrading a PAR
 - Establish priorities for field monitoring
 - Provide a basis for comparing consequences of different plant response options (e.g., early CNMT venting as opposed to late CNMT failure)

Purpose of Dose Assessment (Con't)

- Dose assessment results can be used to generate PARs in cases for which the offsite consequences cannot be readily assessed on the basis of plant conditions, for example, events involving spent fuel, radioactive waste storage, etc.
- Inform offsite emergency worker “turnback” criteria (e.g., pocket dosimeter vs TEDE correlations)
- Inform PAR decisions for personnel onsite (e.g., outside repair teams, security posts) or at emergency response facilities
- NRC considers the ability to perform dose assessments to be one of the four **risk-significant** planning standard functions in the reactor oversight program.

Steps in Dose Assessment





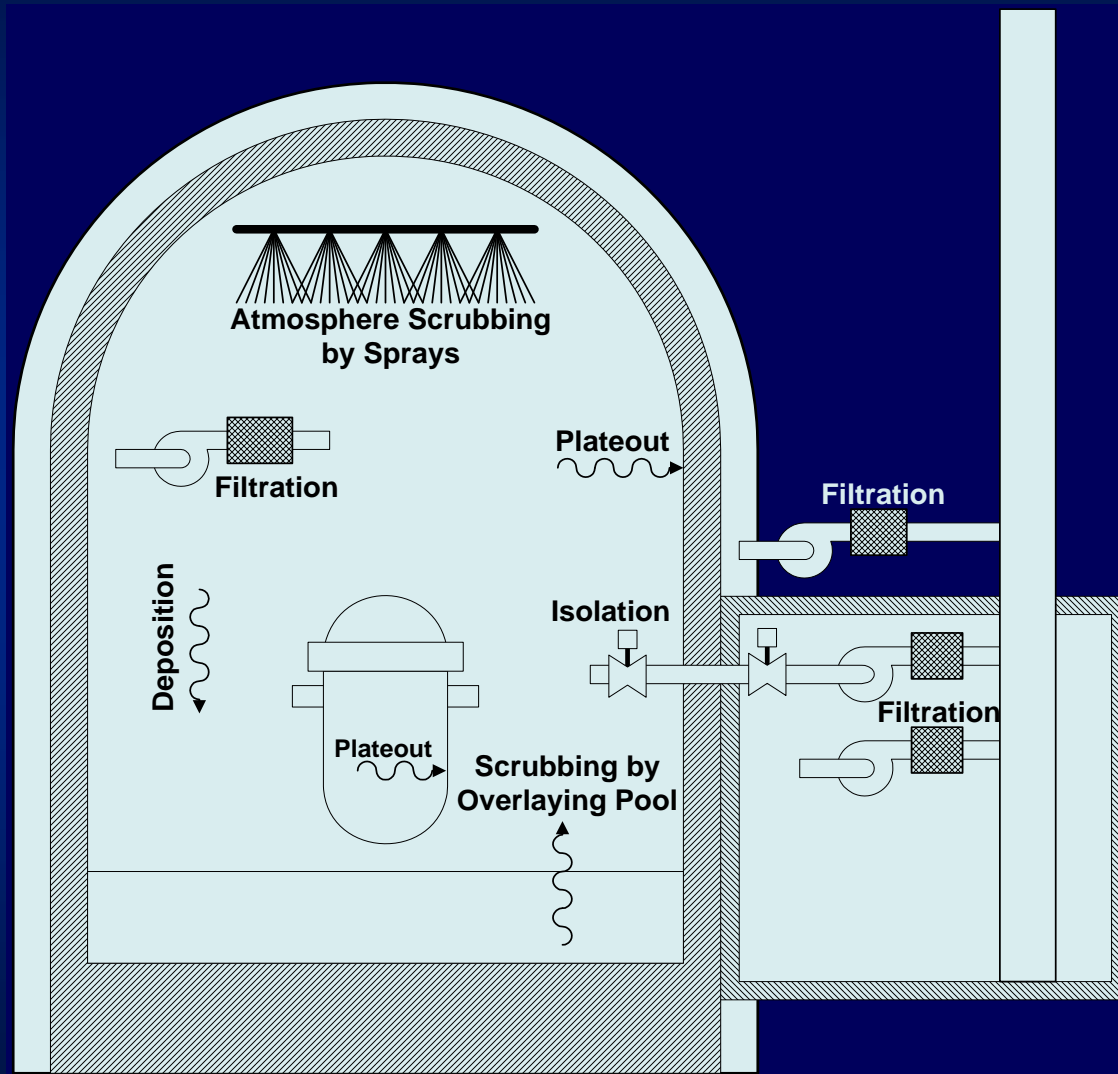
1. Source Term

Source Term

The magnitude and mix of radionuclides available for release to the environment, as well as their chemical and physical form, and the timing of their release

- The release to the environment is *not* the source term, but rather is the result of the source term being acted upon by various transport and mitigative features and phenomena:
 - Hold-up in the containment
 - Plateout and deposition within plant systems
 - Filtration systems
 - Radioactive decay
- Crude thumb rule: 0.5 curies per watt of reactor thermal power at time of shutdown

Release Mitigation Features



Source Term Inventory

- Hundreds of possible radionuclides; 30-60 of which are significant to accident dose; two major groups:
 - **Fission products**
 - Iodines contribute to thyroid dose.
 - Noble gases (Kr, Xe) contribute to whole body submersion or immersion dose from cloud shine.
 - Others (Alkali Metals, Tellurium, Barium, Noble Metals, Lanthanides, Cerium) are released as aerosols that contribute to ground deposition / ingestion doses.
 - **Activation products**
 - Due to irradiation of reactor structural components or RCS impurities.
 - Co, Fe, Mg, Zr, etc.

Source Term Inventory

(Typical)

V
O
L
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T
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Y

Nuclide Group	Inventory, Ci	Accident Release Fraction
Noble Gases (Xenon, Krypton)	6.4E+8	1.0
Halogens (Iodine, Bromine)	8.2E+8	0.6-0.8
Alkali Metals (Cesium, Rubidium)	5.6E+7	0.6-0.8
Tellurium Group (Te, Sb, Se, Ba, Sr)	9.7E+8	0.3
Noble metals (Ru, Rh, Pd, Mo, Tc, Co)	8.2E+8	0.005
Cerium (Ce, Pu, Np)	2.7E+9	0.0006
Lanthanides (La, Zr, Nd, Eu, Nb, Pm, Pr, Sm, Y, Cm, Am)	1.6E+9	0.0005

Inventory based on 3500 MWt with 60,000 MWD/MTU burnup; Release fractions from NUREG-1465 (all release phases)



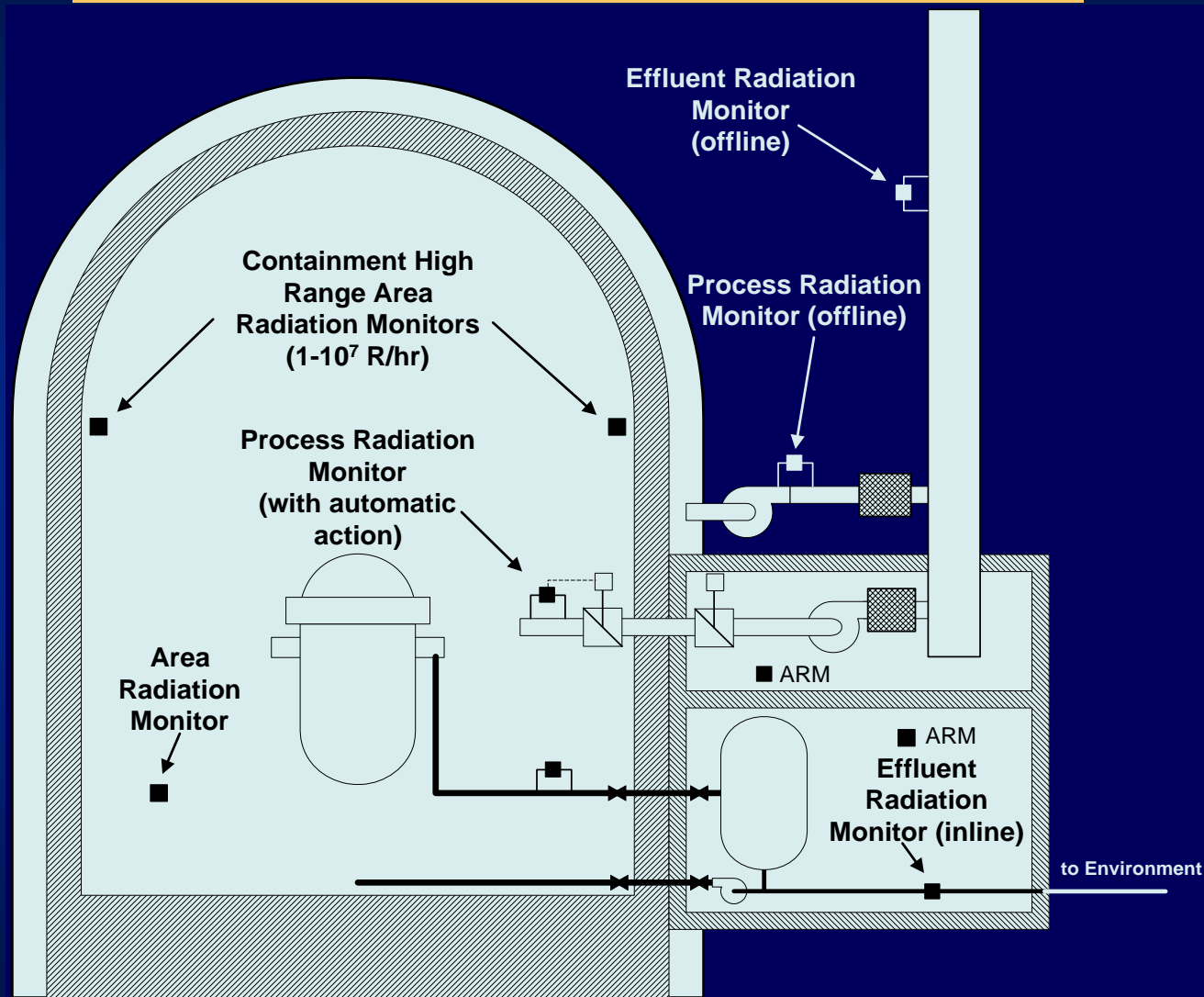
Reactor Radionuclide Inventories (Typical)

Location	Inventory, Ci	
	Noble Gases (Xe,Kr)	Iodine (I)
Reactor core total (EOL)	4.0E+8	7.5E+8
Reactor core fuel gap (EOL)	3.0E+7	1.4E+7
Spent fuel storage pool (multiple cores)	1.0E+6	5.0E+5
Reactor coolant activity	1.0E+4	6.0E+2
PWR waste gas storage tank	1.0E+5	1.0
BWR steam line	1.0E+4	25.0
Shipping cask	1.0E+4	1.0

Source Term Steps

- Estimate the inventory of radioactive material available for release
- ↓
- Estimate the fraction of the inventory released from the primary fission product barriers
- ↓
- Estimate the fraction removed on the way to the environment (e.g., filters, sprays)
- ↓
- Estimate the amount of radioactive material released to the environment

Radiation Monitors



Radiation Monitor Calibration

- A radiation detector generates a electronic signal that is proportional to the energy deposited or the rate at which the radiation enters the detector.
- During manufacture, the vendor performs a primary calibration that determines the response of the detector to particular radiation sources, chosen to be representative of the radionuclides *expected to be monitored*, often in terms of uCi/cc/cpm. This information is provided to the purchaser.
- The response of the detector to radiation is dependent on the type of radiation and the energy of its emissions; the response is seldom linear and the *uCi/cc/cpm value varies from radionuclide to radionuclide*.
- As such, the response of the detector *depends on the radionuclide mix in the release stream*.
- Newer radiation monitor systems display results in terms of uCi/cc or uCi/sec; this indication is accurate *only* if the radionuclides in the release stream are comparable to the radionuclides used in calibration and calculation of the engineering unit conversion that converts cpm to the activity units.

Release Estimation Methods #1

■ Release stream radiation monitor readings

- Continuously monitor the radioactivity release to the environment; indicate in the control room
 - Noble gas, iodine, particulate channels
 - Individual isotope data generally not available
- Provides immediate direct measurement of the release to the environment, provided:
 - The release to the environment is monitored
 - The release is ongoing.
- Sources used for calibration may not be representative of the radionuclides in a particular release stream during an accident

Release Estimation Methods #2

■ Process radiation monitor readings

- Continuously monitor the radioactivity contained in plant systems; indicate in the control room
 - Noble gas, iodine, particulate channels
 - Individual isotope data generally not available
- Provides immediate direct measurement of radioactive contamination of plant systems--but not the release to the environment
 - Indications can be used to *project* the radioactive inventory available for release to the environment
 - Release does not need be ongoing
- Sources used for calibration and development of correlations may not be representative of the radionuclides in a particular release stream during an accident

Release Estimation Methods #3

■ Area radiation monitor readings

- Continuously monitor the ambient dose rate at various plant locations; indicate in the control room and locally
 - Primarily a radiation worker occupational dose control
 - Containment high range area radiation monitors
- Does not measure the release to the environment
 - Indications can be used to *project* the radioactive inventory available for release to the environment
 - Release does not need be ongoing
- Sources used for calibration and development of correlations may not be representative of the radionuclides in a particular release stream during an accident

Release Estimation Methods #4

■ Release stream sample analysis

- Most effluent release streams have provision for manual or automatic sampling; plants required to have arrangements for analyzing high activity samples
- Sample analysis results provide direct measurement of the isotopic release to the environment, provided:
 - The release to the environment can be sampled
 - The release is ongoing
- Isotopic results possible

Release Estimation Methods #5

■ **Backcalculation from Field Measurements**

- All licensees have capability of dispatching field survey teams into the environment to obtain dose rate and airborne activity measurements
- Given available field measurements, one can backcalculate an estimate of the release rate from the plant; provided:
 - The release is ongoing
 - The location of the field team with relation to the plume centerline is known
 - The atmospheric dispersion to the field team location is known
- Although the field measurements may be direct, the backcalculated release rate is highly uncertain

Release Estimation Methods #6

■ Safety Analysis Report

- Applicants for licensees perform a series of design basis accident analyses as part of licensing.
 - Highly stylized analyses; may not be representative of an actual event
 - Should not be used directly; may be overconservative
 - Data from these analyses can *inform* source term decisions

■ Severe accident analyses

- All licensees have performed probabilistic risk analyses (PRA) to assess core damage frequency and large early release fractions (level I PRA). Some licensees have also performed analyses of source term magnitude (level II PRA) and dose consequences (level III PRA)
 - Accidents addressed in PRA may not be representative of accident at hand
 - PRA analyses are best estimate
 - Data from these analyses can *inform* source term decisions

Release Estimation Methods #7

■ **Assessment using accident assessment tools**

- These tools provide a flexible capability to model diverse accident conditions
 - Considerable modeling time is required
 - Extensive data needed to support calculation; much of which may not be readily available during the early phase of an accident
 - Not deemed feasible

■ **Pre-calculated assumptions from severe accident insights**

- RASCAL and the Response Technical Manual (RTM) contain a method based on insights of severe accident analyses
 - There is a small set of accident conditions that dominate any accident sequence
 - There are parameters that can characterize these dominant sequences
 - These parameters can be recognized or characterized during an accident

Release Duration

- Protective action guides are expressed as projected avoided dose
- A good estimate of the release duration is critical to proper protective action decisions
- Release durations can be difficult to estimate
- Requires the active participation of the technical support center (TSC) staff as well as the dose assessors.
- Default release durations (e.g., “use four hours”) should be used only as the last resort
 - Although we want to issue an adequate PAR, we also need to avoid overconservative PARs
 - Overconservative PARs can place the public at unnecessary risk—a non-conservative situation
 - Short release durations (e.g., 1 hour with dose assessments repeated every hour) could result in no PAR when one would be indicated when a more appropriate release duration was used