GENII Version 2
General Purpose Environmental Radiation Software

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GENII Overview

► A set of computer programs for estimation of radionuclide concentrations in the environment and dose/risk to humans from:

  ■ Acute or chronic exposures from

  ■ Radiological releases to the atmosphere, surface water, or

  ■ Initial contamination conditions

► One of a set of quality-assured and configuration-controlled safety analysis codes managed and maintained for DOE's Safety Software Central Registry

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GENII Development History

▶ 1988 - Version 1. Released

  ■ ICRP-26/30/48 dosimetry

▶ 1990 - Version 1.485 stabilized

▶ 1992 - GENII-S stochastic version

▶ 2004 - GENII Version 2

  ■ ICRP-72 age-dependent dosimetry

  ■ EPA HEAST slope factors

  ■ Federal Guidance Report 13 risk factors

▶ 2006/7 – V&V

▶ 2008 – New features, DOE toolbox status

Available Models in GENII

▶ Atmospheric transport

▶ Surface water transport

▶ Waste/soil redistribution

▶ Terrestrial uptake

▶ Human Exposure

▶ Dose/Risk

▶ Uncertainty/Sensitivity

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Types of Scenarios

▶ Far-Field scenarios

- Atmospheric transport (acute or chronic)
- Surface water transport (acute or chronic)
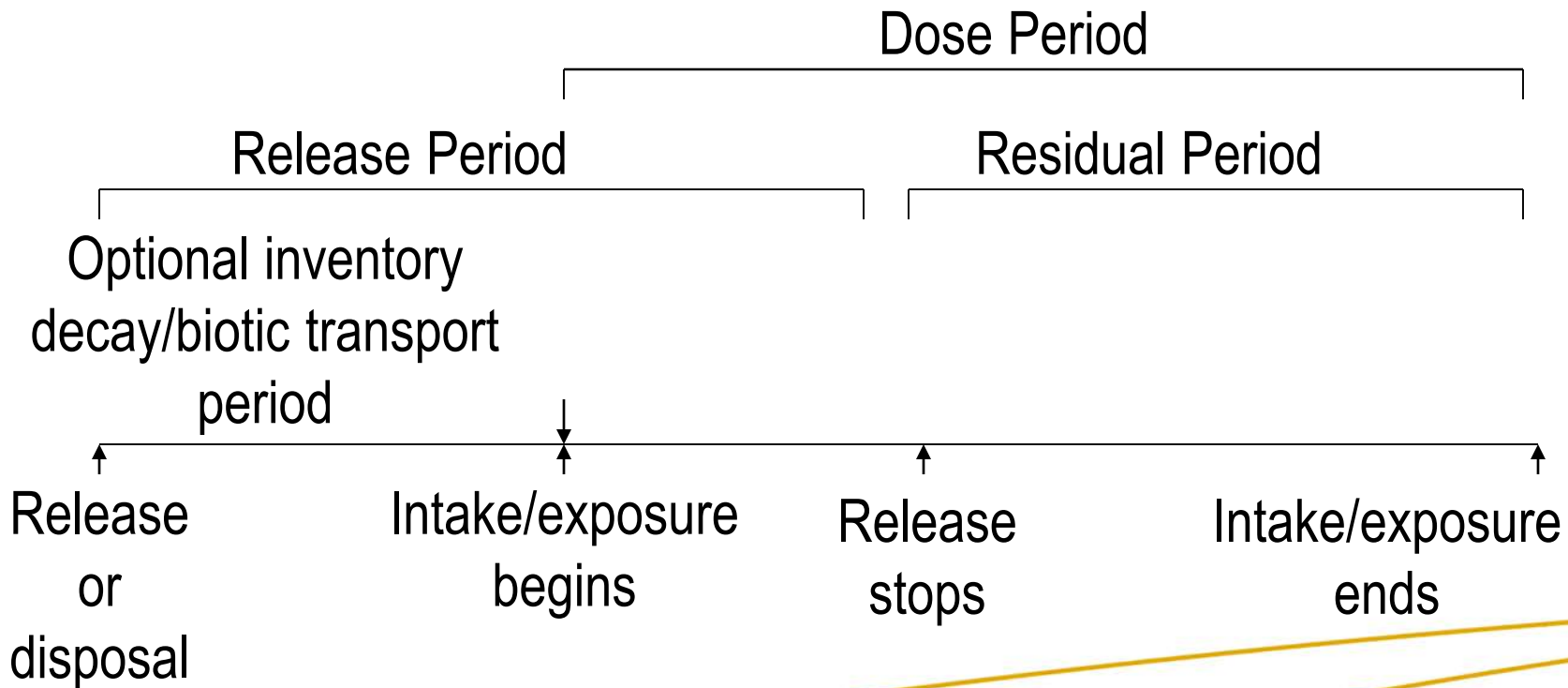
▶ Near-Field scenarios

- Spills
- Buried waste
- Groundwater use - groundwater transport modeling is NOT an explicit part of GENII

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GENII V.2 Time Line

Radionuclides of Interest

▶ All those with half-lives greater than 10 minutes, except radon progeny

▶ And all decay progeny

■ Some are included "implicitly" with the parent radionuclide

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GENII V.2 Atmospheric Transport Options

▶ Chronic
  ■ Gaussian Plume
  ■ Lagrangian Puff

▶ Acute
  ■ Gaussian Plume
  ■ Lagrangian Puff

▶ Estimation of 95th percentile dispersion conditions

▶ Input of pre-calculated dispersion parameters

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GENII V.2 Chronic Plume Model

▶ Straight-line, sector-averaged Gaussian plume model
  - Uses hourly observations or joint-frequency data
  - Multiple, independent sources
    - Ground level or elevated releases
    - Point or area sources
    - Finite flow correction
  - Sectors by 16 compass points or 10 degrees
  - Radial output grid

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GENII V.2 Chronic Puff Model

▶ Lagrangian puff releases based on a single meteorological station

- ■ Hourly time step (variable number of puffs/hour) using hourly observations or quasi-hourly built from joint-frequency data
- ■ Cartesian (rectangular) grid
- ■ Multiple sources
  - Point or area sources
  - Ground level or elevated releases

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GENII V.2 Acute Plume Model

▶ Straight-line centerline Gaussian for individuals

- For short (~2 hour releases)
- Single source
- Ground-level or elevated releases

▶ Radial grid

- Radial sectors by 16 compass points or 10 degrees

▶ A specialized module for 95th percentile conditions is now available (currently NOT the NRC RG 1.145 approach for sector and site, but could be revised)

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GENII V.2 Acute Puff Model

▶ Lagrangian puff based on a single meteorological station
  - Hourly time step using hourly observations or quasi-hourly inputs derived from joint-frequency data
  - Single source
  - Cartesian (rectangular) grid
  - Ground-level or elevated releases

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Parameterizations for Diffusion Coefficients

▶ Briggs open country

▶ Briggs urban conditions

▶ Pasquill-Gifford (ISC-3)

▶ Pasquill-Gifford (NRC: PAVAN, MESORAD, XOQDOQ)

▶ Turbulence Statistics (NRC: RASCAL)

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Parameterizations Available in All Dispersion Models

▶ Building wake/low-speed meander correction to diffusion

▶ Buoyancy-induced diffusion

▶ Plume rise/downwash corrections

- Momentum
- Buoyancy

▶ Diabatic wind profile

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GENII V.2 Atmospheric Deposition

▶ All models have plume depletion/mass balance
▶ Dry deposition
  ■ "Resistance model"
  ■ Includes gravitational settling of larger particles
▶ Wet deposition
  ■ Washout dependent on precipitation rate
  ■ Rain and snow considered

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Sources of Meteorological Data for Atmospheric Models

▶ Hourly data

- CD-144 format (National Climatic Data Center - NCDC)
- SAMSON format (NCDC)
- Precipitation in TD-3240 format (NCDC)

▶ Joint frequency data

- STAR (ISC-3) [provided for many US sites]
- GENII V.1.485

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GENII V.2 Air Submersion Dose Rates

▶ Infinite plume
- Based on Federal Guidance Report FGR-13 models

▶ Finite plume
- Close to release - array of line sources
- Intermediate distances - stacked series of infinite planes
- Long distances - defaults to infinite plume

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GENII V.2 Surface Water Transport Models

▶ Simple models derived from NRC's LADTAP
  - Rivers: analog to atmospheric Gaussian plume
    - Constant depth, width, velocity
    - Straight channel
    - Continuous discharge
  - River - dilution volume (well mixed)
  - Acute river (time integral)
  - Lake
    - quasi-steady state wind-driven currents

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GENII V.2 Near-Field Soil Model
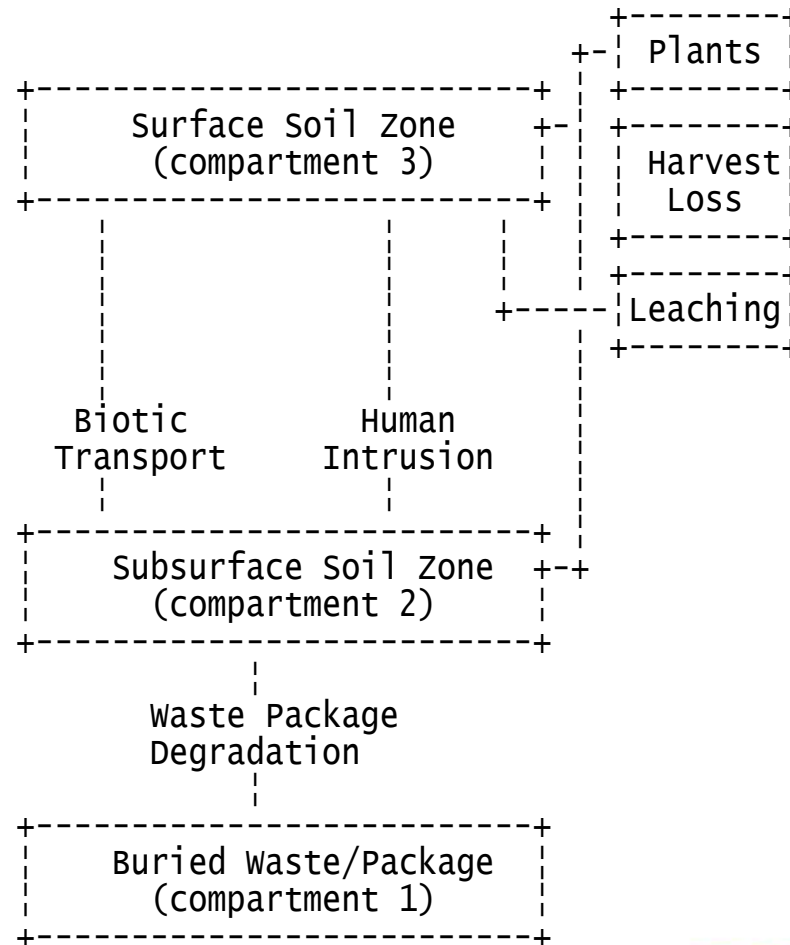
GENII V.2 Near-Field Biotic Transport

▶ Plant roots - root fraction applied to concentration ratio (CR)

▶ Burrowing animals - volume of soil moved versus depth

▶ Applied to arid, humid, or agricultural conditions

GENII V.2 Near-Field Human Intrusion

▶ Buried waste and/or deep soil may be manually redistributed at the start of exposure to the surface soil.

▶ Process is a step function manual redistribution factor (m^3/m^2).

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GENII V.2 Exposure Pathways

▶ External

- Transported air
- Soil
- Swimming
- Shoreline

▶ Inhalation

- Transported air
- Resuspended soil
- Volatilized indoor air pollutants from water

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GENII V.2 Exposure Pathways, Continued

► Ingestion

- Leafy vegetables
- Other vegetables
- Fruit
- Grain
- Meat
- Milk
- Poultry
- Eggs

- Fish
- Crustaceans
- Molluscs
- Water plants
- Drinking water
- Shower water
- Swimming water
- Soil

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GENII V.2 Crop Contamination

▶ Plant = Soil * CR + intercepted deposition

- Concentration ratios (CR) are traceable to current U.S. and international literature (PNNL-21950).
- Interception function of crop biomass
  - Wet interception
  - Dry interception

GENII V.2 Animal Product Contamination

▶ Animal Product = TF Σ (Crop * Ingestion rate)

- Transfer factors (TF) are traceable to current U.S. and international literature (PNNL-21950).

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GENII V.2 Aquatic Biota Contamination

▶ Fish = Water concentration * BF

- ■ Bioaccumulation factors (BF) are traceable to current U.S. and international literature (PNNL-21950).

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GENII V.2 Tritium Specific Activity Model

▶ Environmental media assumed to have same specific activity (Bq/kg water) as contaminating medium (water or air)

▶ Fractional content of both water and non-water portions of the food product is used

▶ In acute cases, rapid equilibration/de-equilibration is assumed (~8 hours)

▶ Based on observations at Chalk River

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GENII V.2 Carbon-14 Specific Activity Model

▶ For atmospheric sources, model is parallel to that for tritium

▶ For water sources, equilibration is assumed with soil carbon atom ratios

▶ For acute cases, uptake via photosynthesis is slow, long de-equilibration

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GENII V.2 Human Exposure

▶ Up to 6 age groups allowed, following ICRP-56,67,69

3 months	0-1 year
1 year	1-2 year
5 year	2-7 year
10 year	8-12 year
15 year	13-17 year
20 + year	17-110 year

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GENII V.2 Acute-Deposition Food Pathways

▶ GENII V.2 presents results for 4 seasons (winter/spring/summer/autumn)

▶ This is a surrogate for a complex set of underlying assumptions about plant growth, weathering, uptake, and time-to-harvest

▶ Selection of season depends on meteorological input (this is related to the uncertainty capability)

▶ *Season definitions are a user input, because seasons below the equator are reversed!*

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External Exposure - Doses

▶ Dose rate conversion factors from Federal Guidance Report FGR-12, provided by Keith Eckerman, ORNL

- Air Submersion
- Water Immersion
- Soil Plane
- Soil Volume

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Internal Exposure - Doses

▶ Effective dose equivalent: ICRP-30
  ■ Adult only

▶ Effective dose: ICRP-72
  ■ 6 age groups
  ■ 24 organs/tissues
  ■ Inhalation classes Fast (F), Medium (M), Slow (S)

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Risk Calculations – Dose-to-Risk Conversions

▶ ICRP provides estimates of cancer incidence and mortality in relation to effective dose

- ICRP-30 effective dose
- ICRP-72 organ dose

▶ The BEIR VII report supports these values with minor revision

- Risk = Dose (Sv) * Conversion (risk/Sv)

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Risk Calculations – FGR-13

▶ US Federal Guidance Report 13 provides coefficients for 15 cancer sites

- Inhalation (risk/Bq)
  - Inhalation classes F, M, S
- Ingestion (risk/Bq)
  - Accounts for different consumption patterns with age
    - ◆ Drinking water
    - ◆ Food crops

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GENII V.2 Uncertainty Analysis

▶ Parameter uncertainty and sensitivity may be addressed using the SUM^3 processor in FRAMES.

▶ All non-control parameters are allowed to be varied, using description files to define 'available' parameters

▶ Acute atmospheric releases are in important subset. For these, SUM^3 is used to vary start times in the plume or puff models, allowing construction of the location or site cumulative dose/risk distribution function.

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Questions?

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