Deposition Velocity Effects on Dose Consequence at UPF

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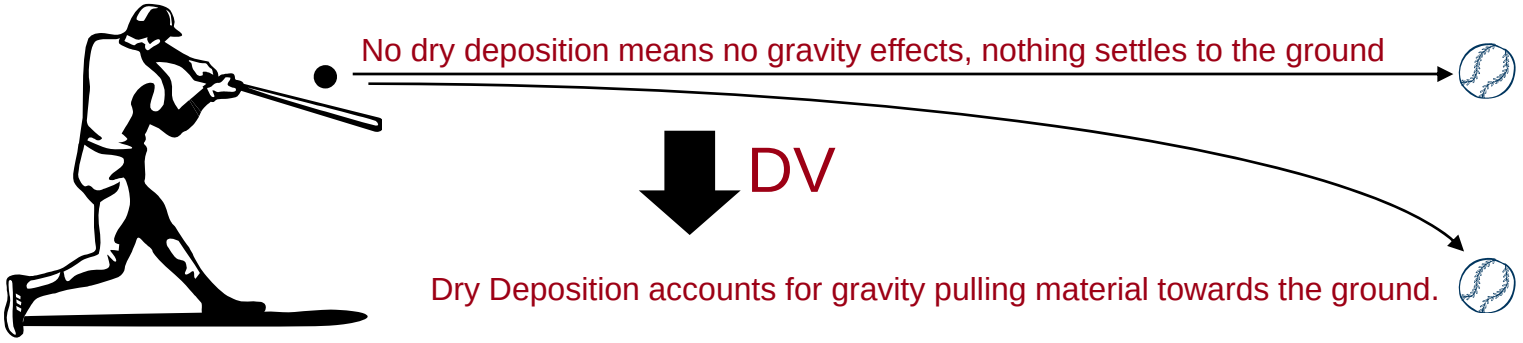
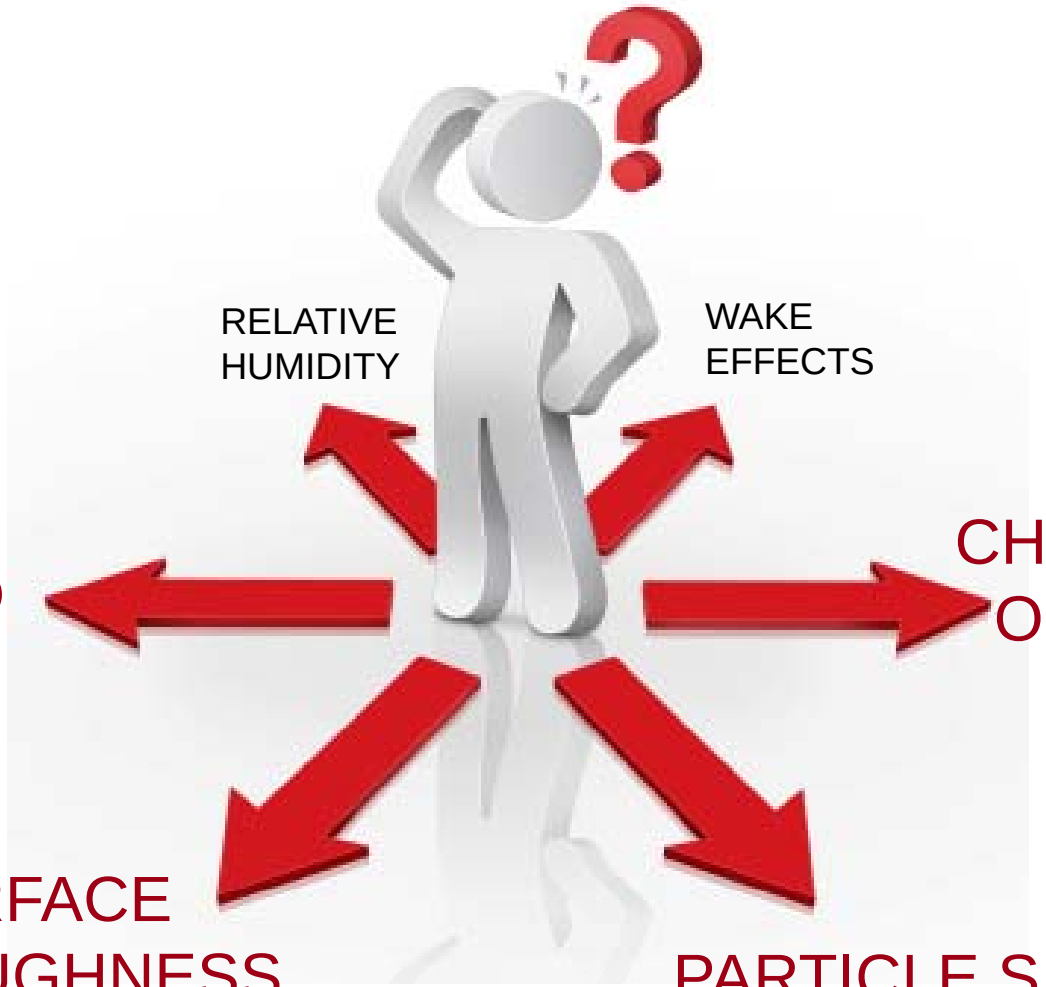
What is Deposition

- Deposition
  - Gravitational deposition,
    - velocity is the settling velocity due to the gravity and drag.
  - Impaction
    - whether or not a certain particle will impact with a certain obstacle - predicted with the Stokes number
  - Brownian Motion
    - obeys both Fick's first and second laws



Factors Affecting Deposition Velocity



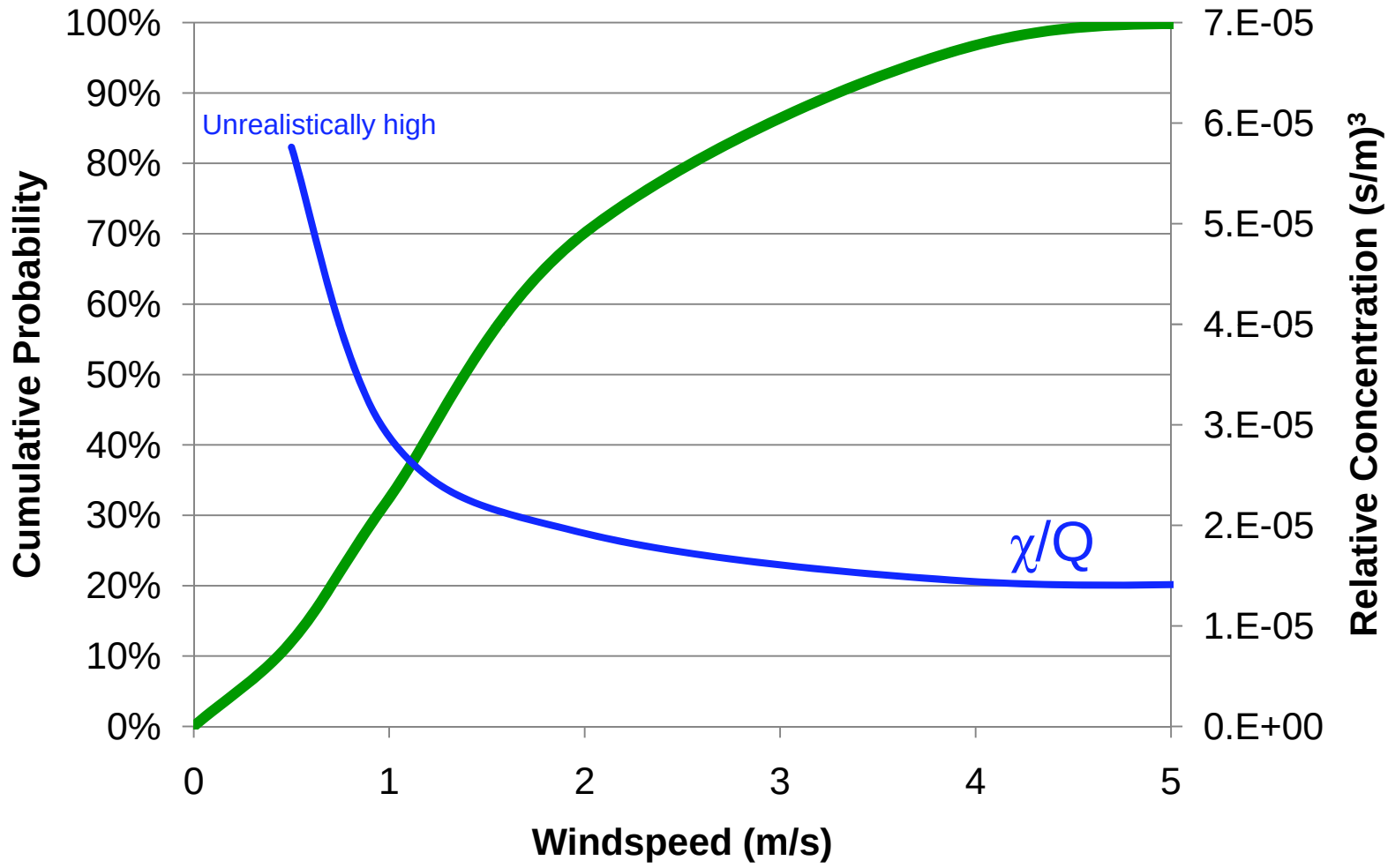
WINDSPEED

CHEMICAL FORM OF PARTICLES
(Solubility Classes)

SURFACE ROUGHNESS
(Terrain Effects)

PARTICLE SIZE

Effects of Windspeed

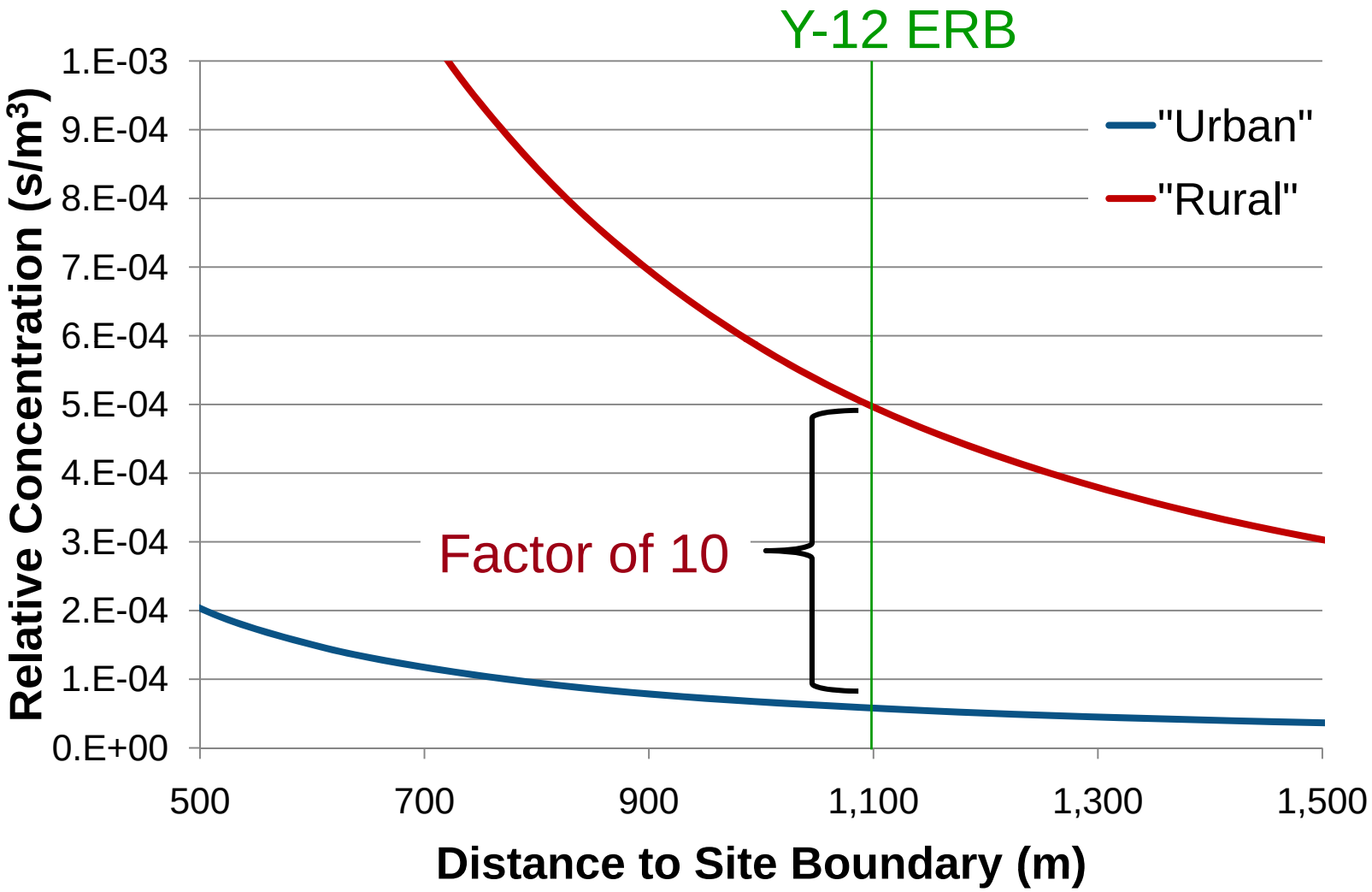


Surface Roughness

Briggs-Urban Surface Roughness

Pasquil-Gifford (Rural) Surface Roughness

General Effects of Surface Roughness



Particle Size Distributions

Releases From Uranium Metal or Oxides[1]

Activity Mean Aerodynamic Diameter	Fraction of Oxide Particulate	Fraction of Total Mass
d > 50 μm	64.4%	5E-2
20 μm < d < 50 μm	22.3%	2E-2
10 μm < d < 20 μm	12.1%	1E-2
5 μm < d < 10 μm	1.0%	8E-4
5 μm < d	0.2%	2E-4

} ARF×RF = 1E-3

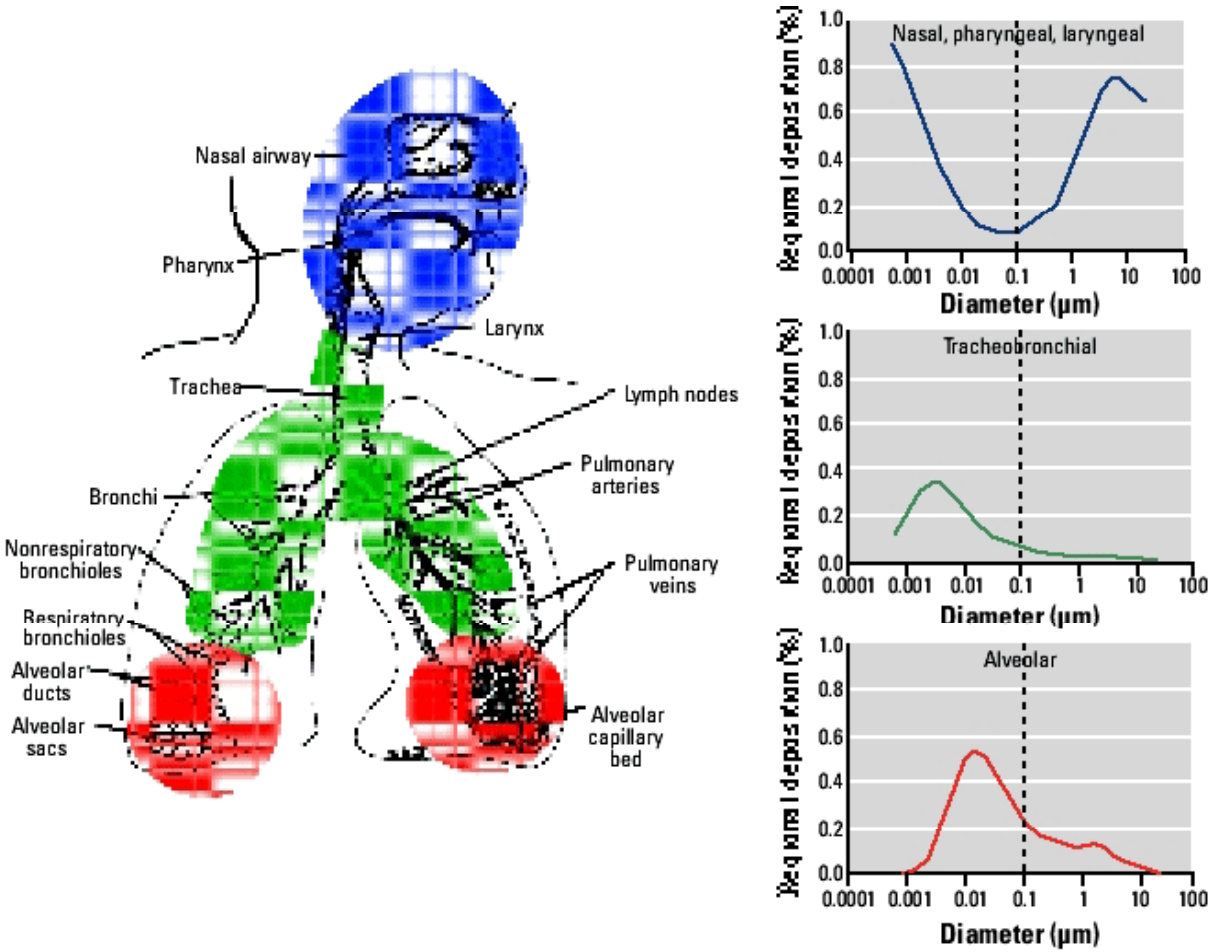
Respirable Fraction is 1.2% of total particulate

VS.

Respirable Fraction (AMMD of 0.6 μm, $\sigma_g = 3.1$) for Uranium Solutions is 99% of total particulate[2]

1. Hoover, M.D. *et al*, "Characterisation of Enriched Uranium Dioxide Particles From a Uranium Handling Facility," *Radiation Protection Dosimetry,* Vol. 79, Nos 1–4, pp. 57–62 (1998)
2. Halverson, M.A., M.Y. Ballinger and G.W. Dennis. March 1987. *Combustion Aerosols Formed During Burning of Radioactively Contaminated Materials - Experimental Results*, NUREG/CR-4736 (PNL-5999), Pacific Northwest Laboratory, Richland, WA.

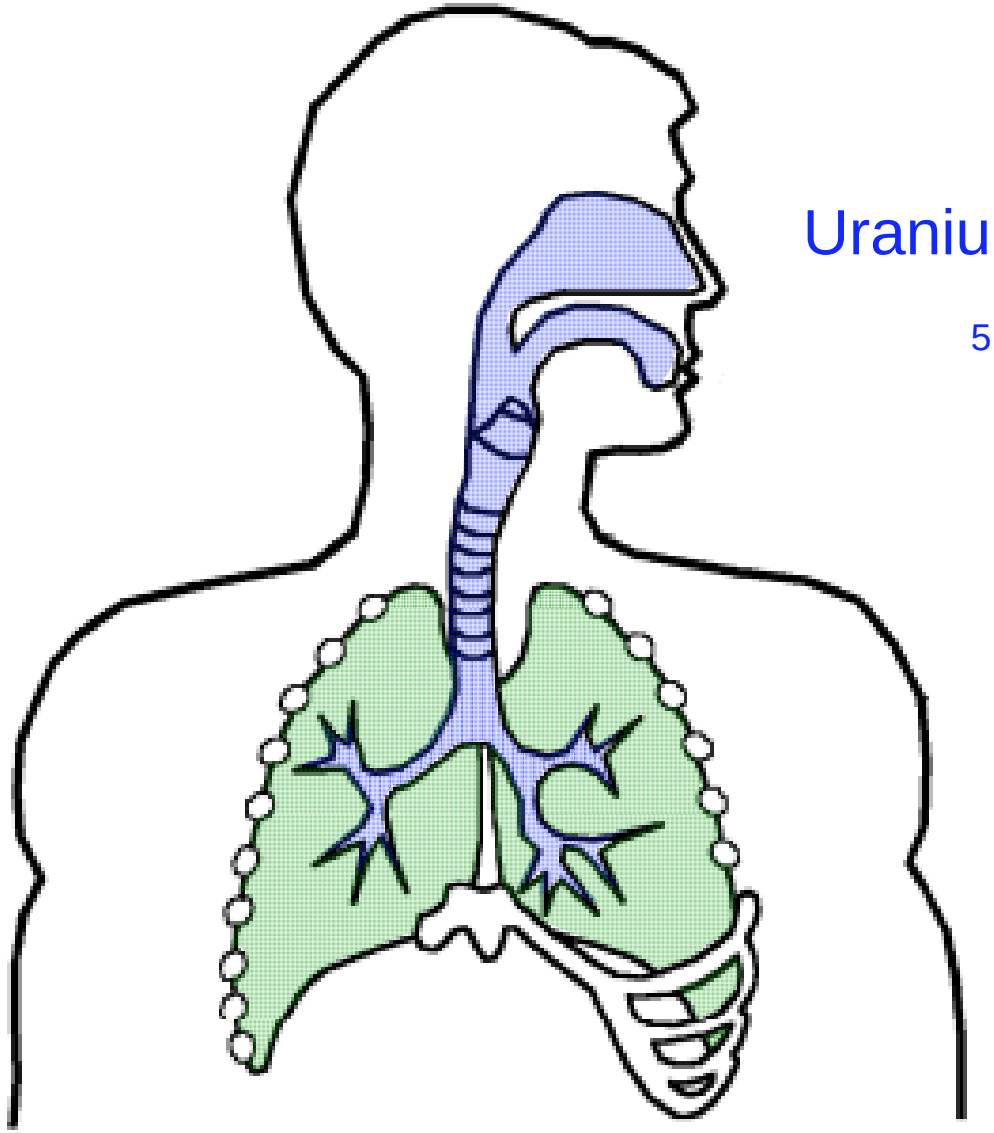
Fractional Deposition of Inhaled Particles



Predicted fractional deposition of inhaled particles in the nasopharyngeal, trancheobronchial, and alveolar region of the human respiratory tract during nose breathing. Based on data from ICRP 66.

1. Oberdörster, G., E. Oberdörster, and J. Oberdörster, "Nanotoxicology: An Emerging Discipline Evolving from Studies of Ultrafine Particles," *Environmental Health Perspectives* ,Volume 113, Number 7, July 2005

Predicted Lung Deposition of Uranium Particles



Uranium Metal & Oxides

1.2% Respirable

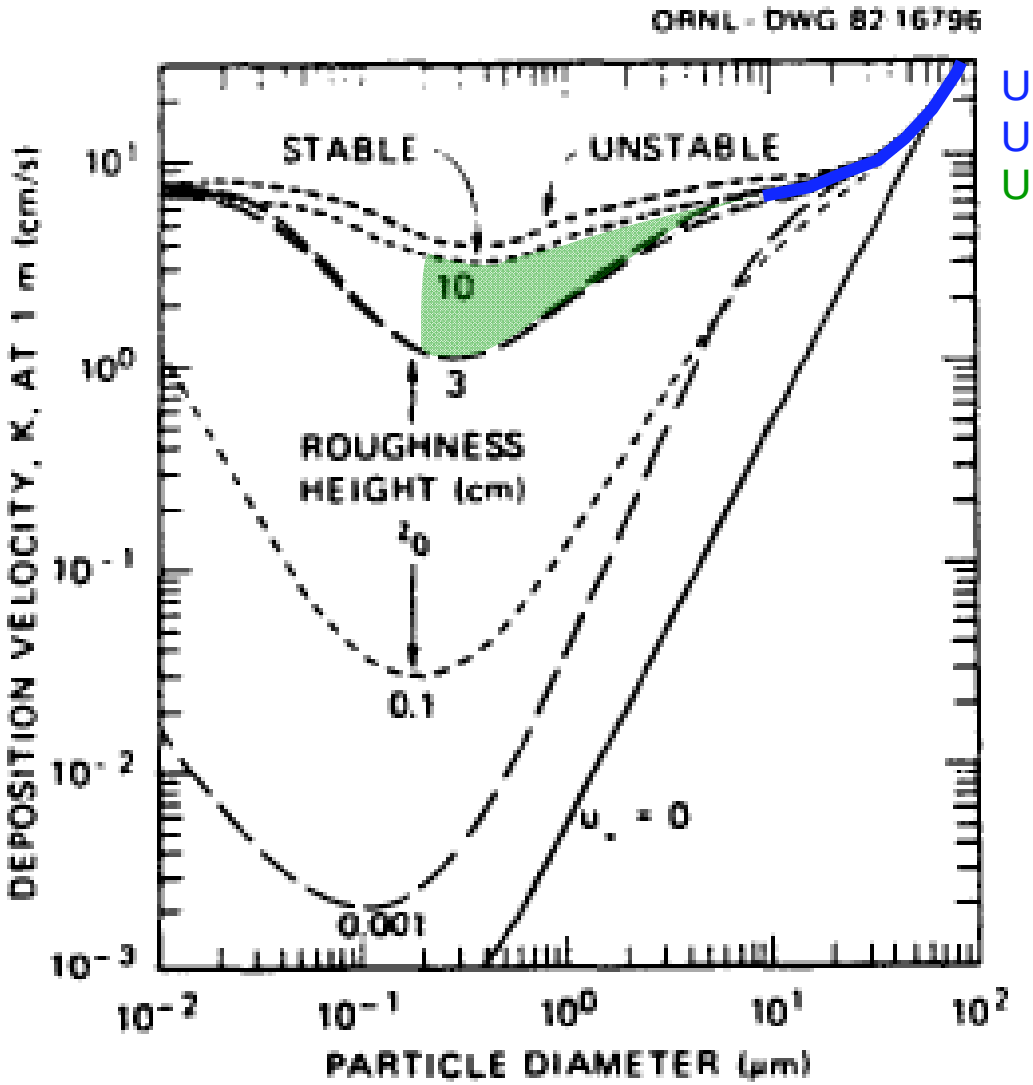
5 μm AMMD - $\sigma_g = 2.1$

Uranium Solutions

99% Respirable

0.6 μm AMMD – $\sigma_g = 3.1$

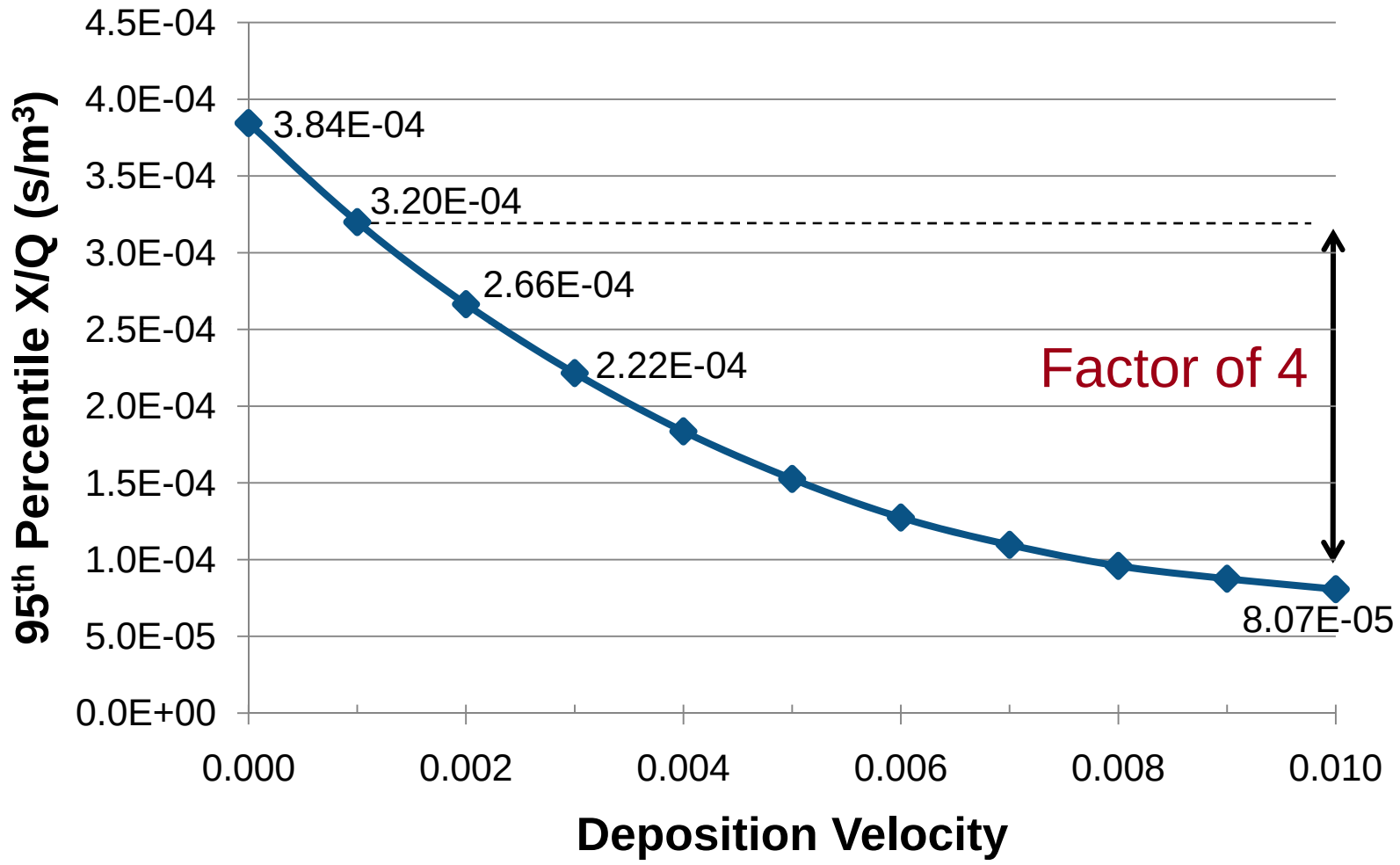
Deposition Velocities Based on Particle Sizes



Uranium Metal
Uranium Oxides
Uranium Solutions

Effect of particle size and surface roughness on predicted deposition velocities (Sehemel 1976)

Effects of DV on the 95th %ile χ/Q at Y-12 ERB

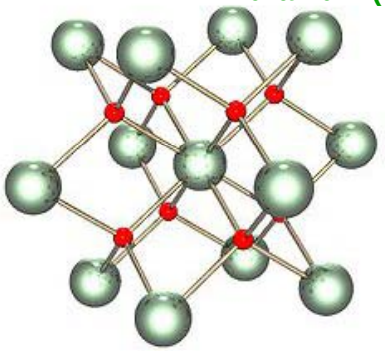


Note: These X/Q's represent a cumulative probability distribution for 3 years of Y-12 meteorological data with distances from UPF to the Y-12 site boundary.

Chemical Form of Particles

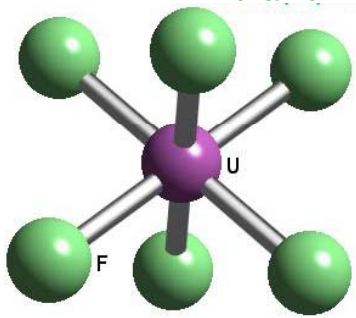
- The Chemical Form of the Particulate impacts the adsorption rate class
- This results in different dose conversion factors not only based on size of particulate, but adsorption rate class
- The difference in dose between moderate and slow adsorption rate class is between 2.15 and 2.75 depending on particle size

uranium (VI) oxide



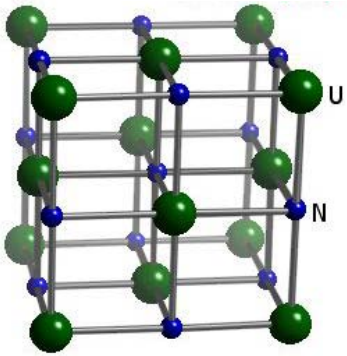
Highly insoluble,
Slow adsorption rate class

uranium (VI) fluoride



Soluble
Fast adsorption rate class

uranium (III) nitride

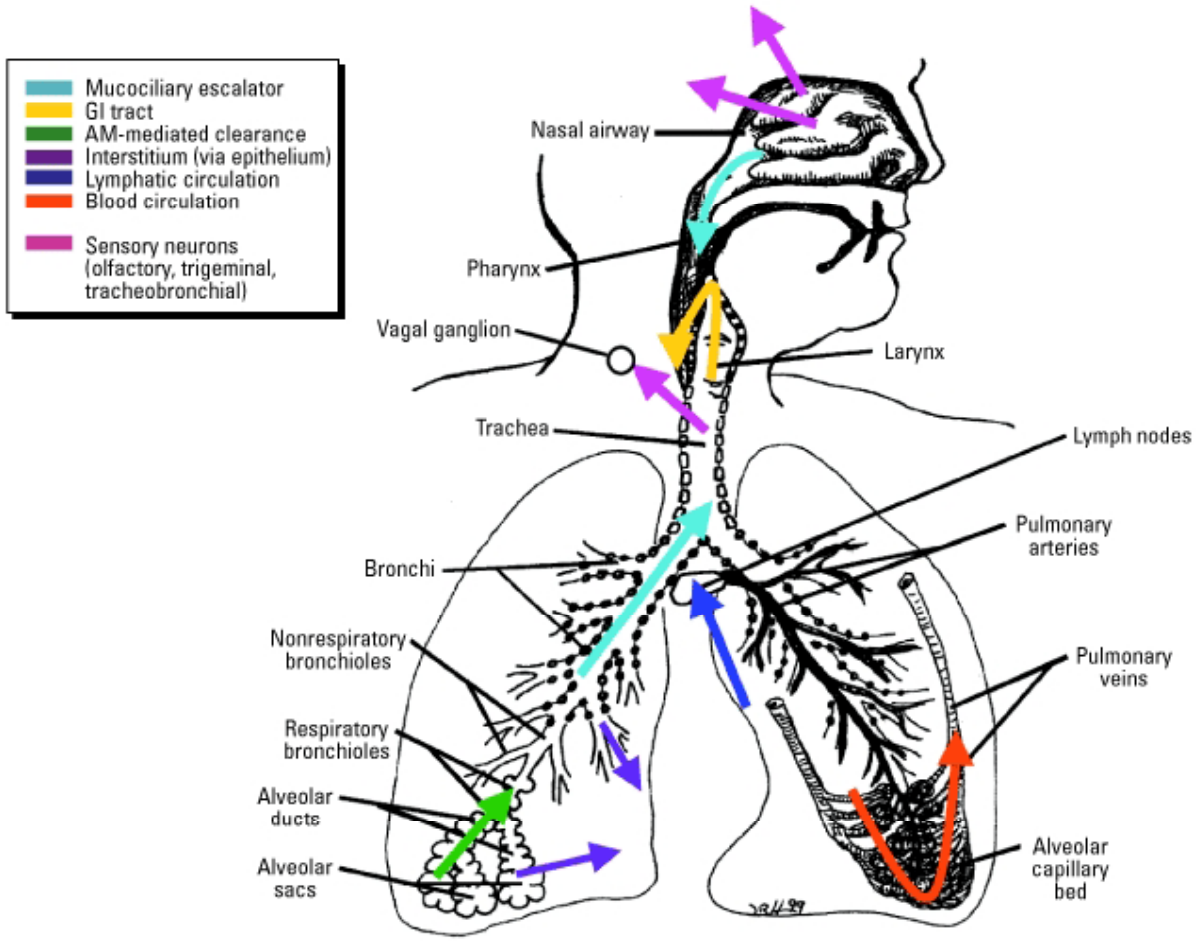


Slightly soluble,
Moderate adsorption rate class

Variations by Chemical Form of Uranium

	Density (g/cm^3)	5 μm AMMD Stokes Diameter (μm)	0.6 μm AMMD Stokes Diameter (μm)	Absorption Rate Class (ICRP 66)
α-U	19.05	1.15	0.137	Slow
UO_2	10.97	1.51	0.181	Slow
α-U_4O_9	11.18	1.50	0.179	Moderate
β-U_4O_9	11.27	1.49	0.179	Moderate
α-U_3O_7	11.05	1.50	0.180	Moderate
β-U_3O_7	11.36	1.48	0.178	Moderate
U_3O_8	8.39	1.73	0.207	Slow
β-UO_3	8.34	1.73	0.208	Moderate
γ-UO_3	7.07	1.88	0.226	Moderate

Solubility Effects in the Respiratory Tract



Pathways of particle clearance (disposition) in and out of the respiratory tract. There are significant differences between nanosized particles and larger particles for some of these pathways.

1. Oberdörster, G., E. Oberdörster, and J. Oberdörster, "Nanotoxicology: An Emerging Discipline Evolving from Studies of Ultrafine Particles," *Environmental Health Perspectives* ,Volume 113, Number 7, July 2005

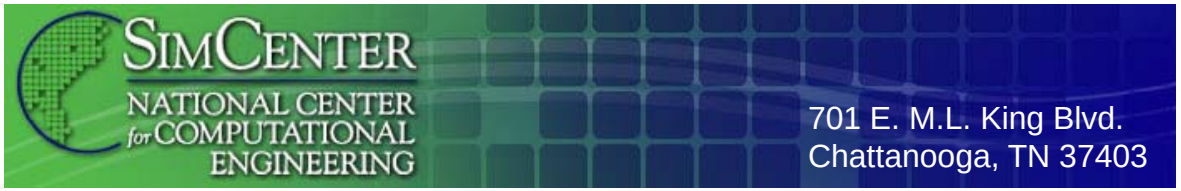
CFD-Driven Modeling of Deposition Efficiency

- To validate how the consequences are impacted by changes in individual parameters, a Computational Fluid Dynamics driven model, based on the Navier-Stokes Equations, was developed.

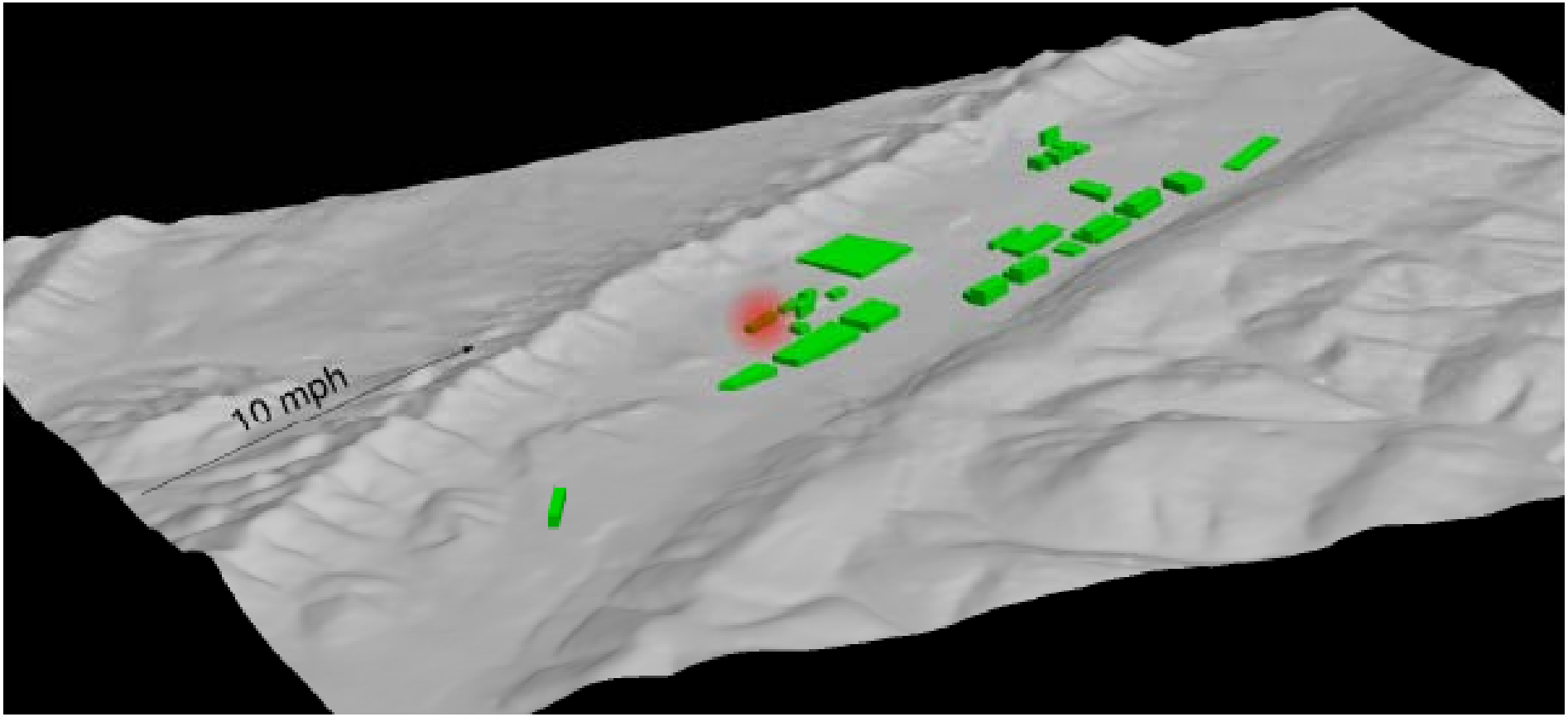
- This code provides a visualization output that helps communicate the impact of making various changes in the DOE “Toolbox” Codes (e.g., MACCS2, ALOHA, EPICODE)

- This tool looks at realistic deposition efficiency for a release of uranium oxide particles during a fire within the Y-12 site.

Model Developed at:

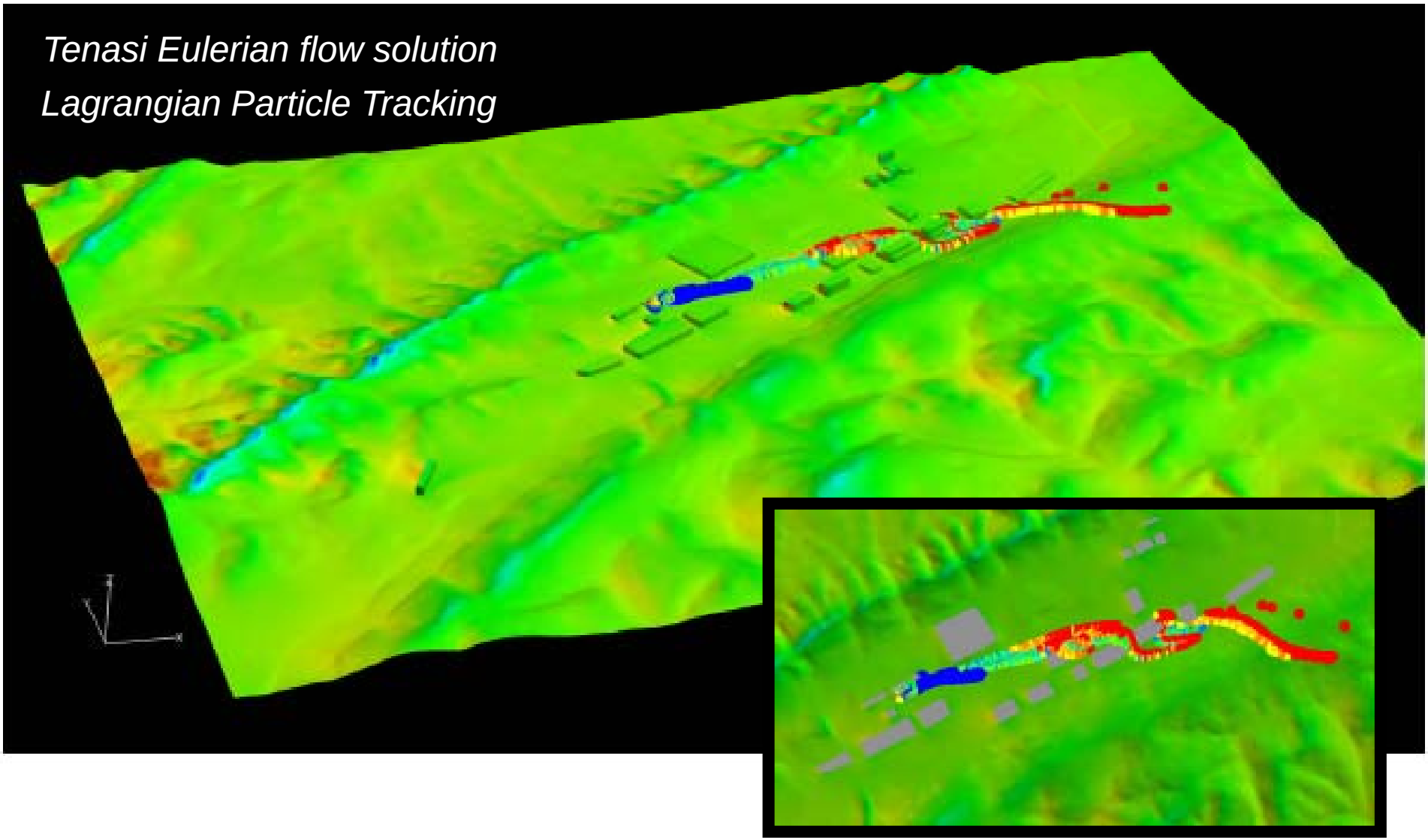


3-D model of Y-12 National Security Complex

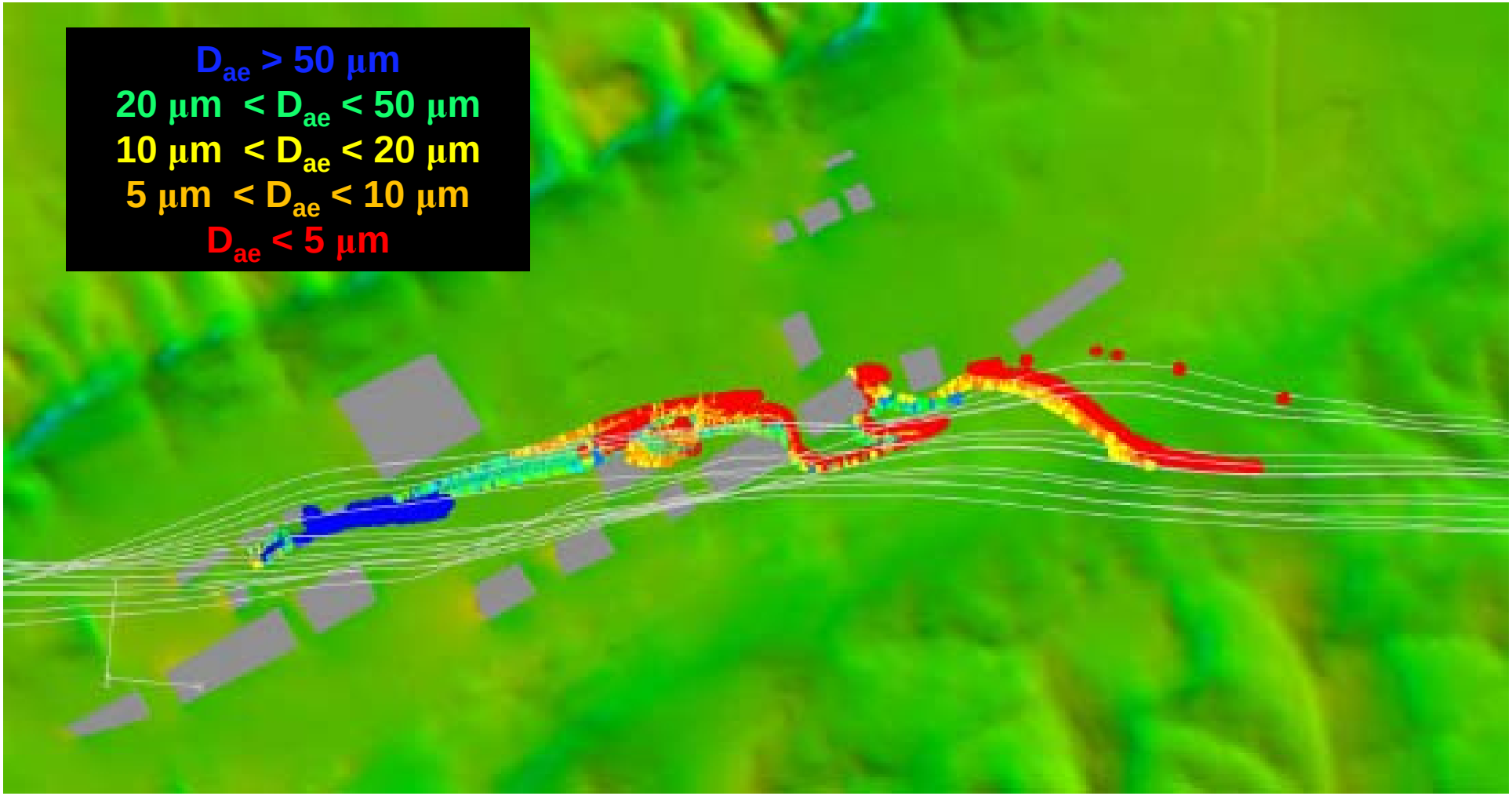


Notes: The computational mesh utilized for the simulation consisted of 3.5 million nodes, 8 million tetrahedrals, and 4 million prisms.

CFD-Driven Model of Uranium Oxide Particulate

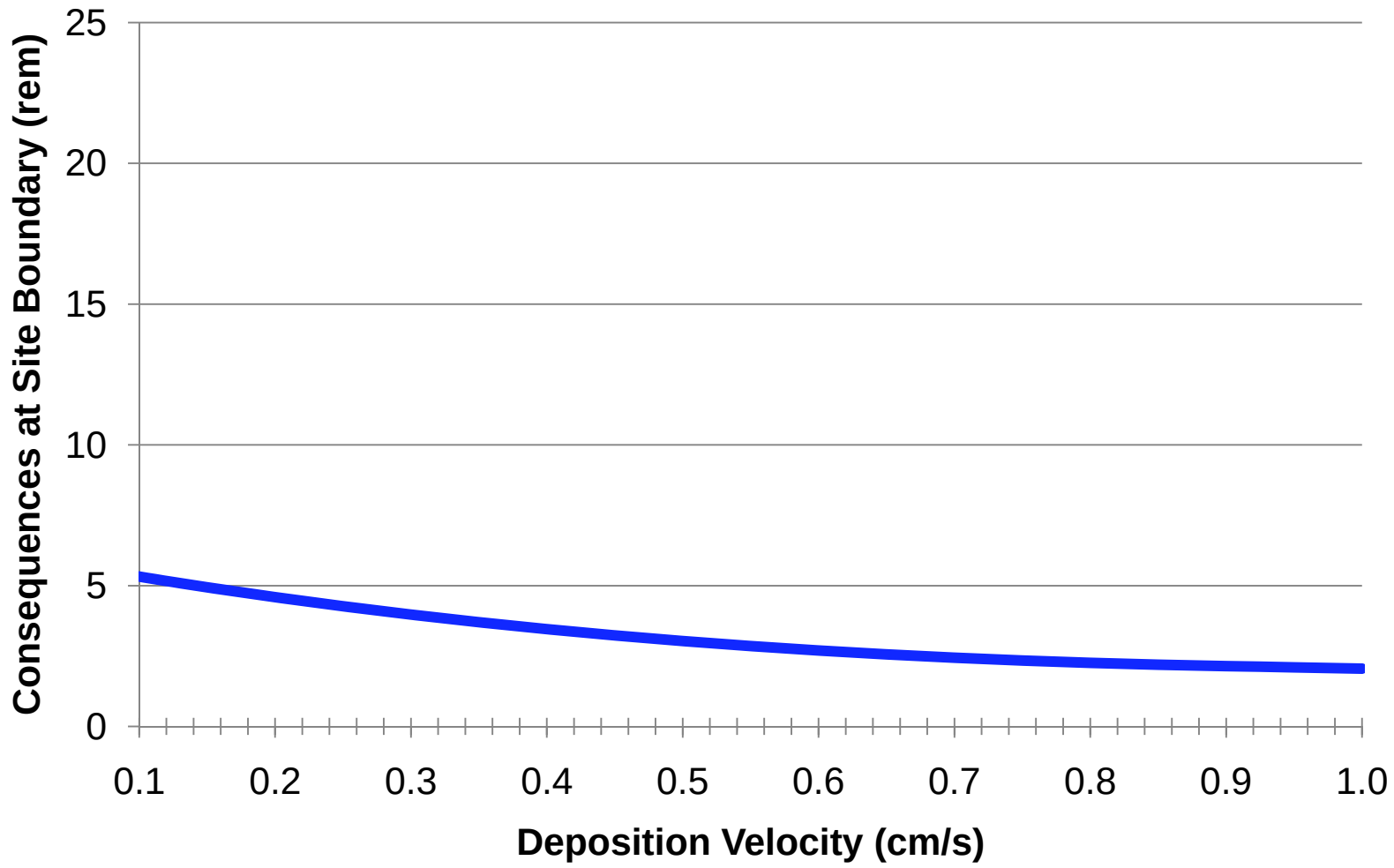


CFD-driven deposition of particulates



Notes: The steady simulation was run for 5000 time steps at a Courant-Friedrichs-Lewy number of 15 with a low Mach number (e.g., Ma = 0.013)

DV Effects on UPF Consequences



Cumulative Conservatism in Consequences

- Windspeed
  - Factor of 2 — from “calms” to 1 m/s
- Surface Roughness
  - Factor of 10 — from Rural to Urban
- Particle Size
  - Factor of 4 — from DV of 1 cm/s to 0.1 cm/s
- Chemical Form of Particulate
  - Factor of 2.15 to 2.75
- Total conservatism could be as much as a factor of 220

Summary

1. Y-12 is following DOE standard 1189.
2. There are many factors which affect Deposition Velocity.
3. Y-12 calculations took a very conservative approach.
4. Y-12 is in compliance with 1cm/s NNSA guidance.

Questions