This paper describes objective technical results and analysis. Any subjective views or opinions that might be expressed in the paper do not necessarily represent the views of the U.S. Department of Energy or the United States Government.

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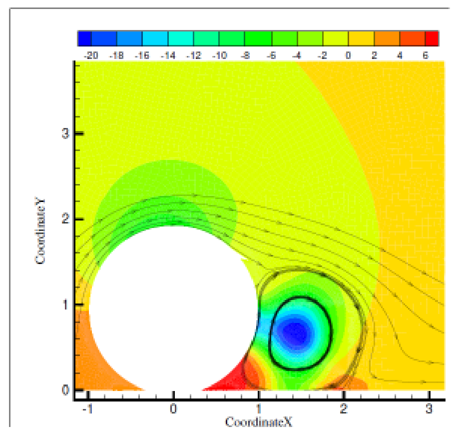
Sandia National Laboratories

Two-Dimensional Local Pollutant Transport by Cask Depressurization



Christopher Clutz

Ruth Weiner

GMU Conference on Atmospheric Dispersion and Deposition

June 24-26, 2014

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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

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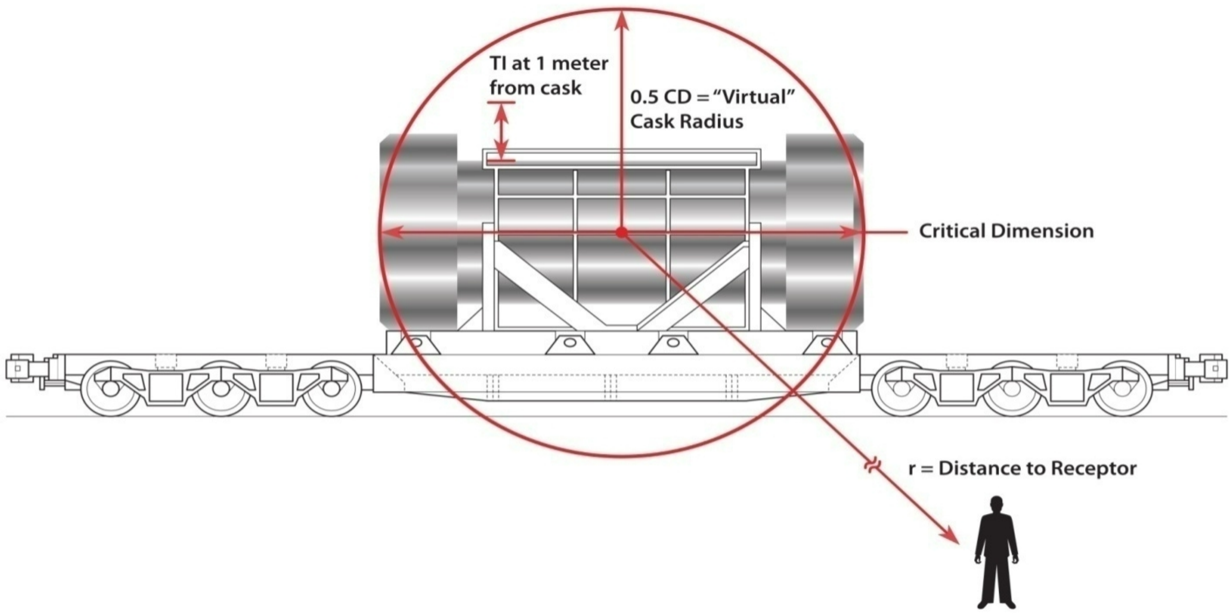
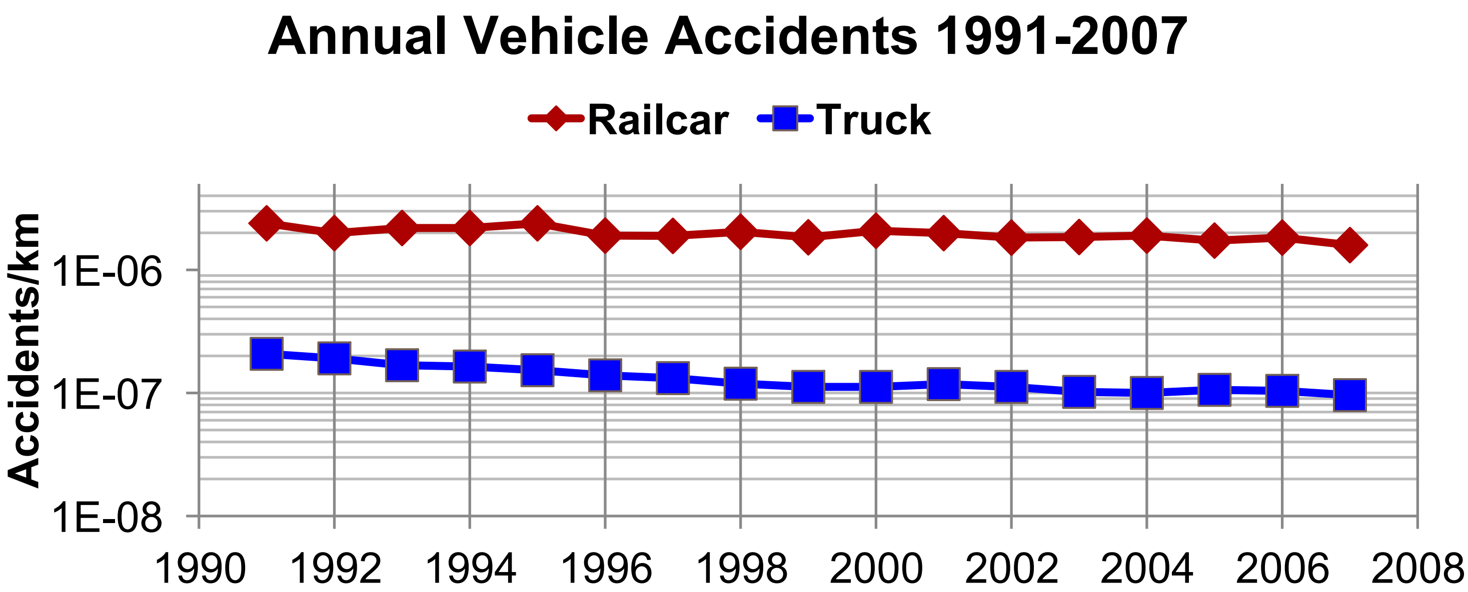
Outline of the Presentation

- Purpose and genesis of the study of the ”near field”.
- Cask behavior in accidents
- Need for a “near field” model
- First approximation to a “near field” model.
- Next steps.

Basic cask model for RADTRAN



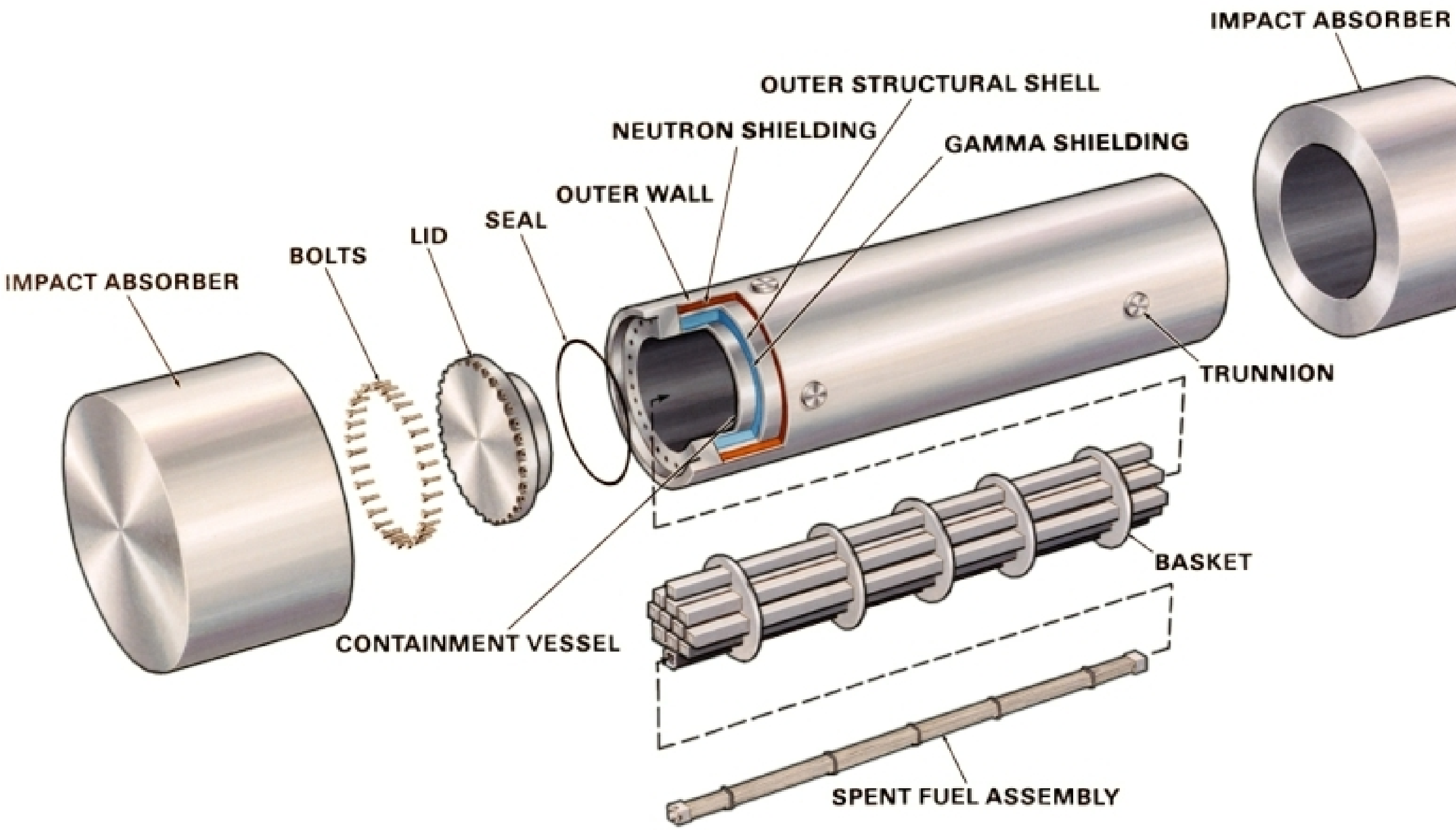
Probabilities of an accident



Accident severities are categorized using an event tree with conditional probabilities.

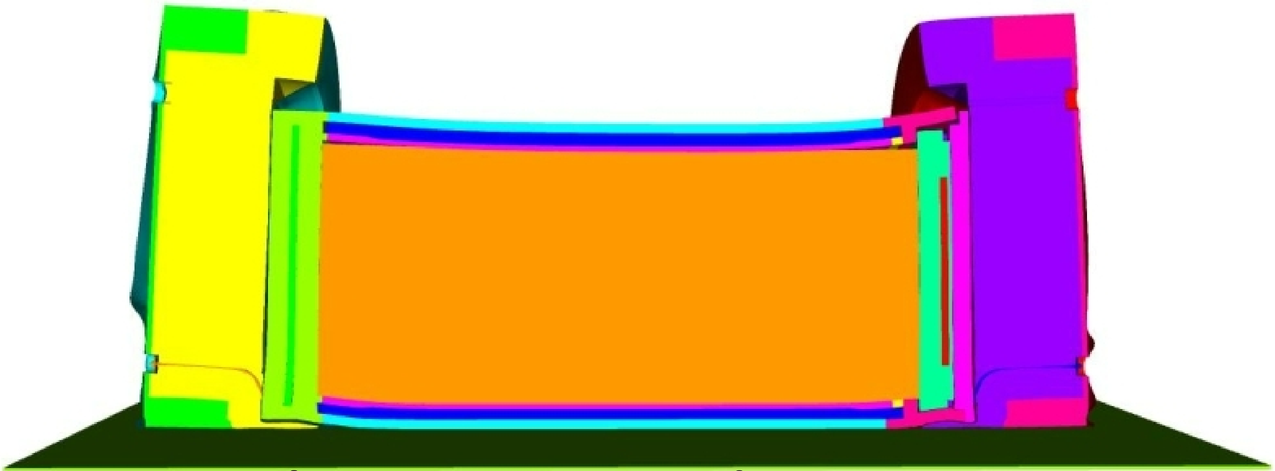
- For trucks, the event tree was developed at Sandia National Laboratories.
- For rail, the event tree was developed at the Volpe National Transportation Systems Center.

SPENT FUEL CASK



Rail-lead cask impact analysis

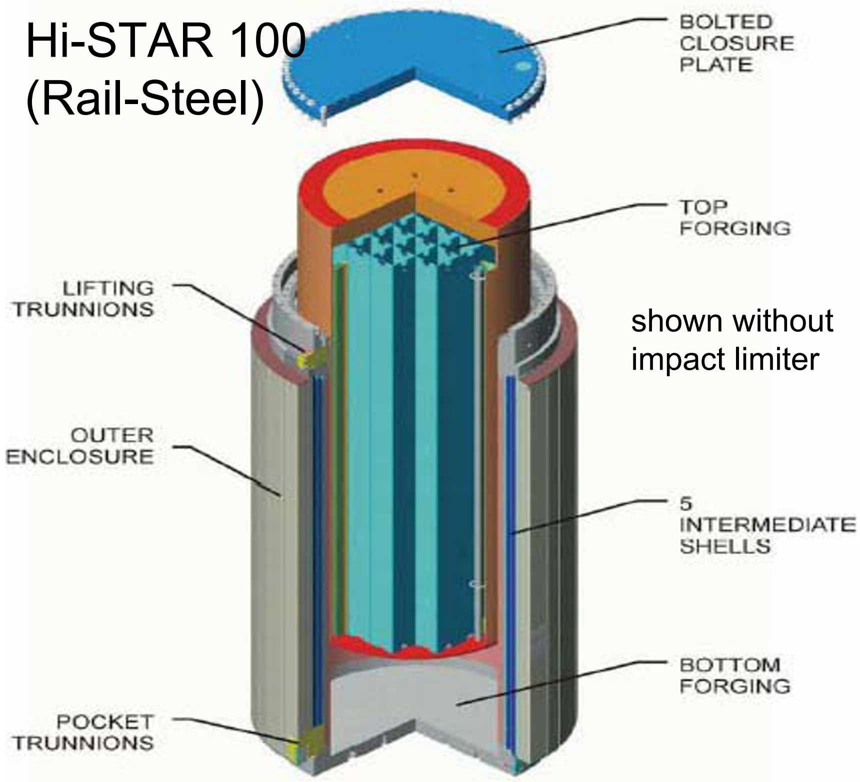
- **Side orientation 90 mph impact onto a rigid target**
- **Only cask and orientation resulting in a leak-path**
  - no leak-path if fuel is loaded in an inner welded canister



- **Side orientation 60 mph impact onto a rigid target**
  - No leak path, but
  - The risk assessment assumes impacts into hard rock (5% of route wayside surface) above 50 mph result in a leak-path
- **Side orientation impacts at any recorded accident velocity onto targets softer than hard rock do not result in a leak-path**

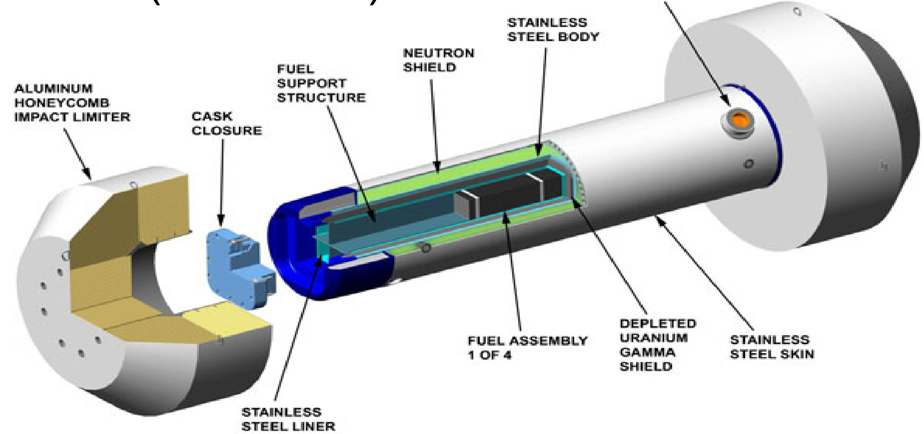
Cask Illustrations

Hi-STAR 100
(Rail-Steel)



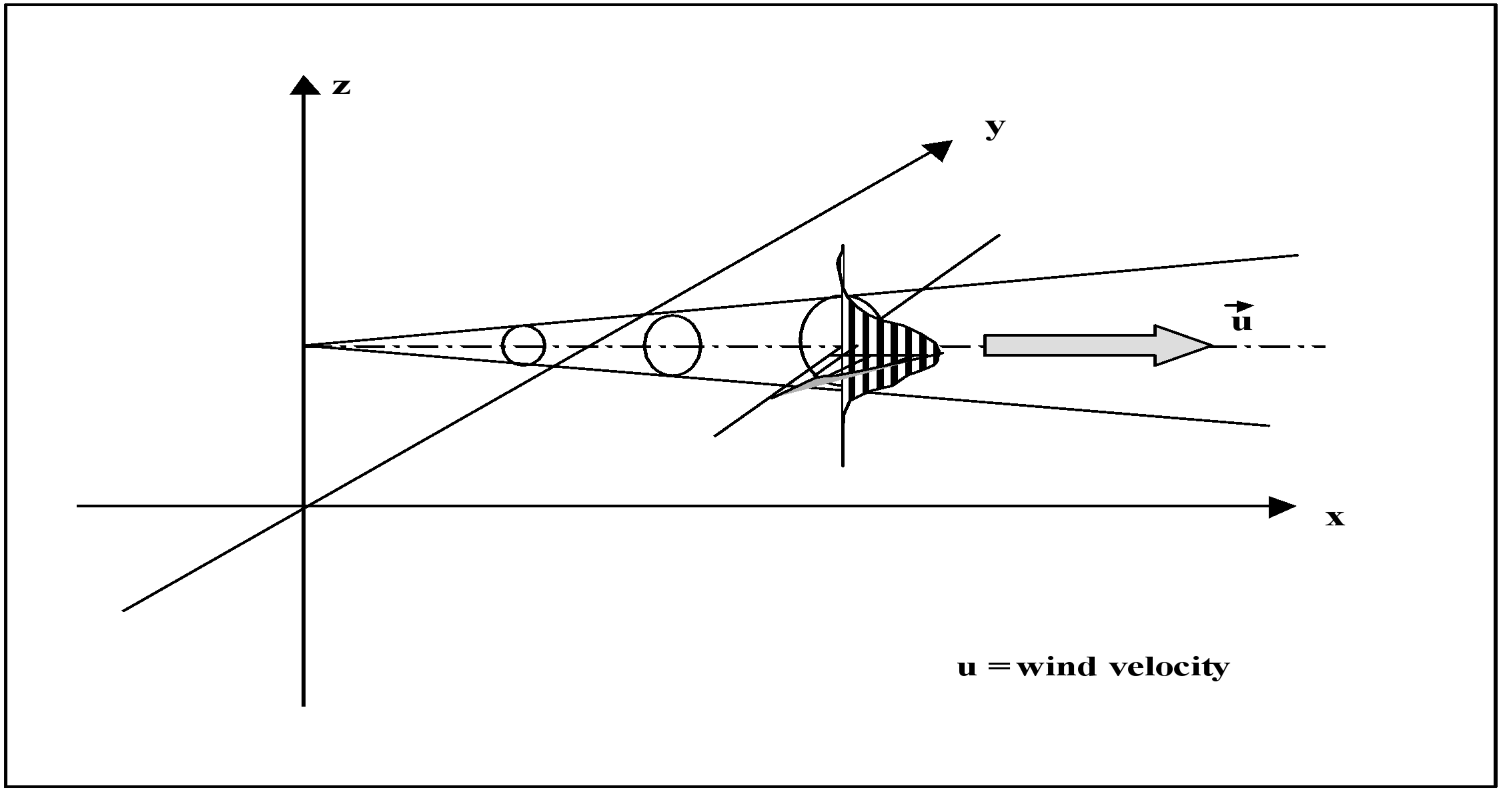
shown without impact limiter

GA-4 (Truck-DU)

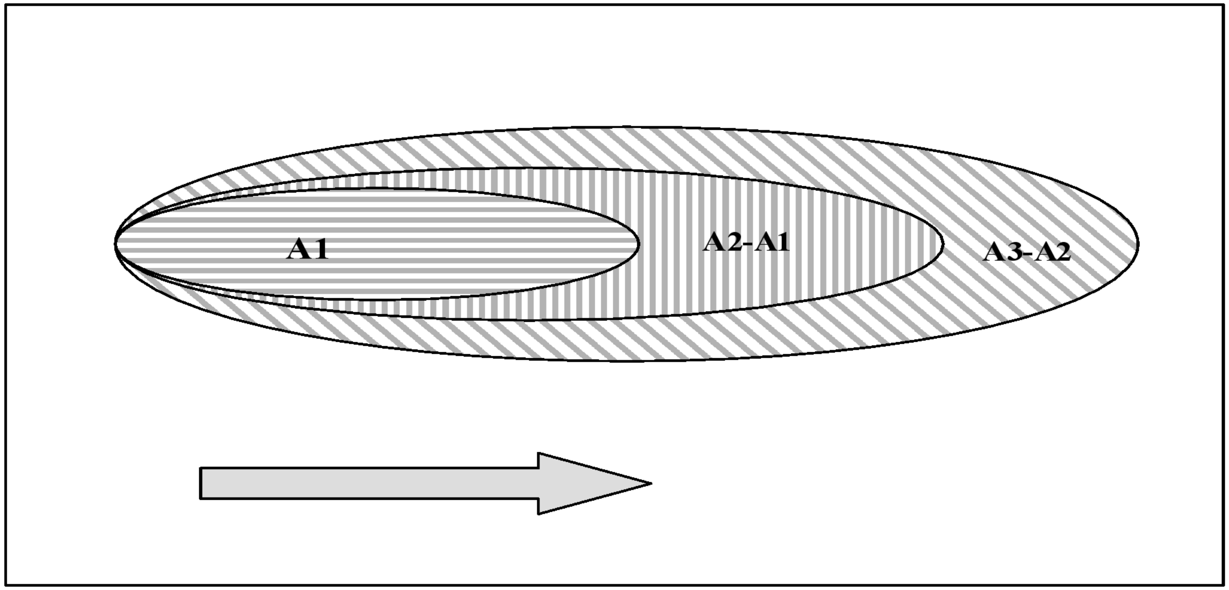


- Each cask represents a type (Rail-Lead, Rail-Steel, Truck-DU)
- Casks of the same type would perform similarly

Atmospheric Dispersion



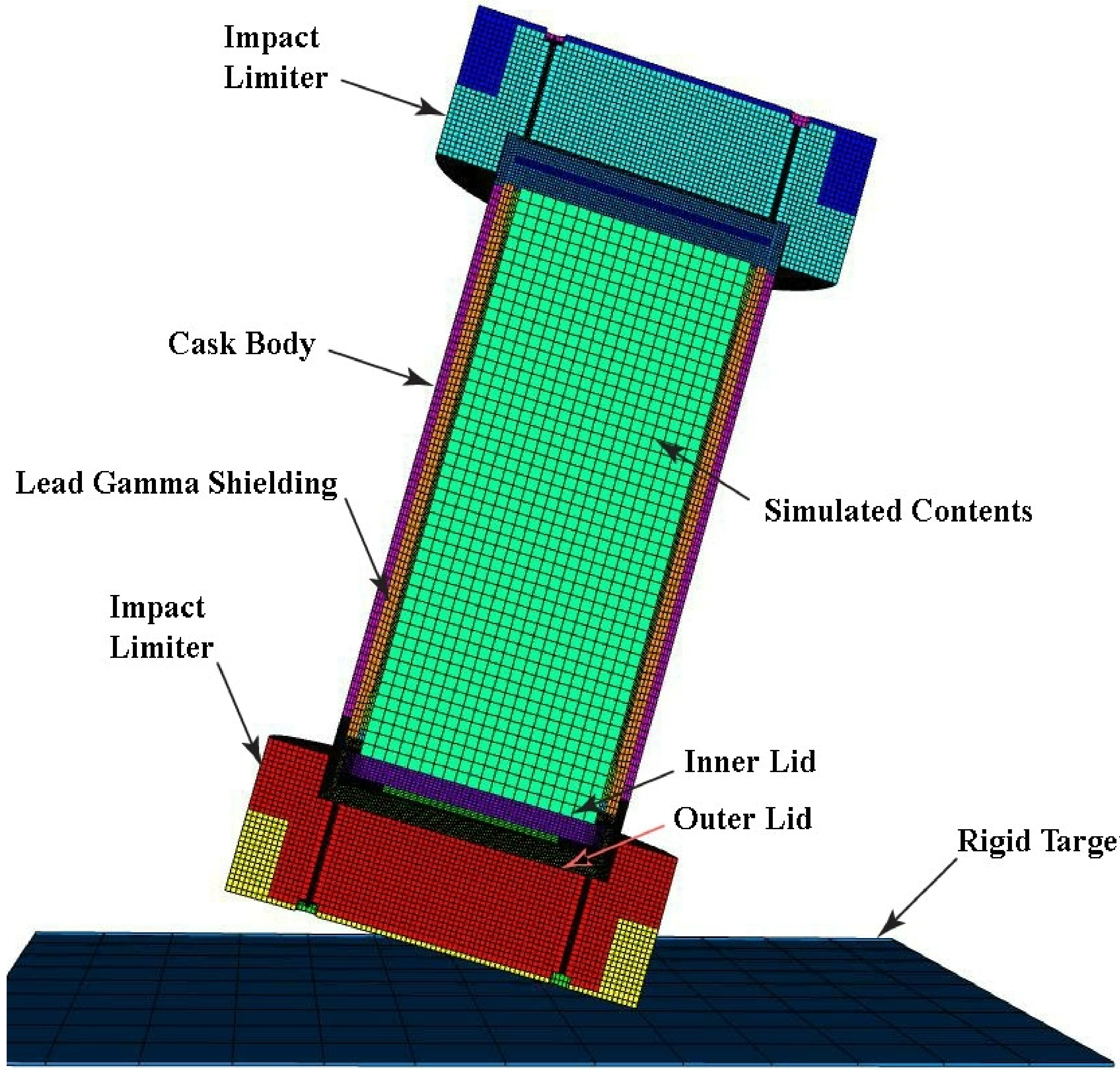
Dispersion Footprint



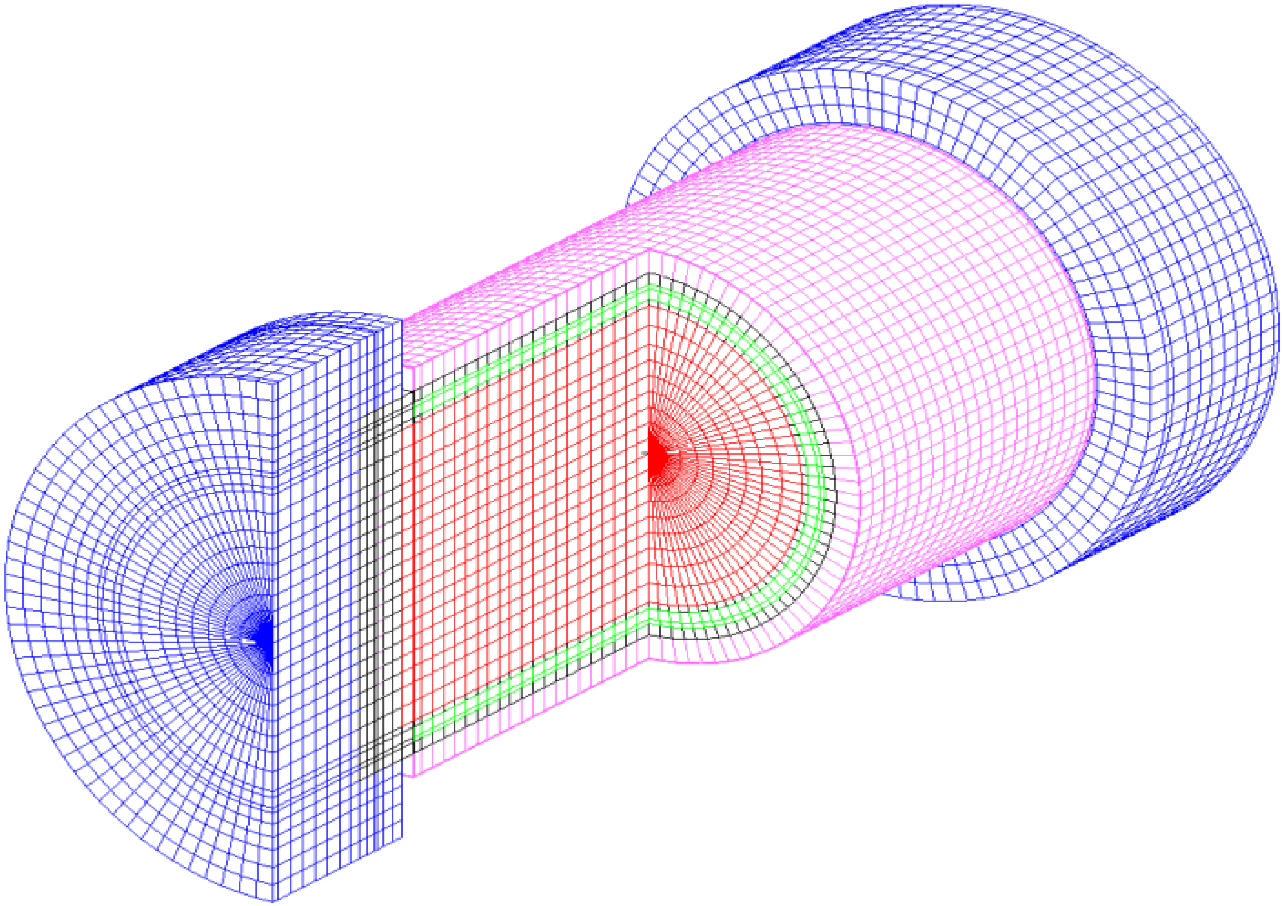
Types of exposed populations

- Residents along the route
- Occupants of vehicles sharing the route
- Residents near stops
- People sharing the stop
- **Crew of the transport vehicle (truck or train)**
- **Inspectors**

Finite element model of the rail-lead cask



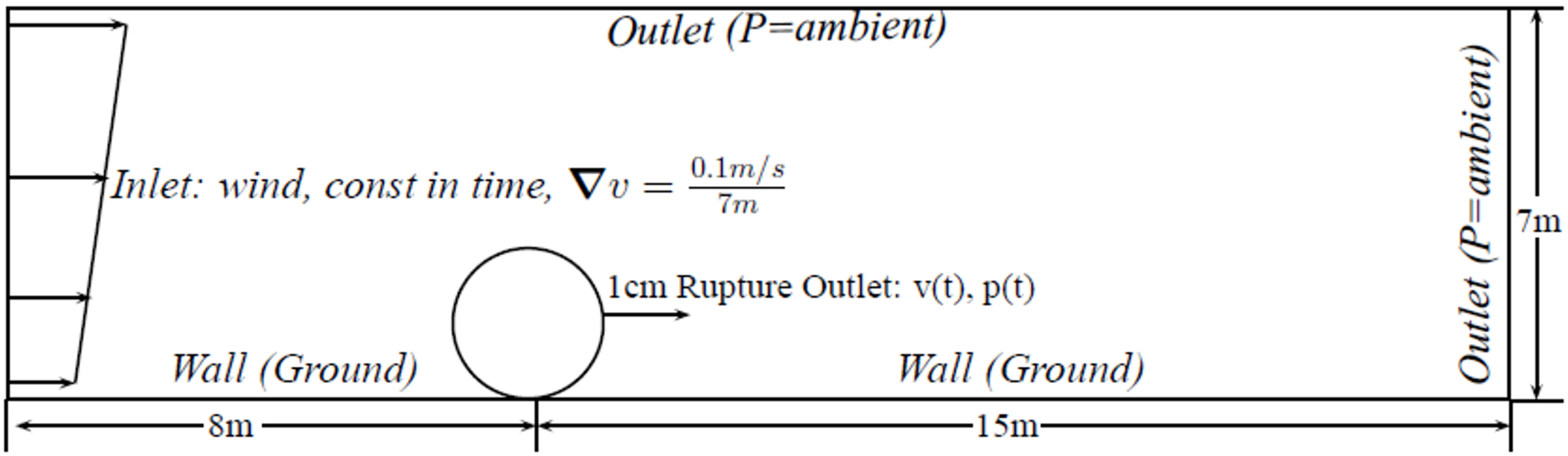
Finite element mesh of the rail-lead cask



Release fractions

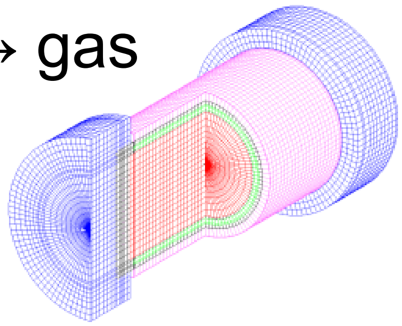
	Cask Orientation	Side	Side
	Rigid Target Impact Speed, kph (mph)	193 (120)	145 (90)
	Seal	elastomer	elastomer
Cask to Environ-ment Release Fraction	Gas	0.80	0.80
	Particles	0.70	0.70
	Volatiles	0.50	0.50
	CRUD	0.001	0.001
Rod to Cask Release Fraction	Gas	0.12	0.12
	Particles	4.8×10^{-6}	4.8×10^{-6}
	Volatiles	3.0×10^{-5}	3.0×10^{-5}
	CRUD	1.0	1.0
	Conditional Probability	1.79×10^{-11}	3.40×10^{-10}

Near Field Simulation Domain



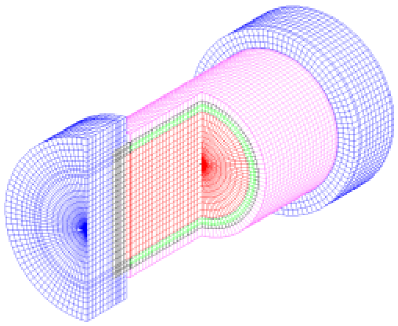
Simulation Conditions

- Temperature change of -0.1 deg K from the bottom to the top of the domain
- Bluff body wake generation induced geometrically, by putting a small re-entrant corner on the cask,
- Change in the horizontal wind velocity of 0.1m/s with altitude upwind of the cask.
- Ground surface upwind of the cask: *zero shear wall*
- Ground surface downwind of cask: *no-slip wall* & *particle traces terminate.*
- 750K inside the cask from radioactive decay → gas pressure of 2.62 *atm* (ideal gas)

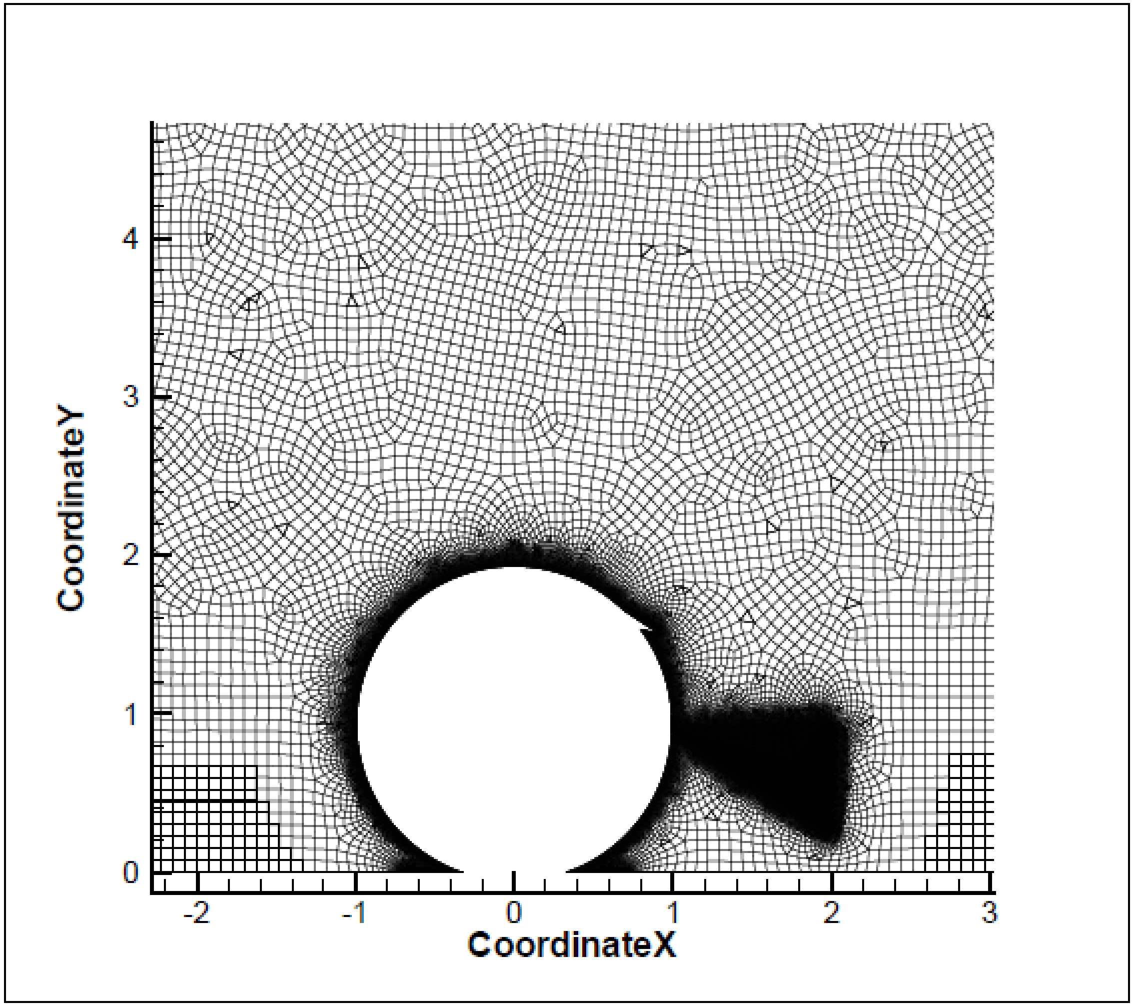


Simulation Conditions -- continued

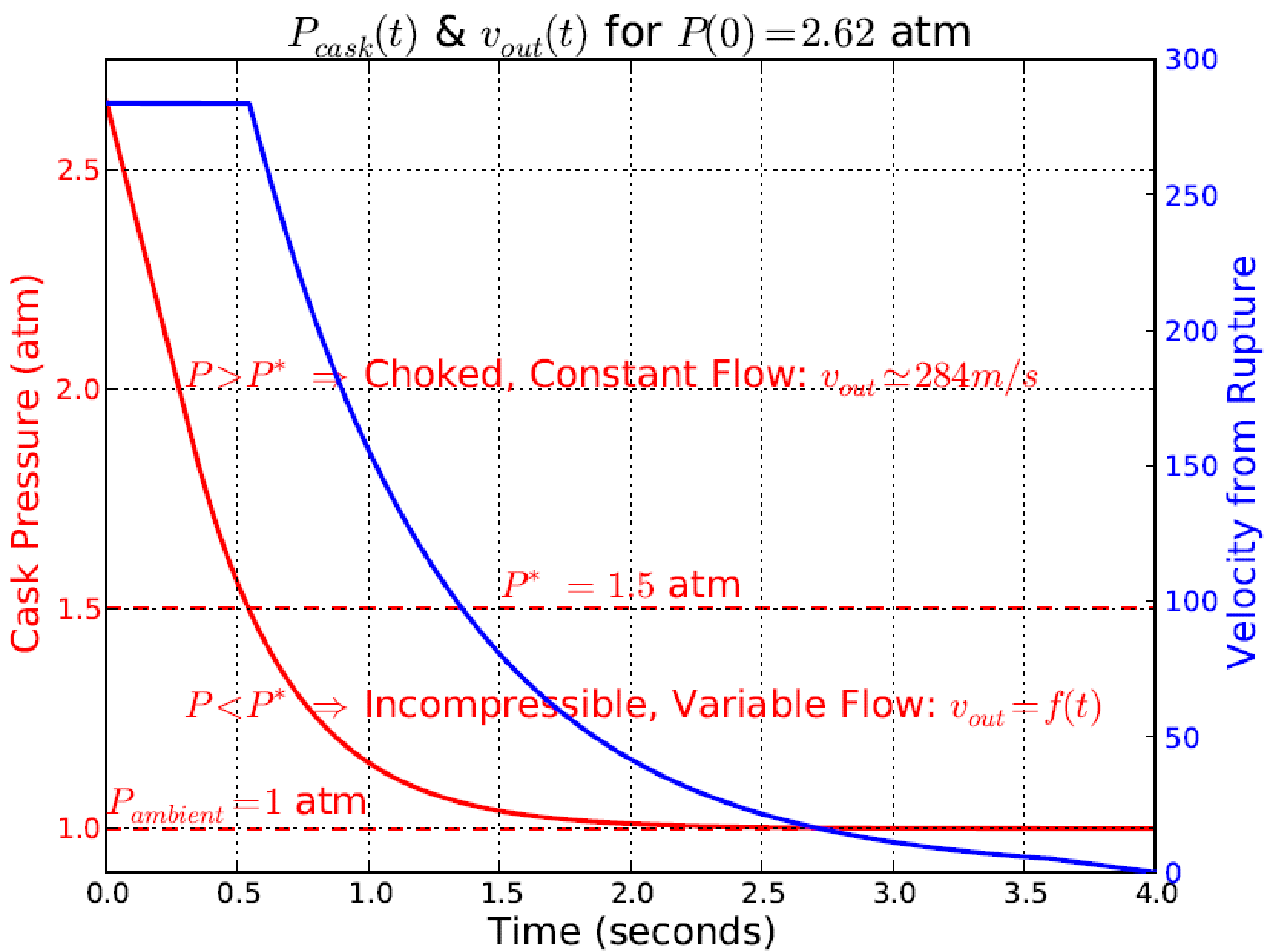
- One-cm gap in cask in 2D: *extended to ±∞ in z-dir*
- 0.662 gm PuO_2 in one micron diameter particles initially inside the cask to simulate a potential worst-case dose.
- Lagrangian simulation of particle motion: *inert, conducting, turbulent dispersion used?*
- The ambient wind field, always present, prevails once outgassing has become *relatively* weak.



Mesh used (X, Y in meters)

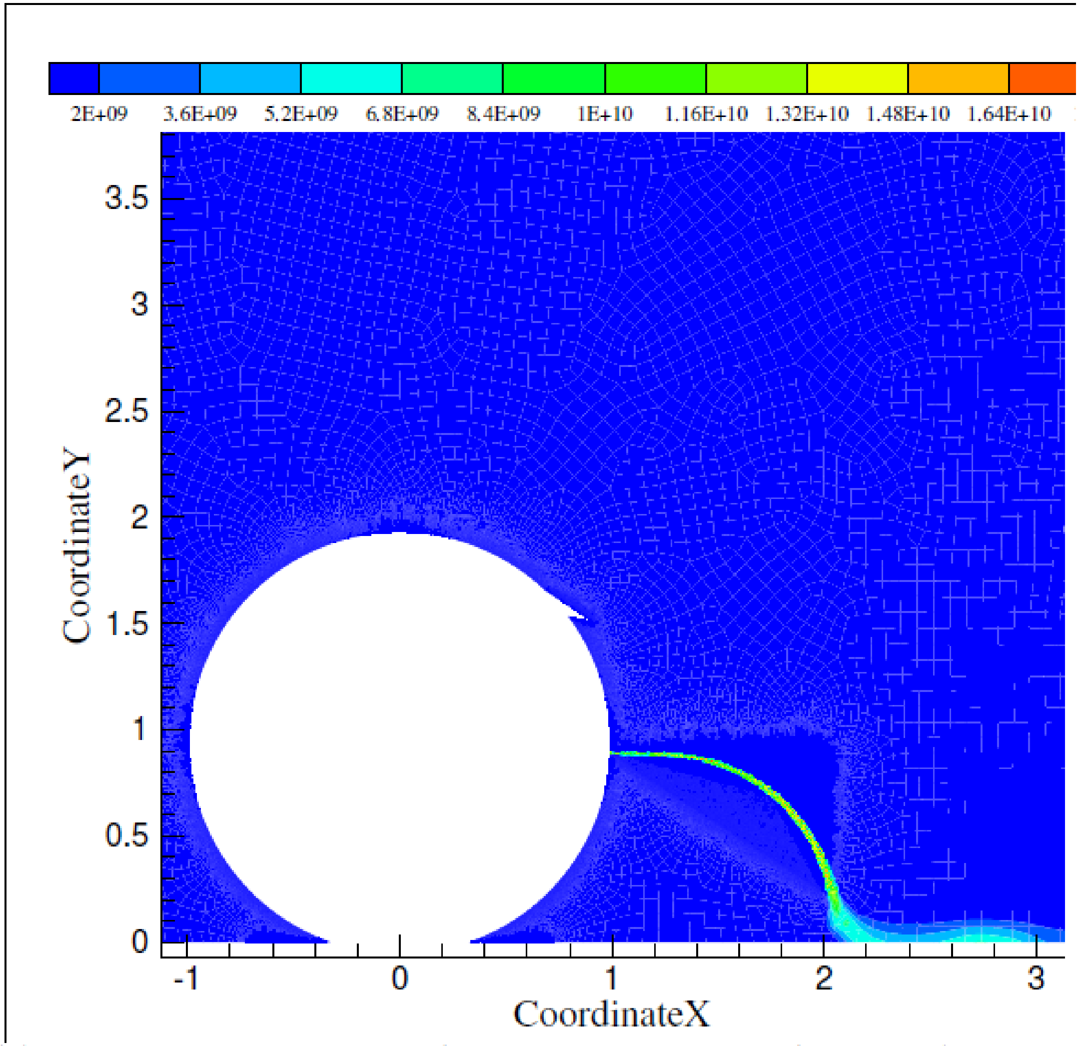


Pressure and Velocity Boundary Conditions with $t_{sim} \cong t_{physical}/500$



$$v_{amb} = 2\ {}^{m}/_{s} \quad and \quad v_{amb} \ll v_{outgass}$$

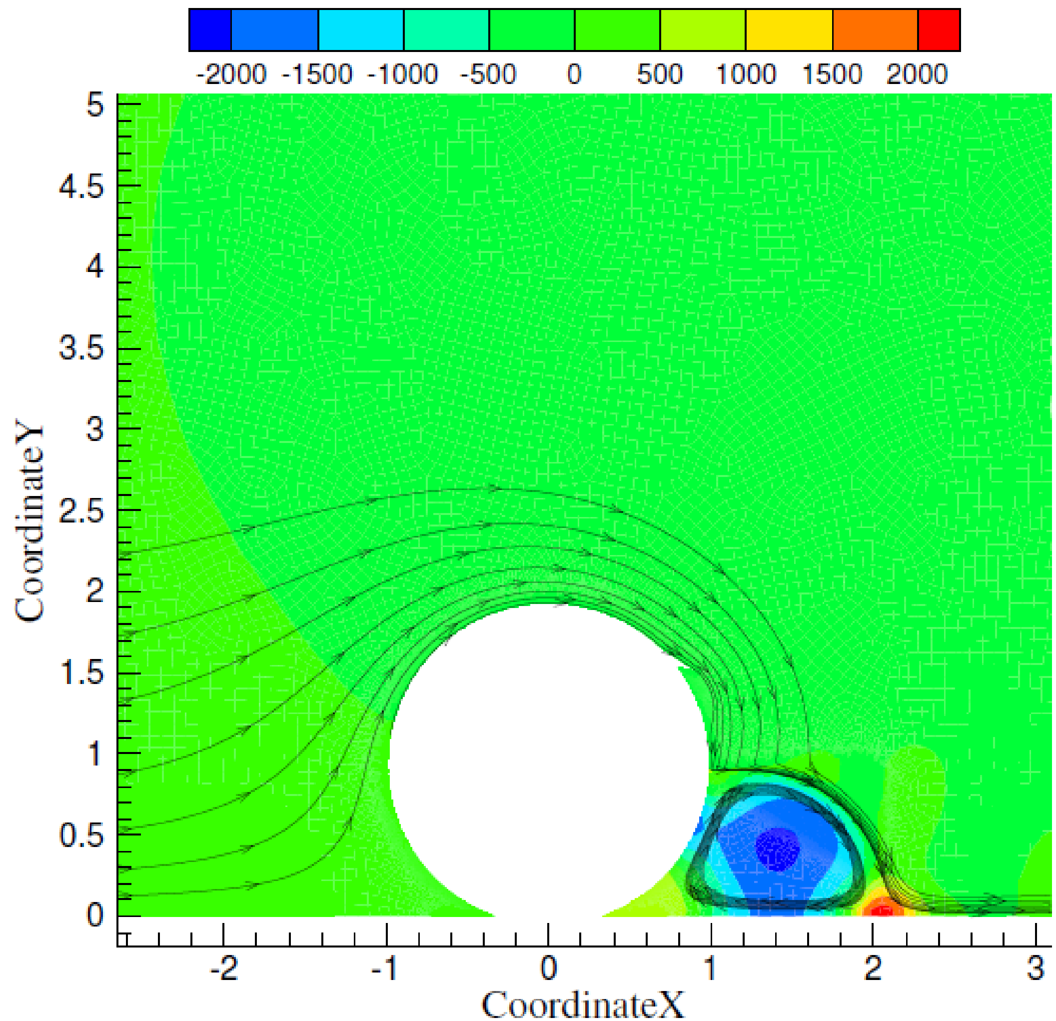
Particle # density during choked flow regime (X, Y in meters)



(a) Particle number density (no. particles in a cell / cell area)

$$v_{amb} = 2 \ {}^{m}/_{s} \quad and \quad v_{amb} \ll v_{outgass}$$

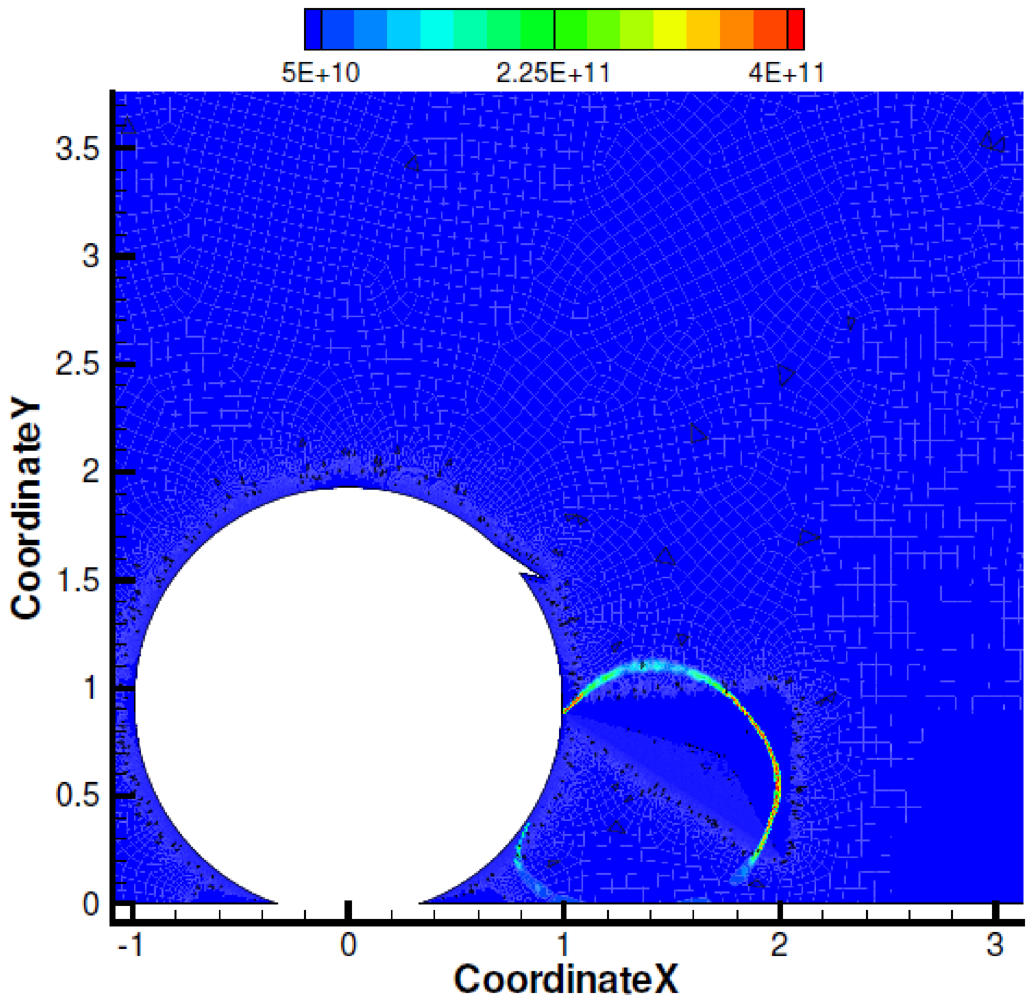
Pressure field during choked flow regime (P in psi with ‘0’ = 1atm)



(b) Pressure field with velocity streamtraces

$$v_{amb} = 2\ {}^{m}/_{s} \quad and \quad v_{amb} \approx v_{outgass}$$

Particle # density near end of outgassing (X, Y in meters)



(a) Particle number density

$$v_{amb} = 2\ {}^{m}/_{s} \quad and \quad v_{amb} \approx v_{outgass}$$

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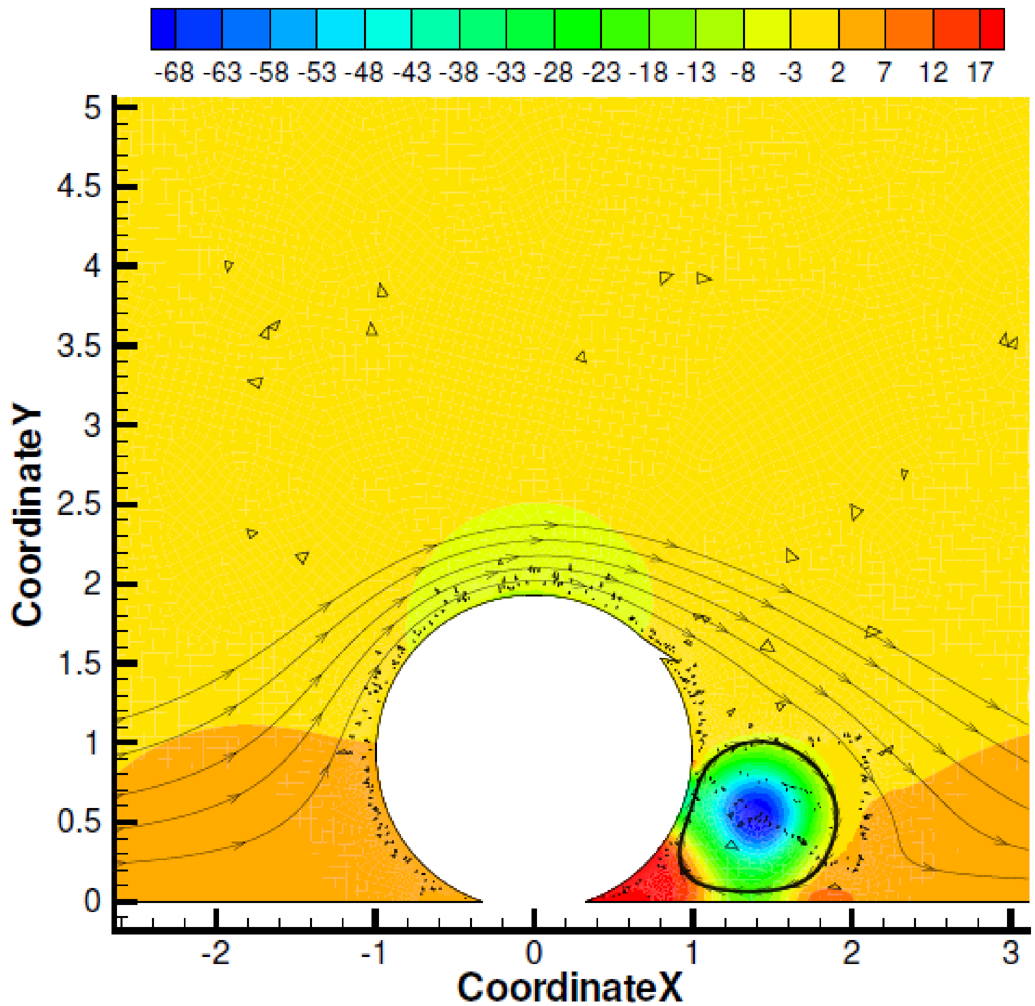
Pressure field near end of outgassing (P in psi with ‘0’ = 1atm)



(b) Pressure field with velocity streamtraces

Fractions of Particles Trapped and Escaped

Wind (m/s)	Escaped	Trapped	Caught in Wake
0.5	0.30	0.50	0.20
2.0	0.26	0.50	0.24
4.0	0.17	0.52	0.31
6.0	0.16	0.41	0.43
8.0	0.13	0.37	0.50

Implications for RADTRAN

- A 3D model is needed! 1cm gap → 1cm hole & 3D bluff body wake.
- Material “caught in wake” is modeling artifice caused by constant wind. *Most of this will escape to the far field*.
- There is no need to model a transition between near and far field.
- Wind speed is already a variable parameter in RADTRAN
- The fraction by which the far field dose is reduced can be coupled to the wind speed.
- A range of wind directions relative to the cask is needed.