

Application of Various Source Term Models to Investigate the Impact on Level 3 PSA

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23 July 2026

Overview

■ Level 3 PSA

- Final step of **Probabilistic Safety Assessment (PSA)**
- Evaluates **offsite consequences** from a nuclear power plant accident
- Estimated via wide spectrum of parameters and inputs
- **Radiological source term** information
 - Information related to the **release of radioactive materials**

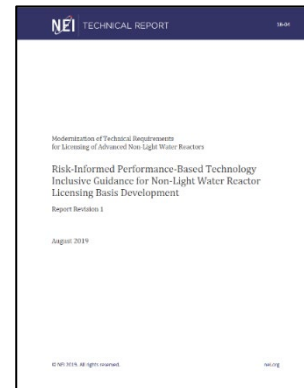
Magnitude	Release delay	Release duration	Release height	Physical form
Frequency	Release heat content	Release flow rate	Particle size	Chemical form

- Impact offsite consequences via dispersion, deposition & plume rise

$$\chi(x, y, z) = \frac{Q}{u} \frac{1}{\sqrt{2\pi} \sigma_y(x)} \exp \left[-\frac{1}{2} \left(\frac{y}{\sigma_y(x)} \right)^2 \right] * \frac{1}{\sqrt{2\pi} \sigma_z(x)} \exp \left[-\frac{1}{2} \left(\frac{z - H}{\sigma_z(x)} \right)^2 \right]$$

■ Current regulation trend

- **TI-RIPB** (Technology Inclusive-Risk Informed Performance Based)
 - **F-C** (Frequency-Consequence) **curve** (NEI 18-04)



NEI 18-04

Source Term

■ Source term information is **difficult** to obtain

- **Dependent on plant and accident scenario**

• Models

– **Technical information document 14844, TID**

– **Alternative source term, AST**

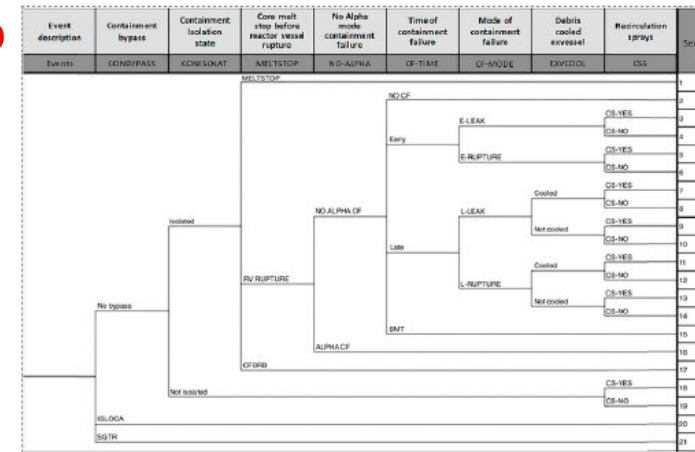
– **NUREG-1465**

– Regulatory guide 1.183 (**Reg 1.183**)

– Regulatory guide 1.183 revision 1 (**Reg 1.183 rev 1**)

– **Mechanistic source term, MST**

– OPR1000 MST source term category (**Cat. 1 to 6**)



OPR1000 STC logic diagram

■ TID and AST still widely used in regulations

Model		TID	AST
Leak rate		0.1%/day	0.1%/day
Total released radionuclides in containment	Noble Gas	100%	100%
	Halogens	50%	30%
	Fission product	1%	0 - 30%

■ **Impact of these discrepancies in offsite consequences**

Objectives

■ Determine **discrepancies among the model**

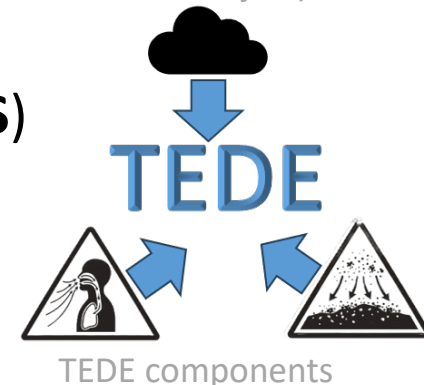
- Identify differences between the models
 - Release fraction
 - Release history
- Evaluate radiological consequences
 - Normalized analysis
 - Incorporates **release fraction and plume duration**
 - Complete MST analysis
 - Includes **plume delay, heat content and release height**
 - Dose contributions
 - Exclusion Area Boundary (EAB)

Plume Segment	PDELAY	PLHEAT	PLHITE	PLMDEN	PLMFLA	PLUDUR
1	10600	4.32E+01	8.4	7.39E-01	4.11E-04	3619.6
2	12800	8.88E+05	24.643	2.95E-01	1.07E+00	3639.9
3	14220	8.97E+01	8.4	6.67E-01	7.40E-04	3600.4
4	16440	6.76E+04	24.643	3.21E-01	9.19E-02	3600.1
5	17820	1.12E+02	8.4	6.42E-01	8.13E-04	3599.9
6	20040	6.10E+04	24.643	2.94E-01	8.30E-02	3599.9
7	21420	1.28E+02	8.4	6.21E-01	8.23E-04	3600
8	23640	5.47E+04	24.643	2.85E-01	7.43E-02	3600
9	25020	1.48E+02	8.4	6.04E-01	8.97E-04	3599.9
10	27240	6.21E+04	24.643	3.45E-01	9.66E-02	3600
11	28620	2.00E+02	8.4	5.80E-01	1.08E-03	3660
12	30840	6.41E+04	24.643	3.64E-01	1.06E-01	3600
13	32280	2.26E+02	8.4	5.66E-01	1.12E-03	3600.2
14	34440	6.88E+04	24.643	3.62E-01	1.12E-01	3600.1
15	35880	2.45E+02	8.4	5.60E-01	1.18E-03	3600
16	38040	7.38E+04	24.643	3.58E-01	1.18E-01	3600.1
17	39480	2.63E+02	8.4	5.55E-01	1.24E-03	3600
18	41640	7.87E+04	24.643	3.55E-01	1.24E-01	3599.9
19	43080	2.85E+02	8.4	5.49E-01	1.31E-03	3600
20	45240	8.38E+04	24.643	3.53E-01	1.29E-01	3600.1
21	46680	3.07E+02	8.4	5.43E-01	1.37E-03	3600.1
22	48840	8.93E+04	24.643	3.55E-01	1.36E-01	3600.1
23	50280	3.30E+02	8.4	5.39E-01	1.43E-03	3600
24	52440	9.51E+04	24.643	3.52E-01	1.42E-01	3599.8
25	53880	3.54E+02	8.4	5.35E-01	1.51E-03	3600

Full MST (U.S. SOARCA Project)

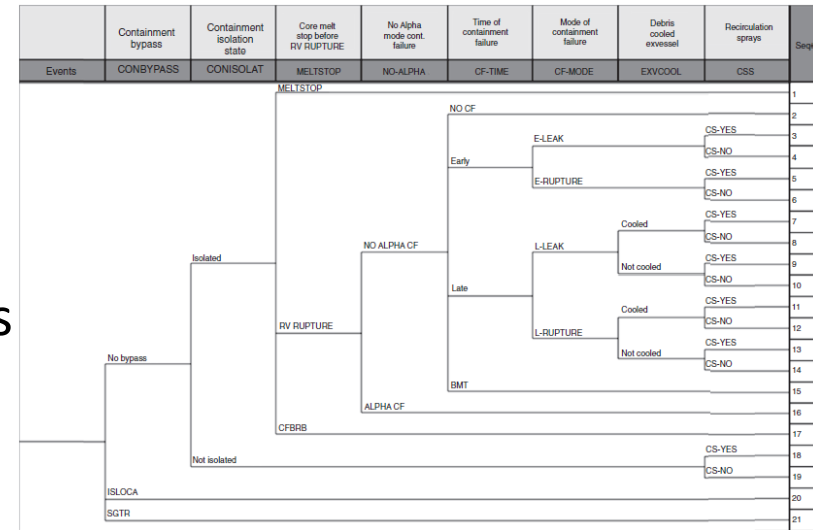
■ Methodology

- MELCOR Accident Consequences Code System (**MACCS**)
- Obtain **TEDE** as comparison
- Constant wind and real weather



Result: Release Fraction

- Summation of total release fraction
 - Assume leak rate of 0.1%
 - TID & AST models
 - Differences due to accident sequences
 - AST models differs in content
 - Reg 1.183 rev 1 more Te & Mo
 - Design basis accident (DBA) like: Cat. 1 & 2
 - MST cases generally more severe

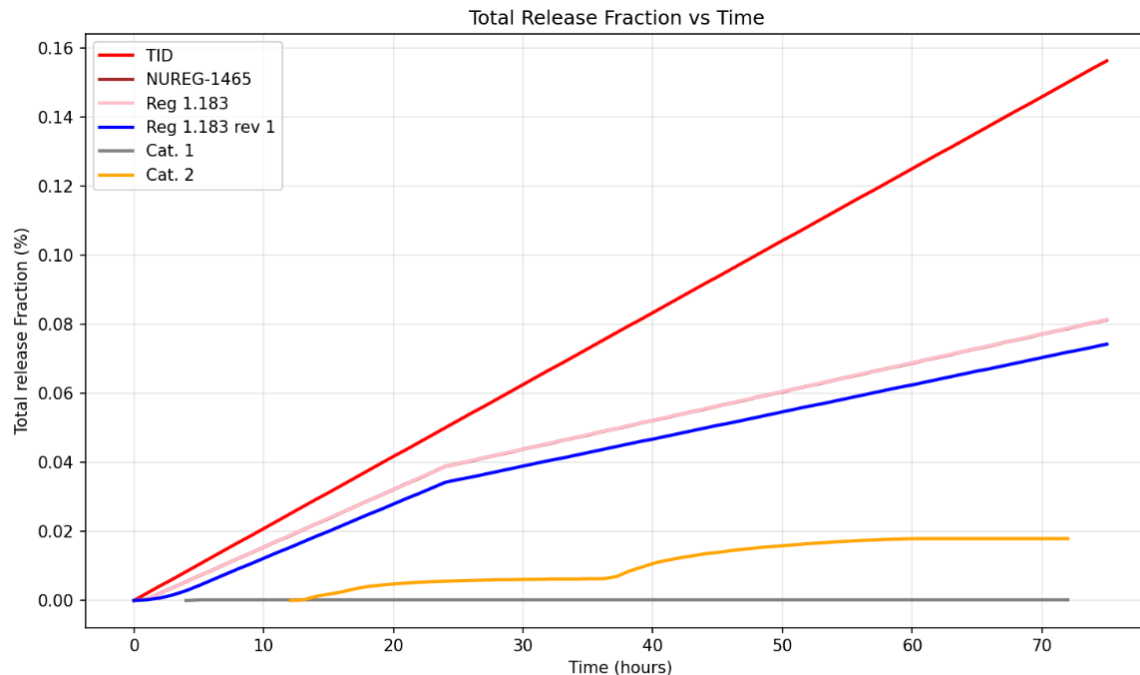


OPR1000 STC logic diagram

Total Release fraction	Xe	Cs	Ba	I	Te	Ru	Mo	Ce	La
TID	0.70%	0.01%	0.01%	0.35%	0.01%	0.01%	0.01%	0.01%	0.01%
NUREG-1465	0.40%	0.12%	0.01%	0.16%	0.02%	0.00%	0.00%	0.00%	0.00%
Reg 1.183	0.40%	0.12%	0.01%	0.16%	0.02%	0.00%	0.00%	0.00%	0.00%
Reg 1.183 rev 1	0.38%	0.09%	0.00%	0.15%	0.12%	0.00%	0.04%	0.00%	0.00%
OPR Cat. 1	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
OPR Cat. 2	0.43%	0.01%	0.00%	0.02%	0.03%	0.00%	0.00%	0.00%	0.00%
OPR Cat. 3	35.51%	0.01%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%
OPR Cat. 4	99.38%	2.71%	0.18%	7.20%	2.61%	0.03%	0.64%	0.01%	0.01%
OPR Cat. 5	55.72%	0.02%	0.00%	0.06%	0.03%	0.00%	0.01%	0.00%	0.00%
OPR Cat. 6	99.93%	7.11%	0.54%	23.67%	4.28%	0.04%	1.71%	0.03%	0.05%

Result: Release History

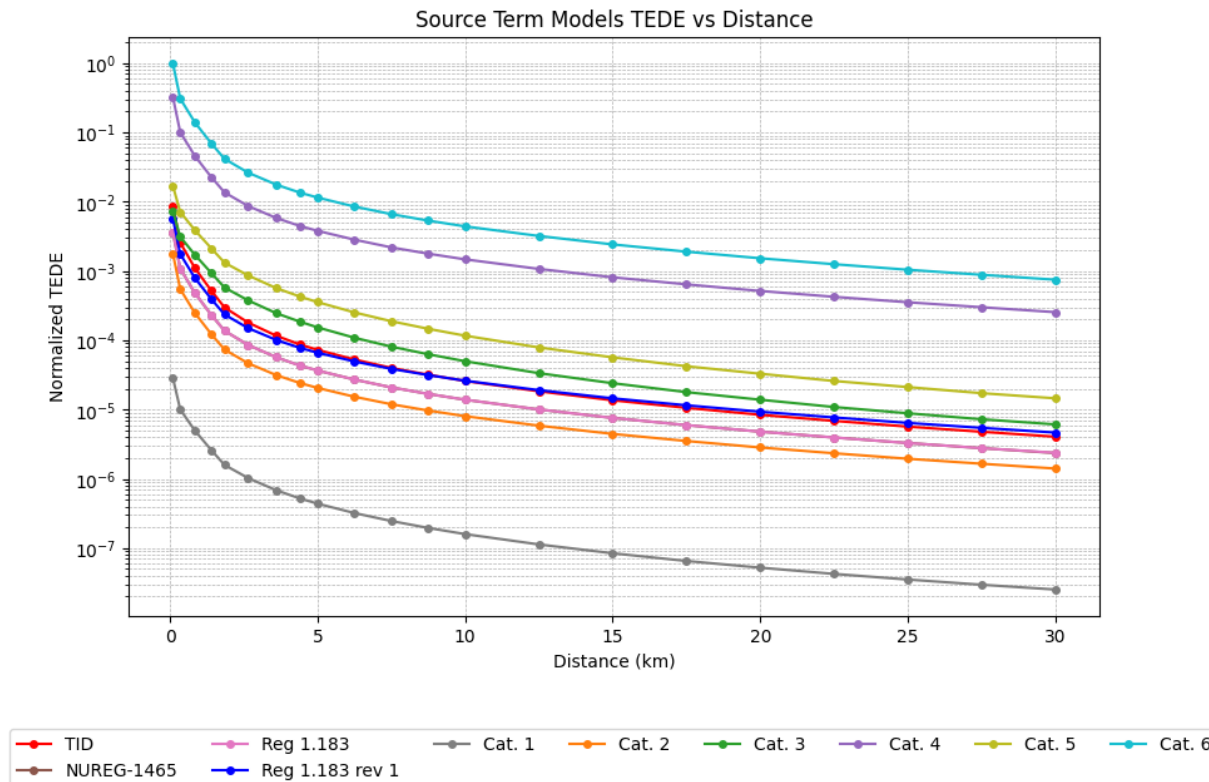
- Release history - Iodine category shown (~75 hours)
 - TID & AST constant release
 - AST models assume 50 % reduction in leak rate after first day
 - Plume delays in MST models
 - DBA MST models generally end within 72 hours



Release History of DBA scenarios

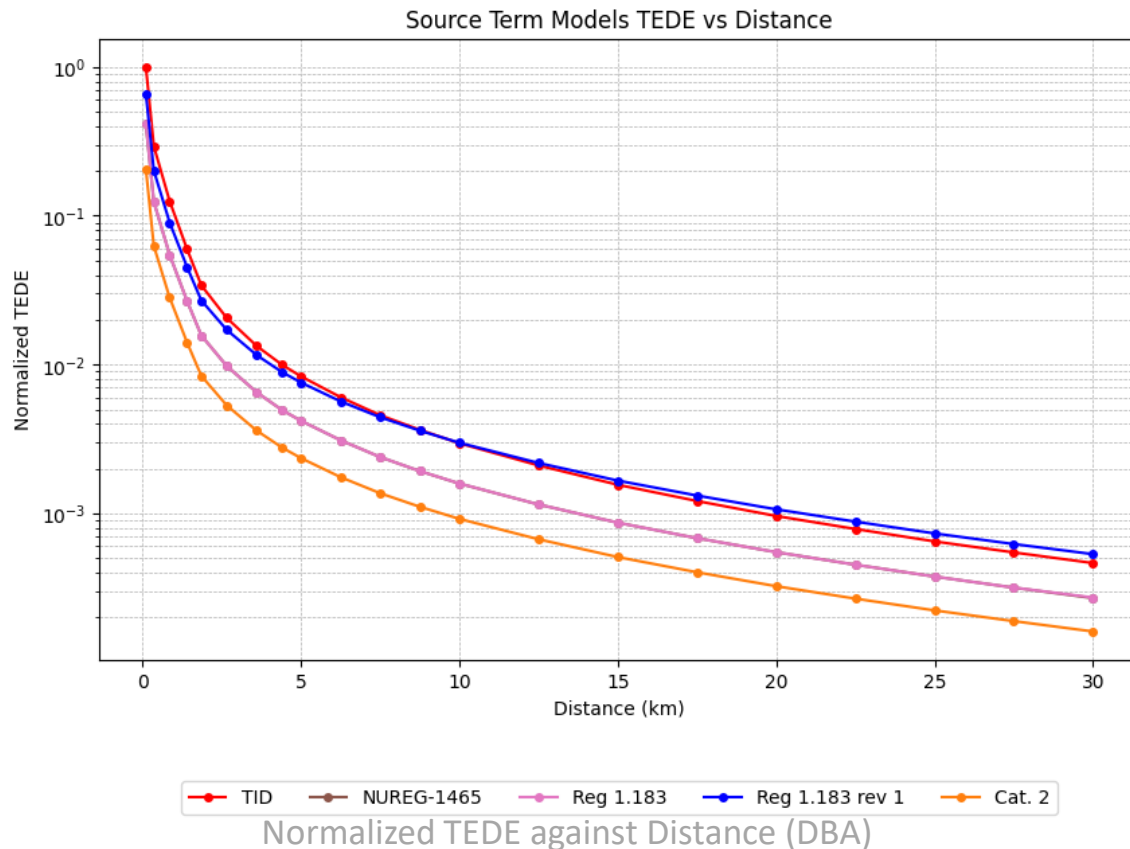
Result: Normalized Analysis

- Parameters other than release fraction and duration normalized
 - OPR1000 Cat. 6 most significant offsite consequence
 - OPR1000 Cat. 1 least significant



Result: Normalized Analysis

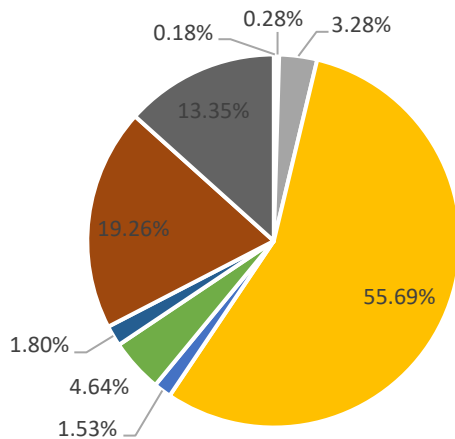
- For DBA like scenarios:
 - TID is the most conservative
 - Reg 1.183 rev 1 more conservative than prior AST models



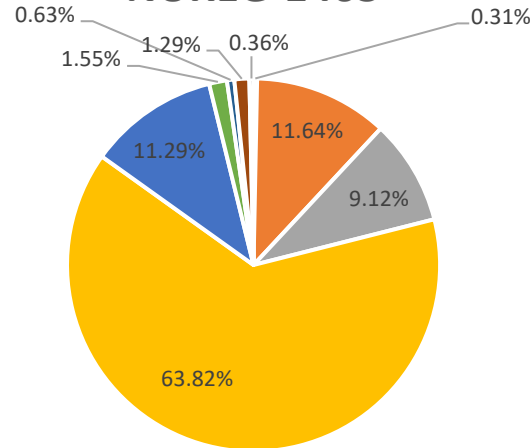
Result: Dose Contribution

- TEDE contribution for each RN category @ 700m (7 days)

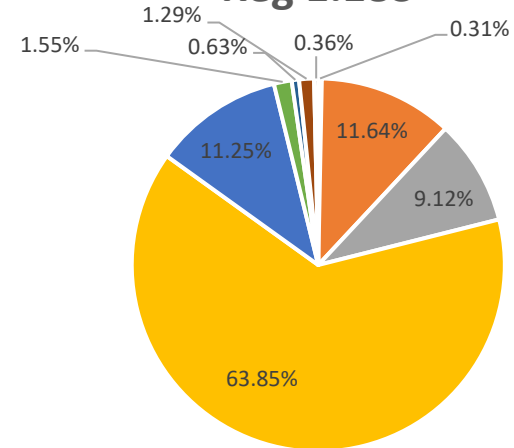
TID



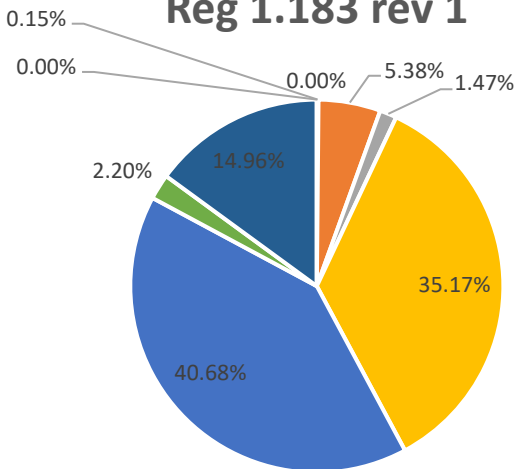
NUREG-1465



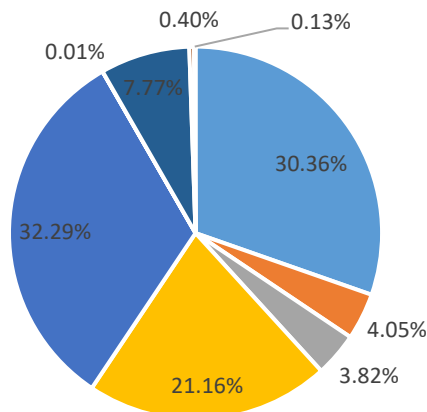
Reg 1.183



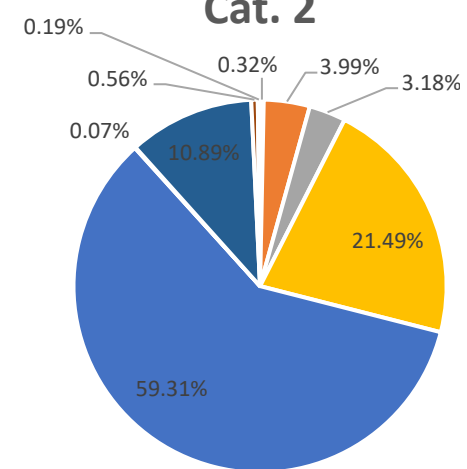
Reg 1.183 rev 1



Cat. 1

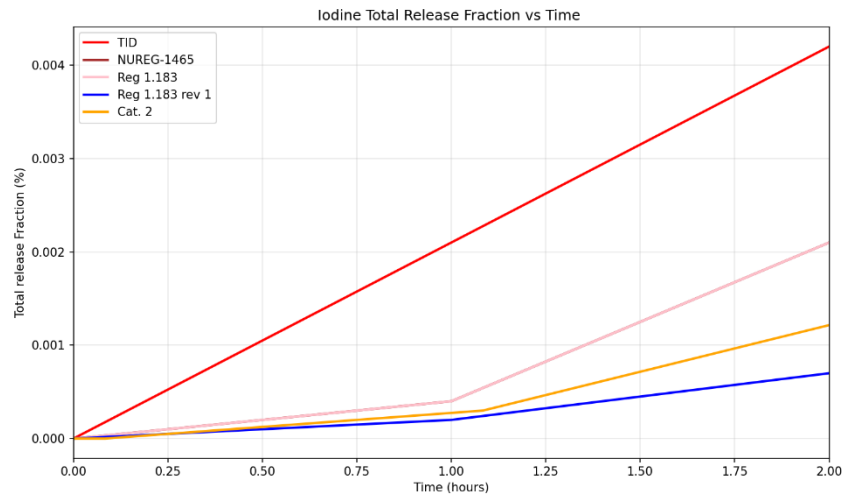


Cat. 2



Result: Exclusion Area Boundary

- Exclusion area boundary (EAB) regulation:
 - 10 CFR part 53: Boundary of EAB < 0.25 Sv TEDE over 2-hour period
 - Consider 2-hour release for all cases
 - Reg 1.183 rev 1 is the least conservative for a limited 2-hour release
 - TID remains the most conservative model
 - All models confirm that EAB for OPR1000 within 700m



Iodine release history (EAB scenario)



Normalized TEDE against Distance (2 hour exposure)

Normalized TEDE against Distance (2 hour exposure)

Conclusion

- Assessed **discrepancy between source term models**
 - **MST (OPR1000)** models include **wide range of scenarios**
 - Many scenarios are **low frequency & high consequences** sequences
 - Result in significantly higher release fraction compared to TID & AST
 - **DBA MST** have significant plume delays and ends before 72 hours
 - Among DBA like scenarios, **TID** still the most conservative
 - Regulatory guide 1.183 rev 1 closest to TID and is more conservative at further distance
- **Both amount and frequency of release are important**
- Contribution of radionuclides **varies** across the models
 - Iodine main contributor to TEDE at 700m for seven days analysis
 - Significant tellurium contribution for some models
- EAB determination consistent across all models
 - 2-hour release results in Reg guide 1.183 rev 1 as **least conservative**
 - May need careful consideration for EAB determination

Thank you.