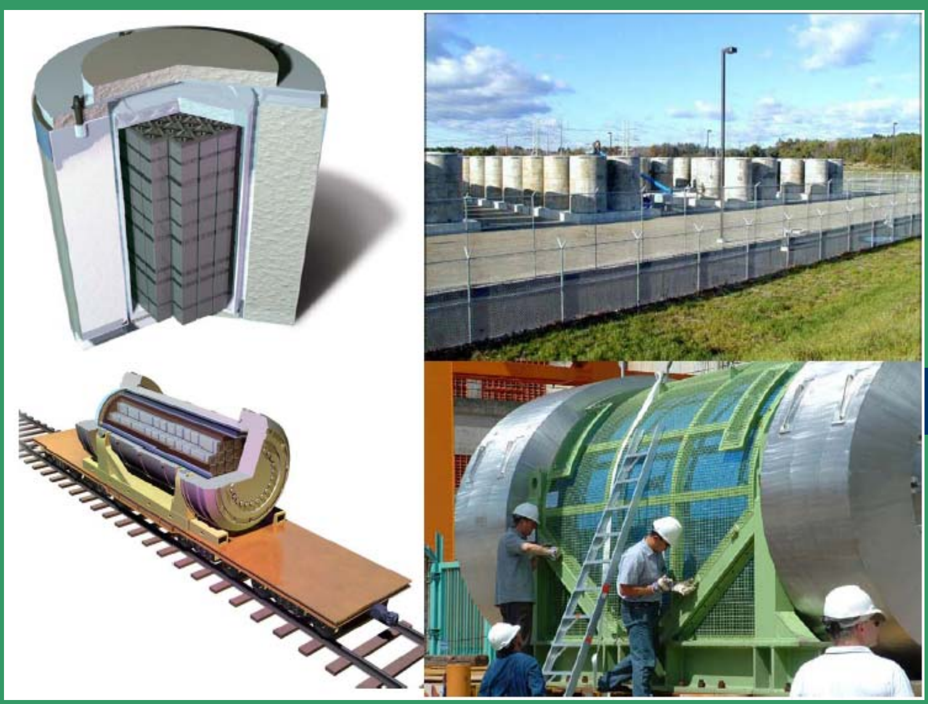
Radiological Safety of Spent Fuel Storage and Transport



PATRAM 2010

International Maritime Organization
London, UK
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A SPENT FUEL TRANSPORT AND STORAGE SAFETY SUMMARY

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NAC INTERNATIONAL

Radiological Safety of Spent Fuel Storage and Transport

Topics

- Introduction and Objective
- Background: The Chernobyl Accident
- Dose Modeling for Beyond-Design-Basis (BDB) Events
- Spent Fuel Storage, Transport System (SFSTS) BDB Event
- Comparative Population Doses from Non-Nuclear Industries
- Conclusions
- Questions

Introduction

In 1994, the Vice President of the United States, Mr. Albert Gore, reportedly called spent fuel transportation a “mobile Chernobyl.”

- These words are well-known by many in nuclear industry
- They have suggested a good framework of comparative assessment of spent SFSTS doses for BDB events to address public concern
- Develop assessment of credible worst-case BDB event for SFSTS, based on Chernobyl accident, post-TMI research, and on cask testing
- Use doses from non-nuclear industries as assessment tool for U.S. society’s comparative radiological risk from SFSTS BDB events
- Compare SFSTS doses for credible worst case BDB event

Objective: conservatively realistic analyses to show BDB event doses below those U.S. society routinely accepts

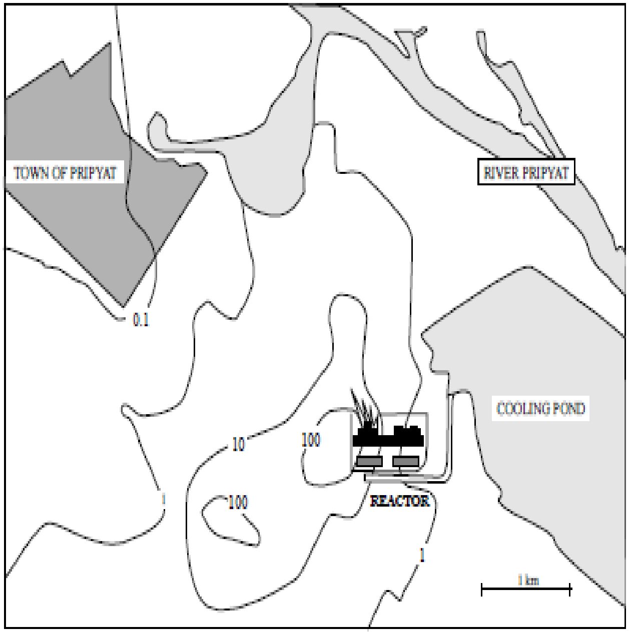
Background: The Chernobyl Accident

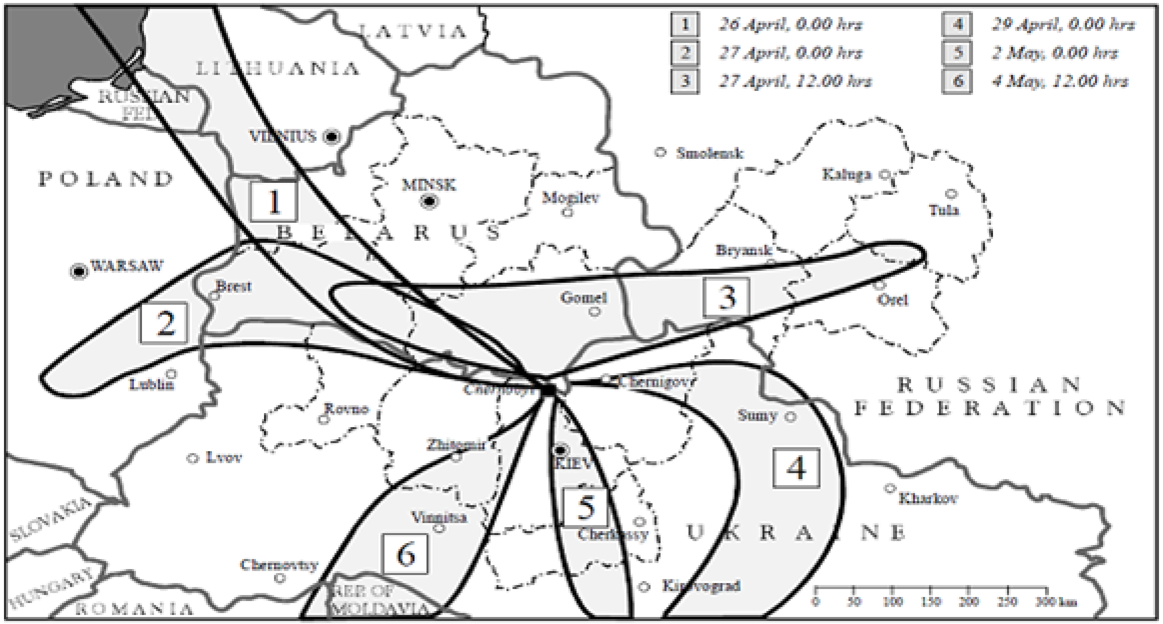
- Chernobyl Unit 4 (CNPP4): 2nd generation RBMK 1000 plant
- Accident occurred 26 April 1986 – explosive reconfiguration
- Up to 60% of core took up residence outside reactor hall
- 100% of core exposed to atmosphere for long period
- Releases continued for 40 days
- Only ~ 30% of Cs inventory released – 139 PBq (3.76 MCi)
- 50 year collective effective dose equivalent (CEDE) from long-lived nuclides: 50,225 person-Sv (p-Sv), or 0.0097 Sv / person
- 50 year collective effective dose equivalent (CEDE) per Ci of long-lived nuclides: about 0.013 Sv / Ci

Results were unacceptable, but not as bad as safety analysis modeling would predict.

Background: The Chernobyl Accident, continued

- Several towns/settlements close to CNPP4
- Initial plumes (24 – 36 hours) in 45° arc to northwest of CNNP4
- 5 km population density in arc is ~ 5000 people / km²
- Evacuation not completed until plume direction changed
- Conservative population densities for transport/storage modeling





Population Dose Modeling for BDB Events

- Conservative safety-analysis-based, dose codes/modeling for dose studies result in BDB event doses far higher than realistic
- Need assessment tool for BDB event doses, a reasonable, objective standard for determining society's comparative radiological risk
- Tool can be used to support stakeholder education on comparative safety of SFSTS for BDB events

Population Dose Modeling for BDB Events, continued

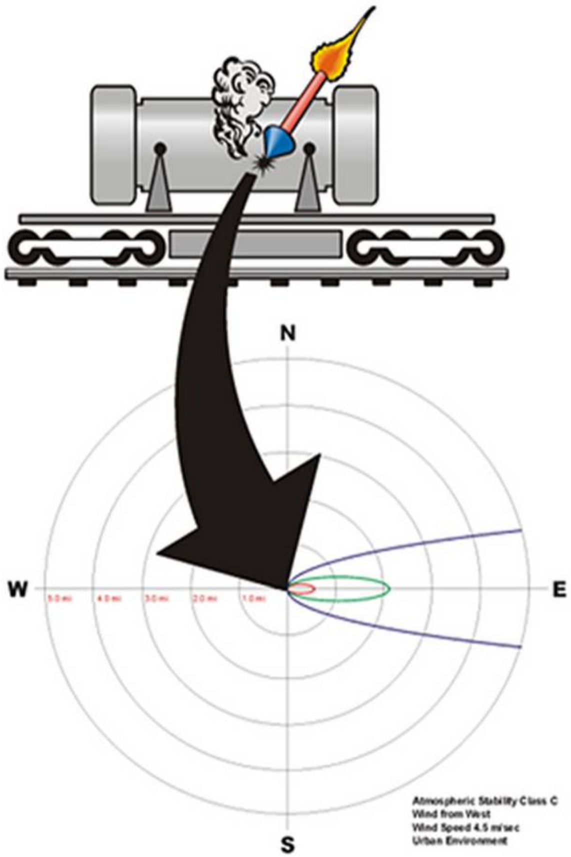
Several typical conservatisms in safety-analysis-based codes/modeling:

- Enhanced source terms typically assumed
- Physical/chemical removal processes during release largely ignored
- Distance from source is surrogate for dose
- Presence in plume is surrogate for external or internal exposure
- No population migration/evacuation – distance is worse surrogate
- Full area populations assumed with no protection/shielding
- Uniform distributions assumed (not natural “lumpy” distributions)
- Internal dose models can use outdated metabolics, DCFs
- Gravity affects poorly modeled - dispersion may be too conservative
- Long-term re-suspension assumed for unrealistic exposures
- Many models assume no decontamination, natural or otherwise
- Local dose reduction features missing – exposures overestimated

ADAPTRAC Population Dose Model Development for BDB Events

- Note: no releases for any design basis (DB) event are acceptable
- Worst case BDB event for SFSTS is high energy density device (HEDD) attack, not an accident
- Use typical U.S. storage/transport system design and contents
- Use U.S. research/testing on fractional releases for containment penetration by HEDD
- Model includes event characteristics of CNPP4 accident, e.g.:
  - Cs and Sr release, dispersal, and dose pathways (upper atmosphere injection, near-by high population densities, long term release period, on-going food consumption, slow evacuation, etc.)
  - Exposed total population of ~ 5.2 million people
  - Dose distribution over 3 time periods in 50 year CEDE
  - Conservatisms in dose assessment as noted by UNSCEAR

SFSTS BDB Event: CEDE From HEDD Attack*



Type of CEDE	Year 1 (person-cSv)	Years 2-10 (person-cSv)	Years 11–50 (person-cSv)	Totals (person-cSv)
External CEDE	770	1,150	1,300	3,220
Internal CEDE	730	1,350	200	2,280
Thyroid CEDE	0	0	0	0
Totals	1,500	2,500	1,500	5,500
Total 50 Year Average Annual Dose to Individual (cSv)	0.0003	0.00005	0.000007	0.00002

*Pennington, C.W., 2010. A demonstration of the comparative radiological safety of commercial nuclear power generation in the USA. *Int. J. Nuclear Governance, Economy and Ecology*, Vol. 3, No. 1, pp.59-103

Comparative Population Doses from Non-Nuclear Industries

Population dose characteristics of these seven non-nuclear industries are not regulated: how they expose the public to radiation

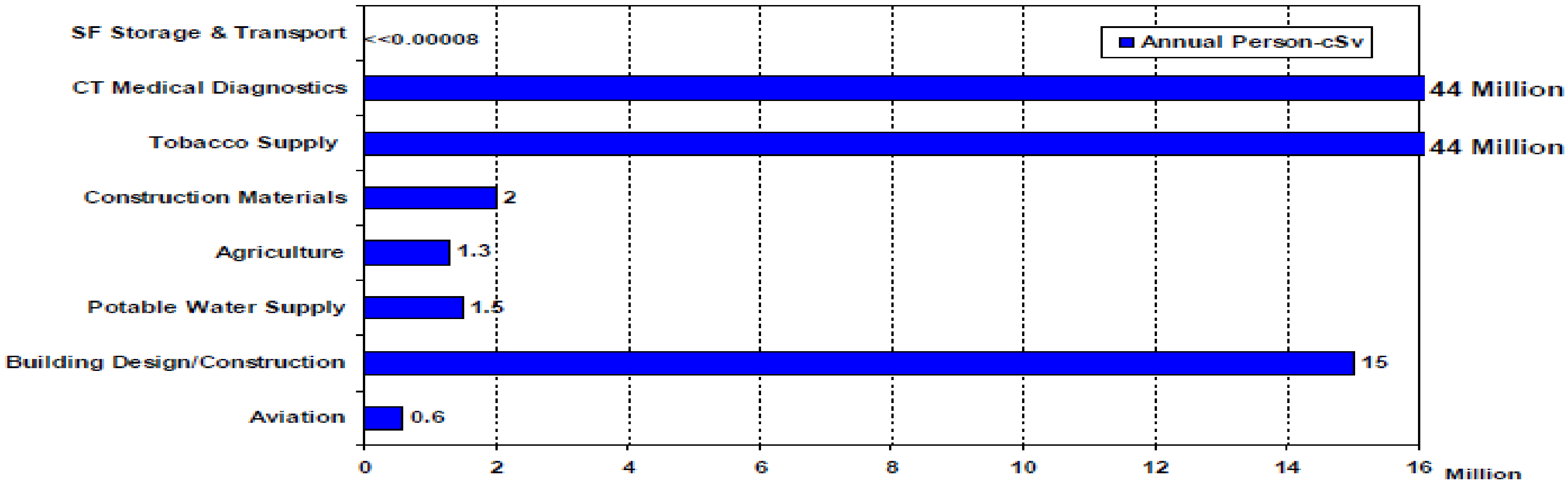
- Medical Diagnostics: radiation for diagnosis of condition
- Tobacco Supply: radionuclide inhalation from cigarette smoking
- Building Design/Construction: radon/thoron in-leakage, trapping; inhalation by occupants
- Potable Water Supply: radon, radium, uranium in public, private water supplies are consumed by public
- Aviation: flying reduces "shielding" from cosmic radiation; crew and passengers are exposed to more cosmic radiation
- Agriculture: soil/fertilizer radionuclides increase direct radiation, release radon, thoron, radioactive dust to workers and others
- Construction Materials: concrete, brick, stone, tile, asphalt are rich in radioactivity; people outdoors and indoors are exposed

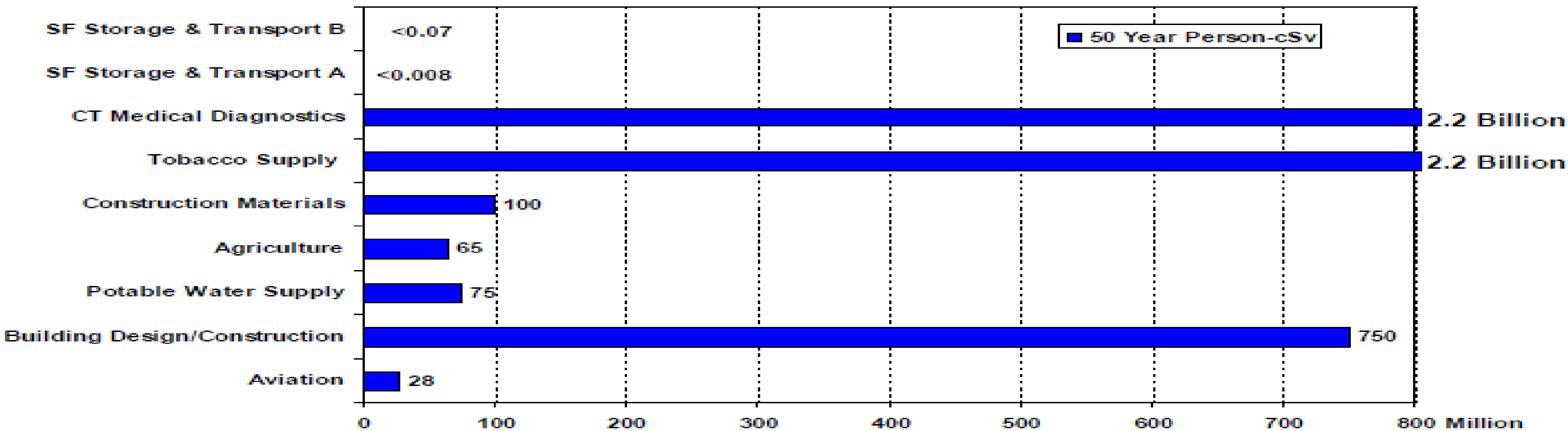
Comparative Population Doses from Non-Nuclear Industries, continued

Comparisons of CEDE for non-nuclear industries with spent fuel storage and transport

Industry	Current Annual CEDE (Person-cSv)	Estimated Previous 50 Year CEDE (Person-cSv)	Projected 50 Year CEDE (Person-cSv)
Aviation	>0.6 million	>12 million	>28 million
Building Design/Construction	>15 million	>430 million	>750 million
Potable Water Supply	>1.5 million	>38 million	>75 million
Agriculture	>1.3 million	>52 million	>65 million
Construction Materials	>2 million	>78 million	>100 million
Tobacco Supply	>44 million	>3 billion	>2.2 billion
CT Medical Diagnostics	>44 million	>1 billion	>2.2 billion
Total for 7 Non- Nuclear Industries	>108 million	>4.6 billion	>5.4 billion
Commercial Spent Fuel Storage and Transport. Supporting growth to 300 reactors over next 50 years; 2 scenarios: A and B	<0.00008 million	<0.002 million	A. Without Breach Events: <0.008 million B. With 10 Credible Breach Events: <0.07 million

Comparative Population Doses from Non-Nuclear Industries, continued





Conclusions

- For HEDD attack on SFSTS, ADAPTRAC projects 50 year CEDE per Ci of long-lived nuclides of about 0.017 Sv / Ci, 30% higher than actual CNPP4 results, demonstrating conservative realism
- For bounding, credible BDB events, SFSTS do offer any significant risk of radiological injury or death to the public
- Many non-nuclear industries produce lognormally distributed CEDE to the public, and the CEDE is typically *unregulated, unmonitored, uncontrolled, unreported, and undisputed*
- Non-nuclear industries produce far higher <u>actual</u> radiological impact on public than any credible <u>hypothetical</u> doses from a BDB event for SFSTS, by orders of magnitude
- SFSTS very safe compared to what society accepts. This can be used to support advocacy of SFSTS safety

Looking to the future
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QUESTIONS?

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BACKUP MATERIAL

Building Design/Construction Industry: Examples by Counties in Six U.S. States

State and Selected Counties	Population with High Exposure (People)	High Exposure Population's Average Annual CEDE (Person-cSv)	High Exposure Population's Average Annual TEDE (cSv)	High Exposure Population Peak Annual TEDE (cSv)	High Exposure Population 50-Year CEDE (person-cSv)
New York	450,000	3.5×10^5	0.8	19	1.8×10^7
Erie	47,000	4.9×10^4	1.0	19	2.5×10^6
Onondaga	54,000	5.6×10^4	1.0	18	2.8×10^6
Dutchess	22,500	1.4×10^4	0.6	7	1.7×10^6
Monroe	20,000	1.8×10^4	0.9	11	9.0×10^5
Pennsylvania	2,865,000	4.8×10^6	1.7	14	2.4×10^8
Lancaster	108,000	1.6×10^5	1.5	5.4	8.0×10^6
Lehigh	86,000	1.3×10^5	1.5	4	6.5×10^6
York	90,500	1.5×10^5	1.7	8	7.5×10^6
Dauphin	73,000	1.4×10^5	1.9	14	7.0×10^6
Iowa	420,000	5.5×10^5	1.3	6.7	2.7×10^7
Polk	76,000	8.9×10^4	1.2	2.3	4.5×10^6
Woodbury	14,000	1.8×10^4	1.3	3.4	9.0×10^5
Scott	13,000	1.6×10^4	1.2	2.4	8.0×10^5
Massachusetts	235,000	3.0×10^5	1.3	3.2	1.5×10^7
Middlesex	44,000	5.9×10^4	1.3	3.2	3.0×10^6
Worcester	19,500	2.3×10^4	1.2	2.1	1.2×10^6
Colorado	250,000	3.4×10^5	1.4	11	1.7×10^7
Adams	25,500	3.2×10^4	1.3	2	1.6×10^6
Arapahoe	47,500	8.2×10^4	1.7	2.5	4.1×10^6
Douglas	23,500	2.8×10^4	1.2	1.7	1.4×10^6
El Paso	25,500	3.2×10^4	1.3	2.4	1.6×10^6
Ohio	400,000	5.6×10^5	1.4	14	2.8×10^7
Cuyahoga	17,000	2.5×10^4	1.5	3.8	1.3×10^6
Fairfield	29,500	5.7×10^4	1.9	12	2.9×10^6
Franklin	66,000	7.8×10^4	1.2	2.4	3.9×10^6
Montgomery	16,000	2.1×10^4	1.3	2.4	1.1×10^6

Dry Spent Fuel Storage

Canister-based, concrete spent fuel storage technology

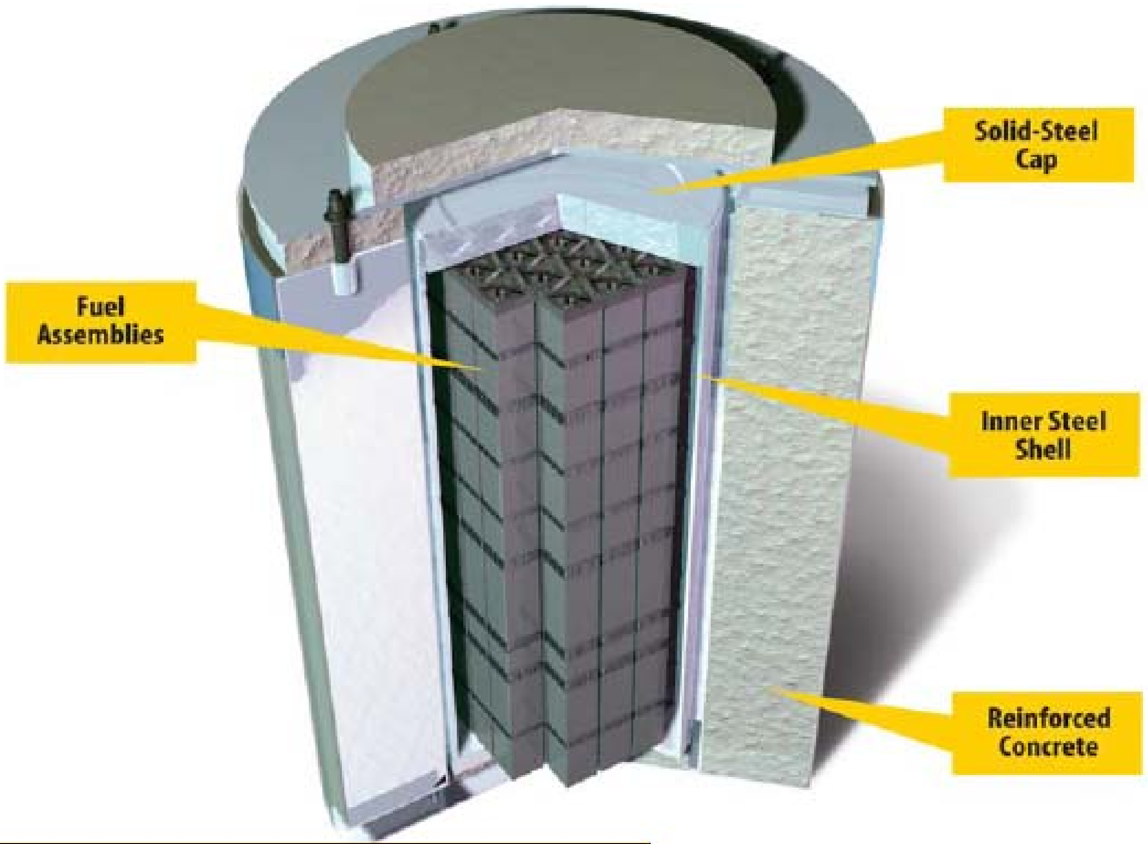
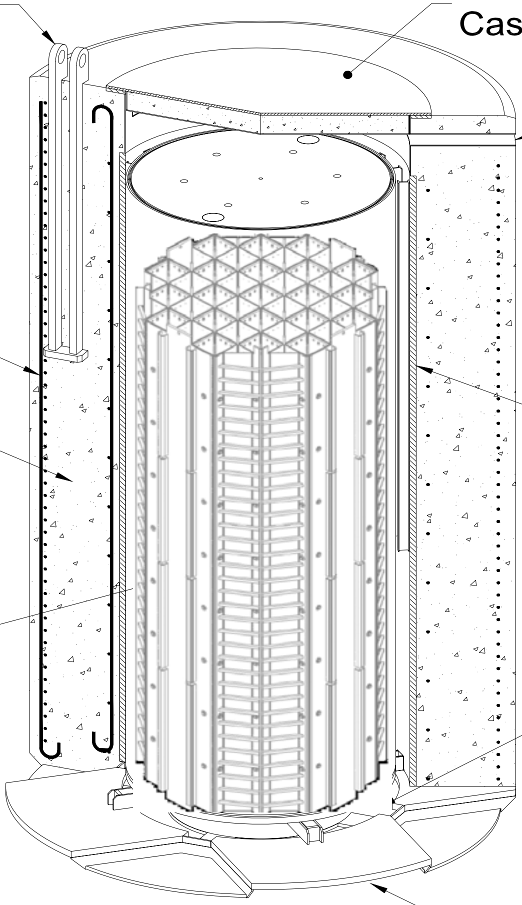


Illustration Courtesy of The Nuclear Energy Institute

NAC Dry Storage System Design

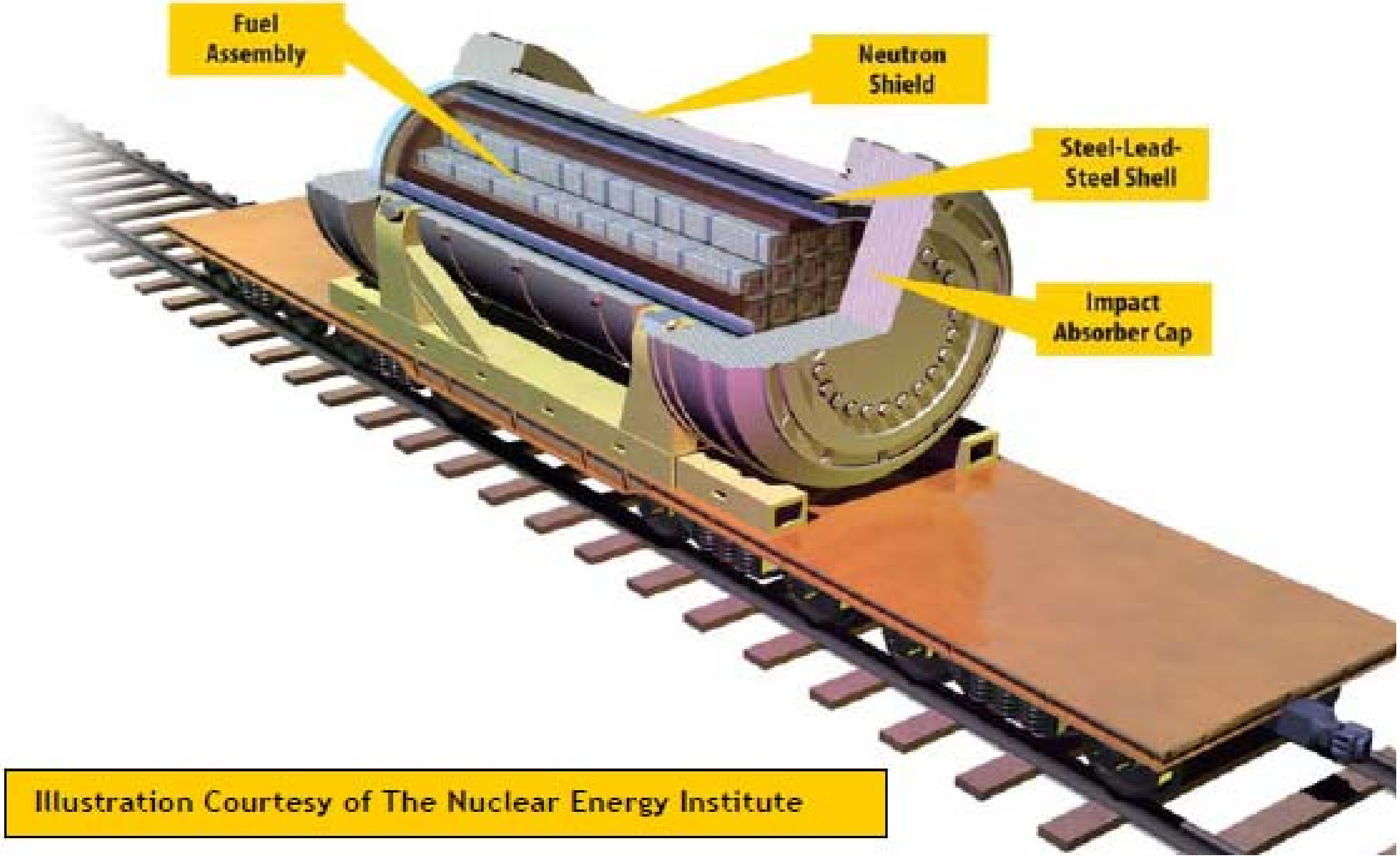
System design features:

- concrete
- aggregate
- rebar
- steel liner (canister armor)
- transportable storage canister (TSC)
- basket

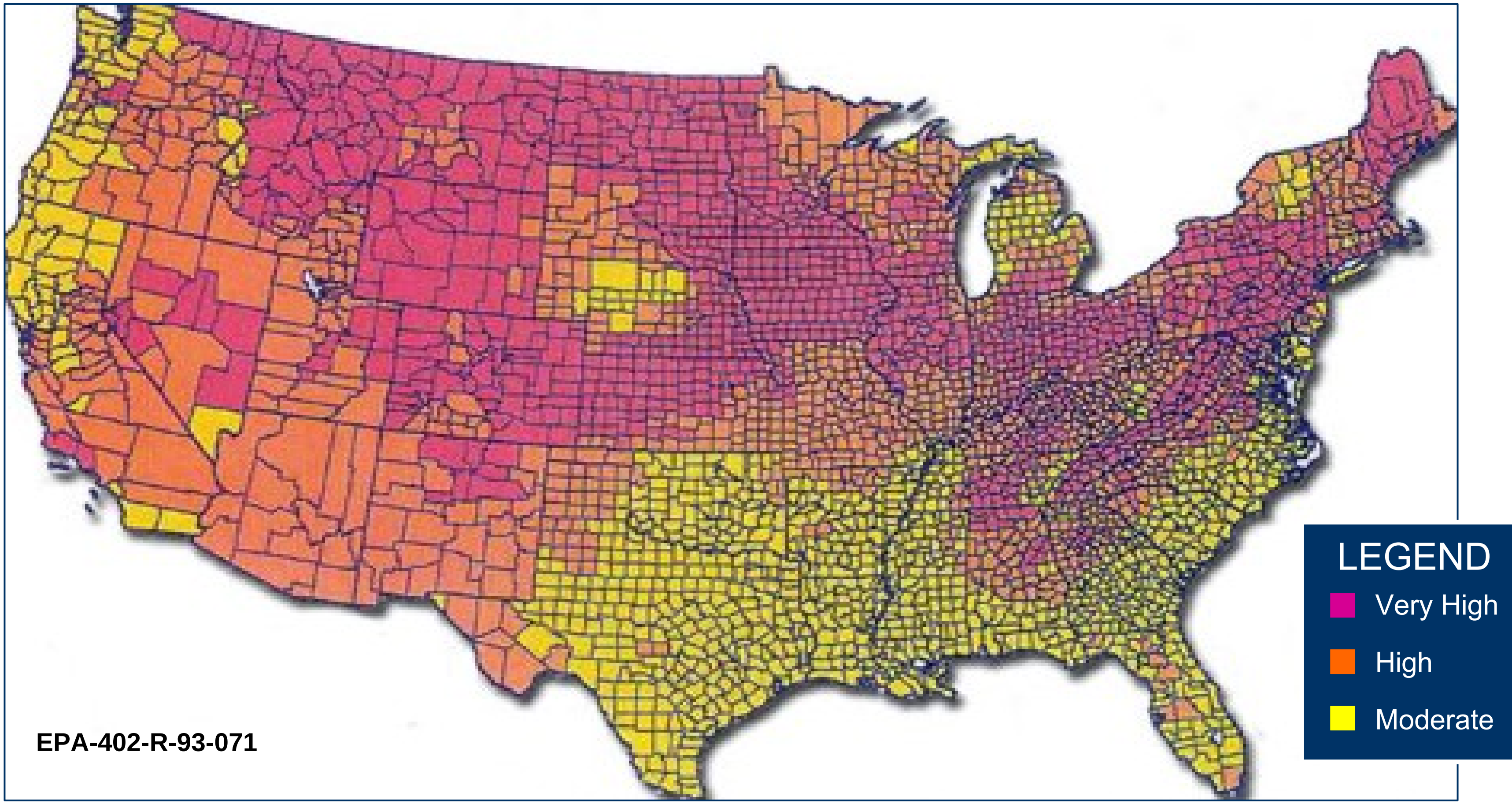


Dry Spent Fuel Transport

Transport cask and transport system



Areas of High Naturally Occurring Radioactive Materials (NORM, including Radon) in the U.S.



Lognormal Distribution

For two non-nuclear industries