# Small Modular Reactor Safety and Security Issues

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# The big question

- Are small modular reactors (SMRs) fundamentally safer and more secure than conventional large reactors?
- Arguments:
  - Easier to cool—allows for “passive” safety
  - Less radioactive material to disperse in an accident (or terrorist attack)
  - Designs different from water-cooled reactors are inherently safer
- Answer: No. It all depends on the details—especially for multi-unit sites

# Small isn't always safer

- Even if the amount of radioactivity in each module is small, the amount that could be released from an SMR plant depends on
  - Number of modules
  - How they interact during an accident
  - Are there common-cause failures that would lead to multiple meltdowns?
    - Earthquakes, flooding
    - Sabotage
  - Spent fuel storage (!)

# “Passive” safety claims are misleading

- Earlier this year design flaws of the NuScale SMR “passive” cooling system came to light
- Could cause unstable conditions resulting in core melt
- The NRC staff “approved” the NuScale design by placing these concerns in a parking lot to be addressed by future applicants
- At least one member of the NRC independent Advisory Committee on Reactor Safeguards believes this was improper and was driven by an arbitrary deadline
- Non-concurring NRC scientist Dr. Shanlai Lu estimates the core damage risk per module due to operator error could be as high as one in 30,000 per year, or one in 2,500 per year for a 12-module plant
  - Higher risk than most large light-water reactors!

# Using up safety margin

- Nuclear safety depends not only on intrinsic features but also many other factors related to design, construction, and operation
- SMRs' so-called inherent safety features are being used to justify
  - Locating them in densely populated urban areas
  - Eliminating off-site radiological emergency planning
  - Reducing or eliminating control room operators
  - Reducing or eliminating protections against terrorist attack
  - Reducing or eliminating containment
  - Eliminating requirements for nuclear-grade safety systems
  - Reduction in regulatory oversight
- Even if SMR designs were fundamentally safer, the cumulative impact of these regulatory rollbacks could undermine those advantages

# Eliminating emergency planning zones

- SMR proponents argue that their reactors are so safe that off-site emergency response actions, such as evacuation or potassium iodide distribution, will not be necessary in the event of a core melt
  - The smaller amount of radioactivity that could be released is a major part of this argument
- But even “small” reactors can release highly dangerous quantities of fission products

# 20 MW-thermal microreactor, 1 year of operation

**4.7 km (2.8 mi)**

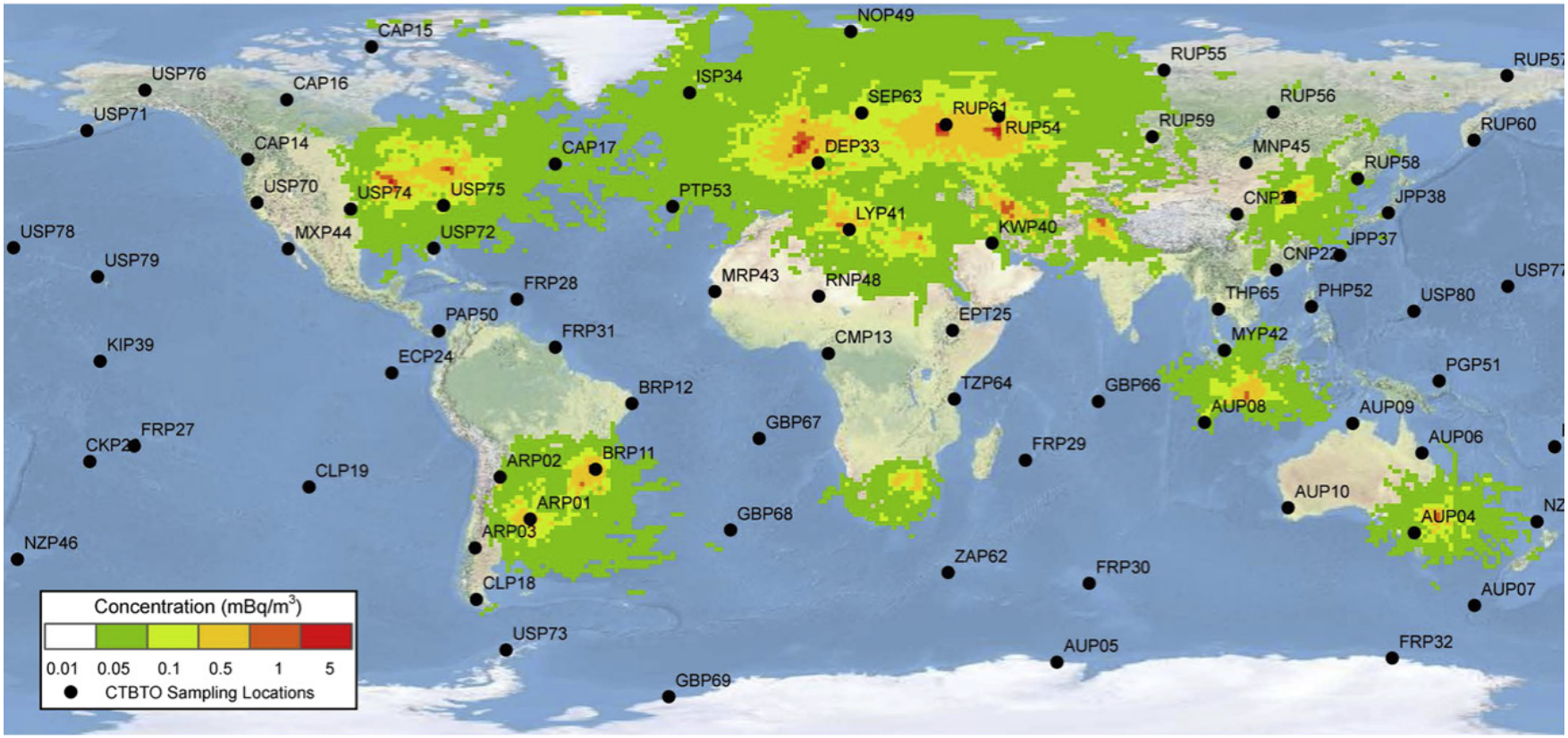
Table 4. Inhalation dose consequences for microreactors.

| Release Type | Source | Collocated Worker, rem | Public, rem |
|---|---|---|---|
| 100% | CED | 4.70E+05 | 8.73E+03 |
| Radionuclide | Cloud gamma | 1.59E+03 | 2.37E+01 |
| Release | Total | 4.72E+05 | 8.75E+03 |
| Sodium Fast | CED | 1.53E+04 | 2.51E+02 |
| Reactor | Cloud gamma | 2.43E+02 | 2.57E+00 |
| Release | Total | 1.55E+04 | 2.54E+02 |
| MCFR | CED | 3.35E+04 | 3.28E+02 |
| Release | Cloud gamma | 5.52E+02 | 5.39E+00 |
| | Total | 3.41E+04 | 3.33E+02 |
| PWR | CED | 1.82E+04 | 1.55E+02 |
| LOCA | Cloud gamma | 2.97E+02 | 3.52E+00 |
| Release | Total | 1.85E+04 | 1.59E+02 |

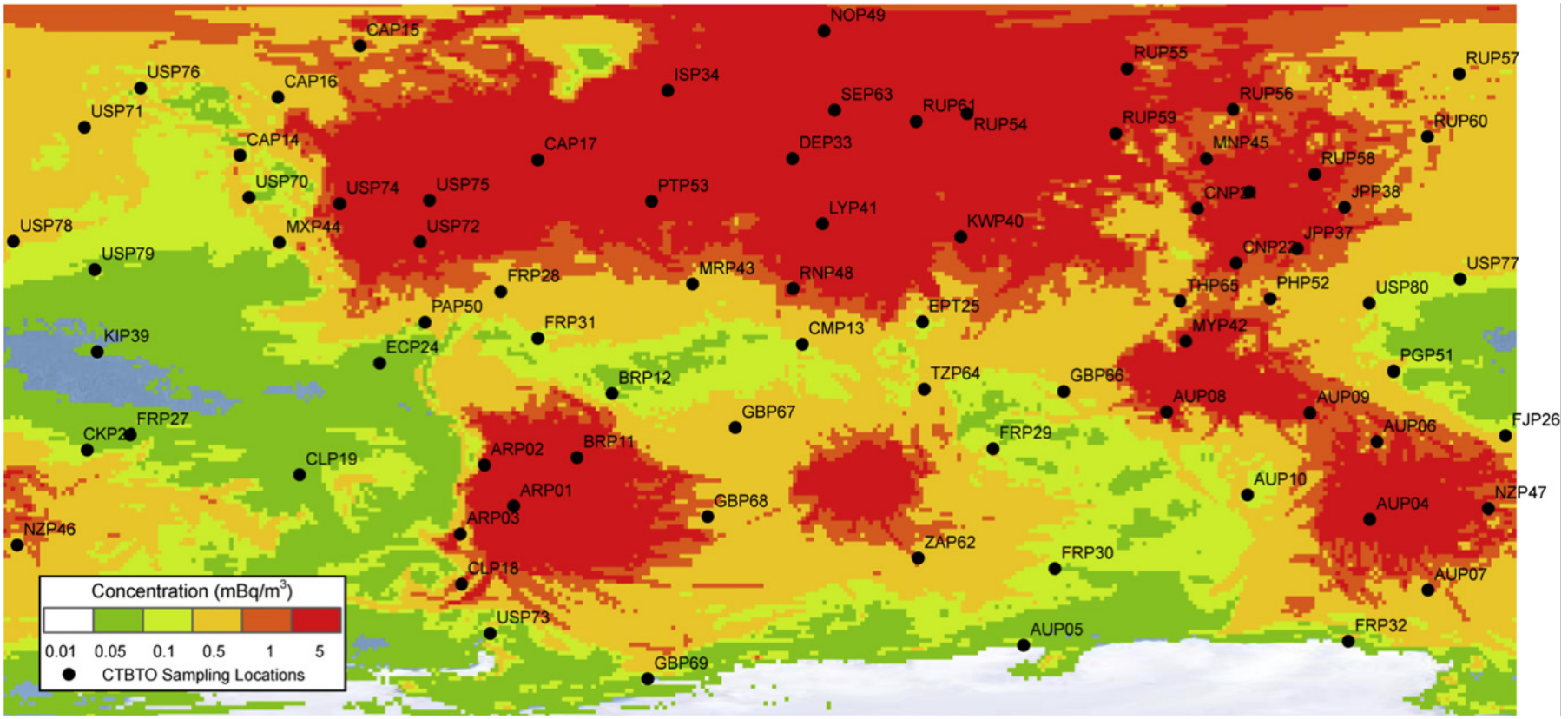
Troy P. Reiss, *Evaluation of Microreactor Inhalation Dose Consequences*, INL/EXT-20-58163, Idaho National Laboratory, April 2020.

# Example of a less safe “advanced” reactor: the MSR

- One of the advantages of the molten salt-fueled reactor (MSR) is the flexibility provided by a circulating liquid fuel
- Noble gas fission products are stripped from the fuel by sparging with helium gas
- MSR vendors such as Terrestrial Energy assert that they will be able to trap and retain noble gas fission products
  - few details provided on the specifications, practicality, efficiency, reliability, and cost of off-gas processing systems
- 40 to 90 percent of cesium-137 generated would be released from the core into the off-gas system under NORMAL conditions
- Xenon (Xe) releases from MSRs could pose problems not only for public health and safety, but for Comprehensive Test Ban Treaty verification




**Global maximum calculated concentration of $^{133}Xe$ expected emission from current isotope producers, assuming releases of $5x10^9$ Bq/day (T.W. Bowyer et al., Journal of Environmental Radioactivity 115 (2013) 192-200)**




**Global maximum calculated concentration of $^{133}Xe$ expected emission from current and future isotope producers, assuming releases of $1x10^{12}$ Bq/day (T.W. Bowyer et al., Journal of Environmental Radioactivity 115 (2013) 192-200)**

# Controlling the xenon background

- Unacceptable IMS interference occurs at Xe emission levels below those needed to meet safety limits
- A definitive 2012 study determined that a maximum average Xe-133 emission rate of **$5x10^9$ Becquerels/day (0.14 curies/day) per facility** would be adequate to control the problem
- 400 $MW_{th}$ Terrestrial Energy molten salt reactor would generate **$1x10^{17}$ becquerels/day** of $^{133}Xe$
  - Source term is seven orders of magnitude greater than the $5x10^9$ Bq/day level