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Change in Two Dose Performance Measures as Modeling Progressed at Proposed US Repository in Tuff

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Recommendations of Blue Ribbon Panel that apply to regulations

- "Ensure that future siting efforts are informed by past experience…"
- US Environmental Protection Agency (EPA) and US Nuclear Regulatory Commission (NRC) should "…work together to define appropriate process (with opportunity for public input) for developing a generic safety standard for geologic disposal sites."
- EPA and NRC should develop standards for deep borehole disposal
- Hence, opportune time examine current usefulness and potential additions to standards governing geologic disposal

Talk will discuss three topics

- Key questions poised by BRC related to regulations
- Status of requirements in regulations related to BRC key questions
- Progression of two measures of dose as characterization and modeling progressed at US repository in tuff

Key questions of BRC

- What is the basis a regulation: desired level of protection or what is reasonably achievable?
- Who is to be protected: individuals or populations?
- What is the indicator of compliance?
  - Release or dose?
  - Groundwater separately protected?
- What is the measure of indicator?
  - Limit of compliance?
  - Length of compliance?
  - Location of compliance?
- How should compliance be demonstrated: quantitatively or qualitatively?
- What is the level of confidence required?

Key questions of BRC (continued)

- How should uncertainty be addressed ?
  - Disruptive scenarios, such as human intrusion?
  - Models and parameters?
  - Assurance issues
    - Retrievability of mined and borehole repositories?
    - Credit for institutional controls and for how long?
- Should there be performance requirements for subsystems of the disposal system?
- Should regulations be adaptive?
  - Site-specific or generic?
  - Finished before characterization?

ICRP and IAEA guidance help address initial questions

- **Basis of regulations?** ***Reasonably achievable since geologic disposal easily below background***
- **Who is protected?** ***Individuals***

(US initially included population also)

- **What is the indicator of compliance?** ***Dose***

(US initially included cumulative release also)

- **What is the measure of indicator?**
  - **Limit of compliance?**
    - ***Maximum of background at sea level (1 mSv/yr)***
    - ***Average of 0.3 mSv/yr***

BRC made recommendations on a few questions

- **Need more progress on generic regulations for mined and deep borehole repositories**
- **Should the regulations be adaptive?** ***Yes and No***
  - ***Developed prior to site selection***
    - ***But encourage adaptive learning***
  - ***Generic regulations for all mined sites***
    - ***But unique regulations for deep borehole disposal***

Current state of regulations for remaining key questions

- **What is the indicator of compliance?**
  - **Groundwater separately protected? *Yes***
- **Performance requirements for subsystems? *No***

(US initially did include subsystem requirements)

- **What is the measure?**
  - **Limit and length of compliance?**
    - ***15 mSv/yr for first 10^4 yr***
    - ***1 mSv/yr thereafter to 10^6 yr***
  - **Location of compliance?**
    - ***Down gradient to NTS boundary (18 km)***
    - ***5 km in other directions***
  - **Qualitative or Quantitative? *Quantitative limit but aspects of assurance requirements qualitative***

Current state of regulations for remaining key questions (continued)

- Deterministic or probabilistic?
  - *Probabilistic mean of committed effective dose equivalent as function of time*

- How should uncertainty be addressed?
  - Disruptive scenarios, such as human intrusion?
    - *Special model case that is not included in probabilistic evaluation (US initially included human intrusion)*
  - Retrievability assurance requirement?
    - Mined repositories? *50 yr from initial placement*
    - Deep borehole repositories?
  - Credit for institutional controls? *Yes for 100 yr*
  - Level of confidence? *Reasonable expectation (NRC initially implied reasonable assurance)*

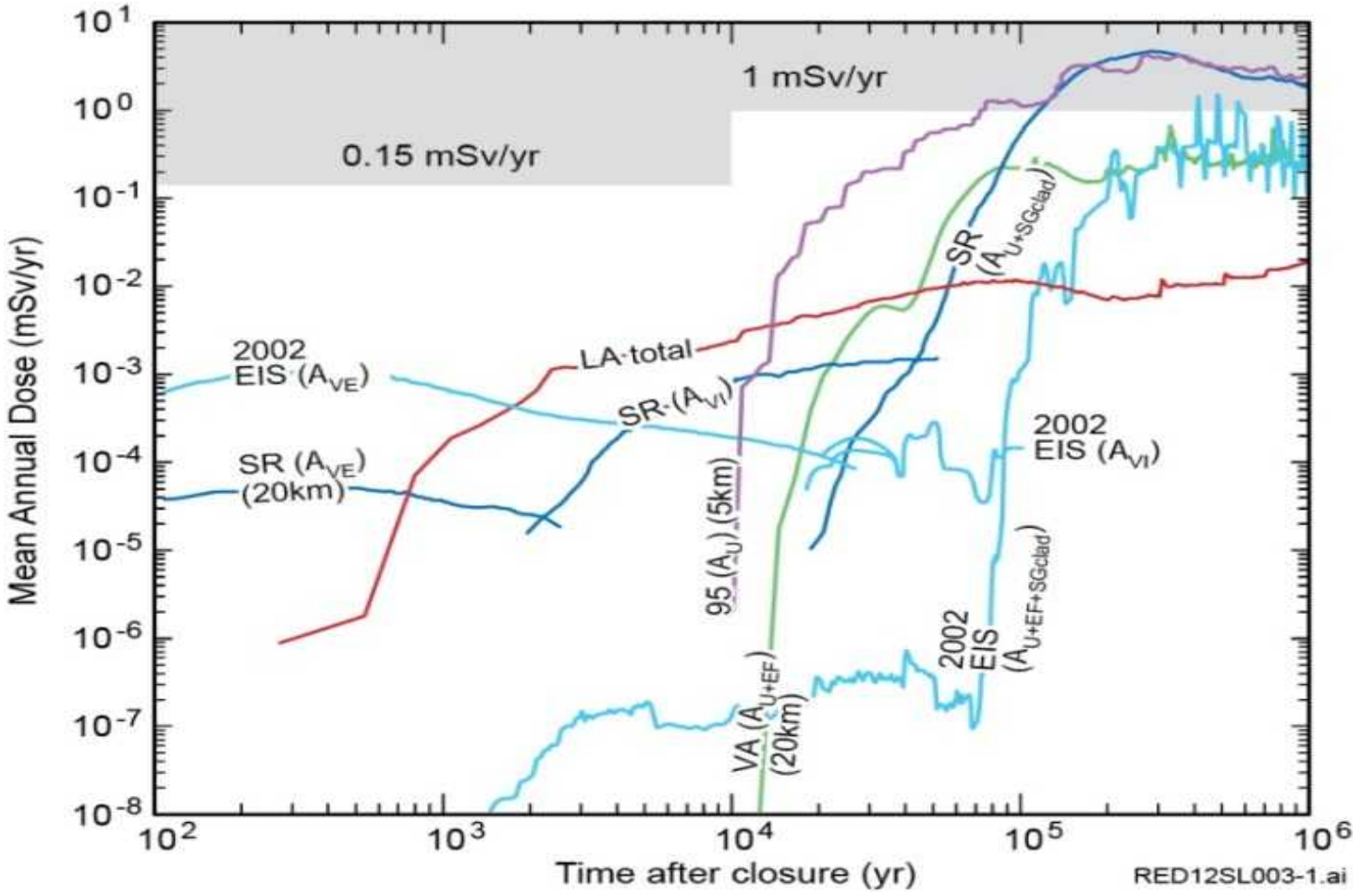
Progression of Modeling

- **Feasibility Analysis**
  - **Design guidance on options for heat and drift placement (minor compliance implications)**
  - **PA-93: 1-D, dual-porosity for UZ (equivalent continue model—ECM); included volcanism**
  - **PA-95: Container degradation model**
- **Suitability/Viability Analysis**
  - **PA-VA: Timing, dilution, dispersion important for dose standard ; thus, major step in model complexity (infiltration, UZ flow, seepage)**
  - **PA-SR: Site Recommendation using conservative assumptions (e.g., Np solubility); volcanism included again and dominated releases at early times**
  - **SSPA and PA-EIS: removed conservatism**

Progression of Modeling (continued)

- **Licensing Analysis**
  - **PA-LA:**
    - **Support for SAR/LA**
    - **Included disruptive volcanism and seismic disruption (required seismic damage codes)**
    - **Both disruptive events dominated dose**
  - **PMA**
    - **More realism in seismic disruption**
    - **Volcanism dominates dose**

Maximum mean dose usually occurred between 10^5 and 10^6 years in performance assessments for repository in volcanic tuff

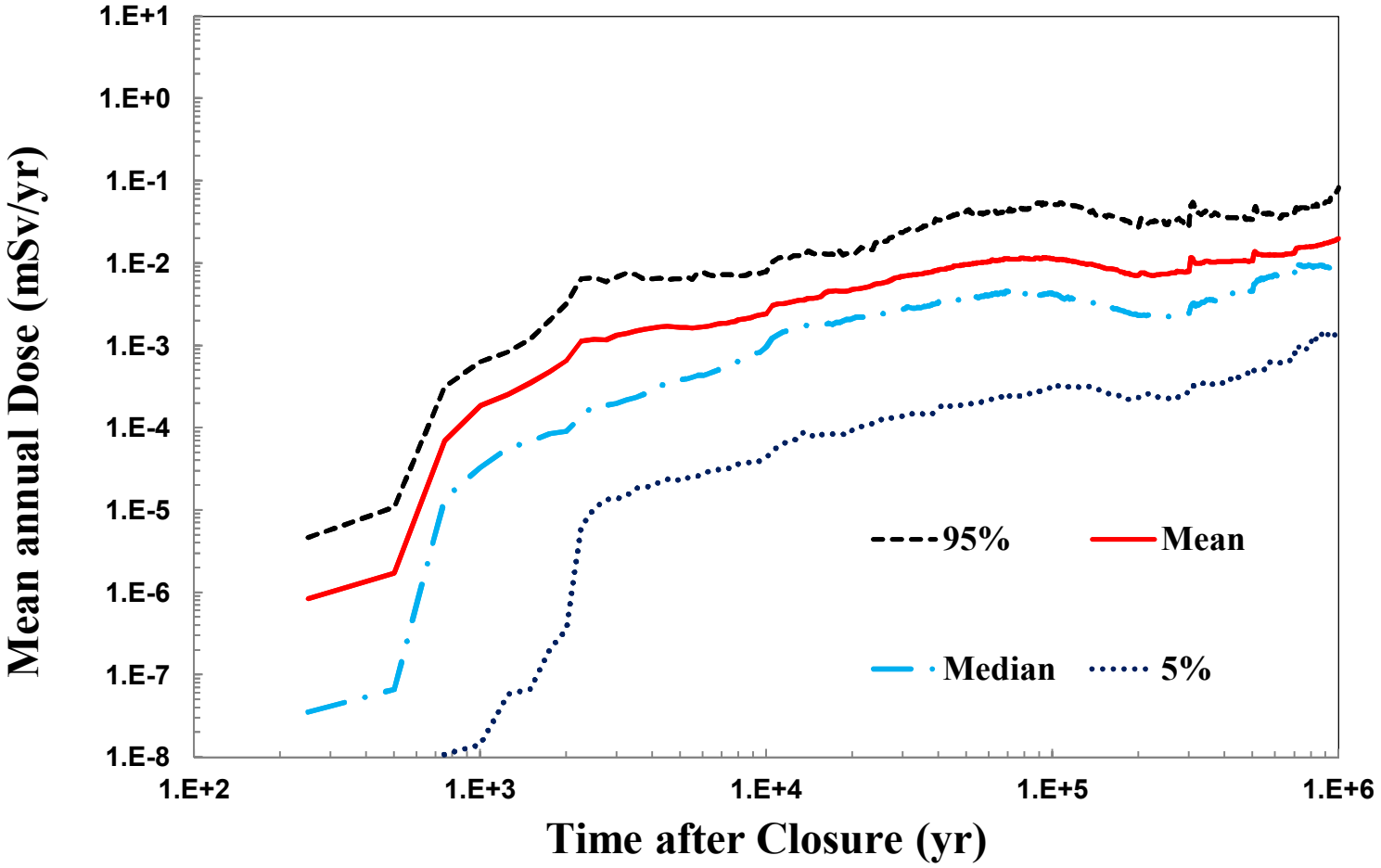


Undisturbed mean doses similar for PA-95 and PA-SR

Undisturbed mean doses similar for PA-VA and PA-EIS

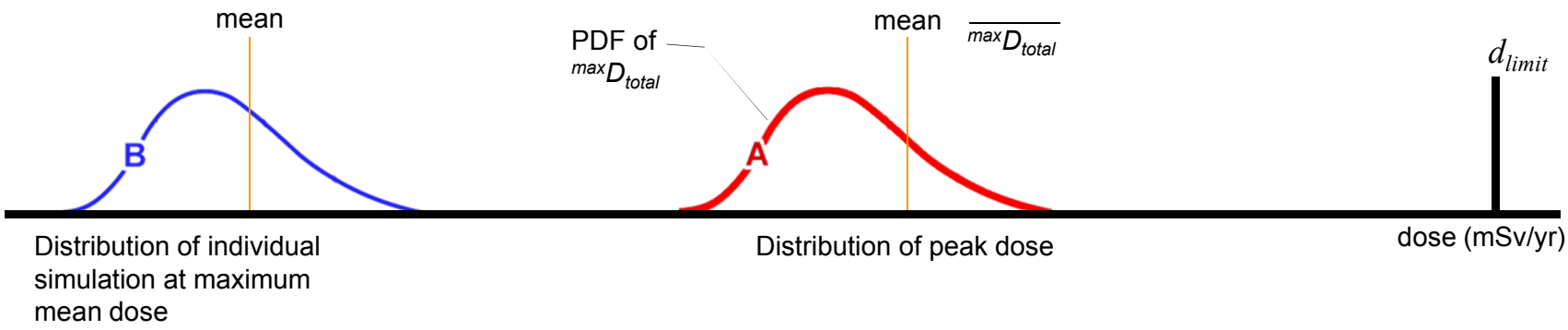
Total doses for PA-LA greatly reduced

NRC requested displaying uncertainty about mean dose



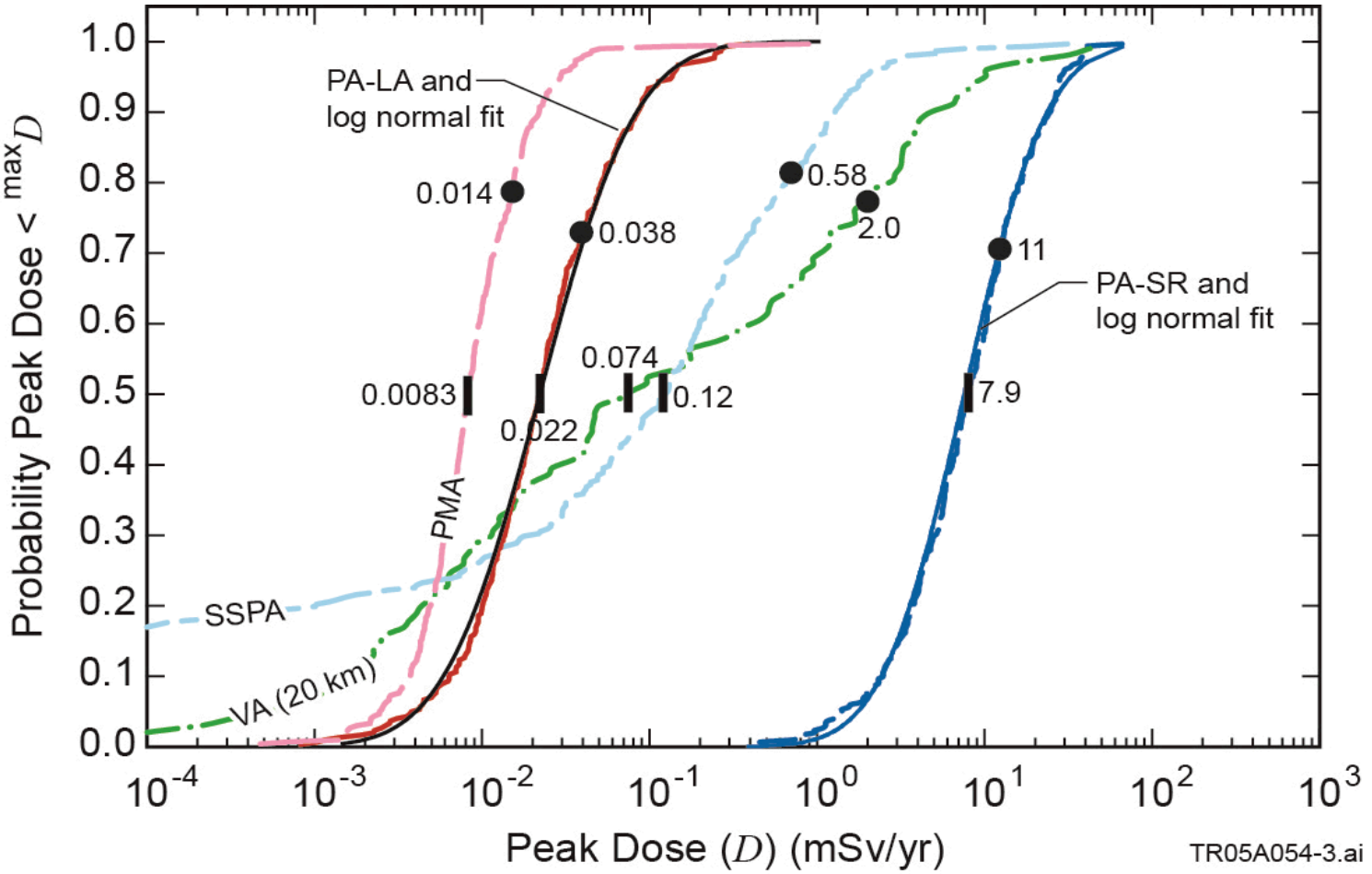
Uncertainty about 0.020 mSv/yr maximum at 10^6 years is 0.001 and 0.083 mSv/yr for 5^{th} and 9^{th} quantiles

If all uncertainty could be quantified, it could be displayed as the spread of results



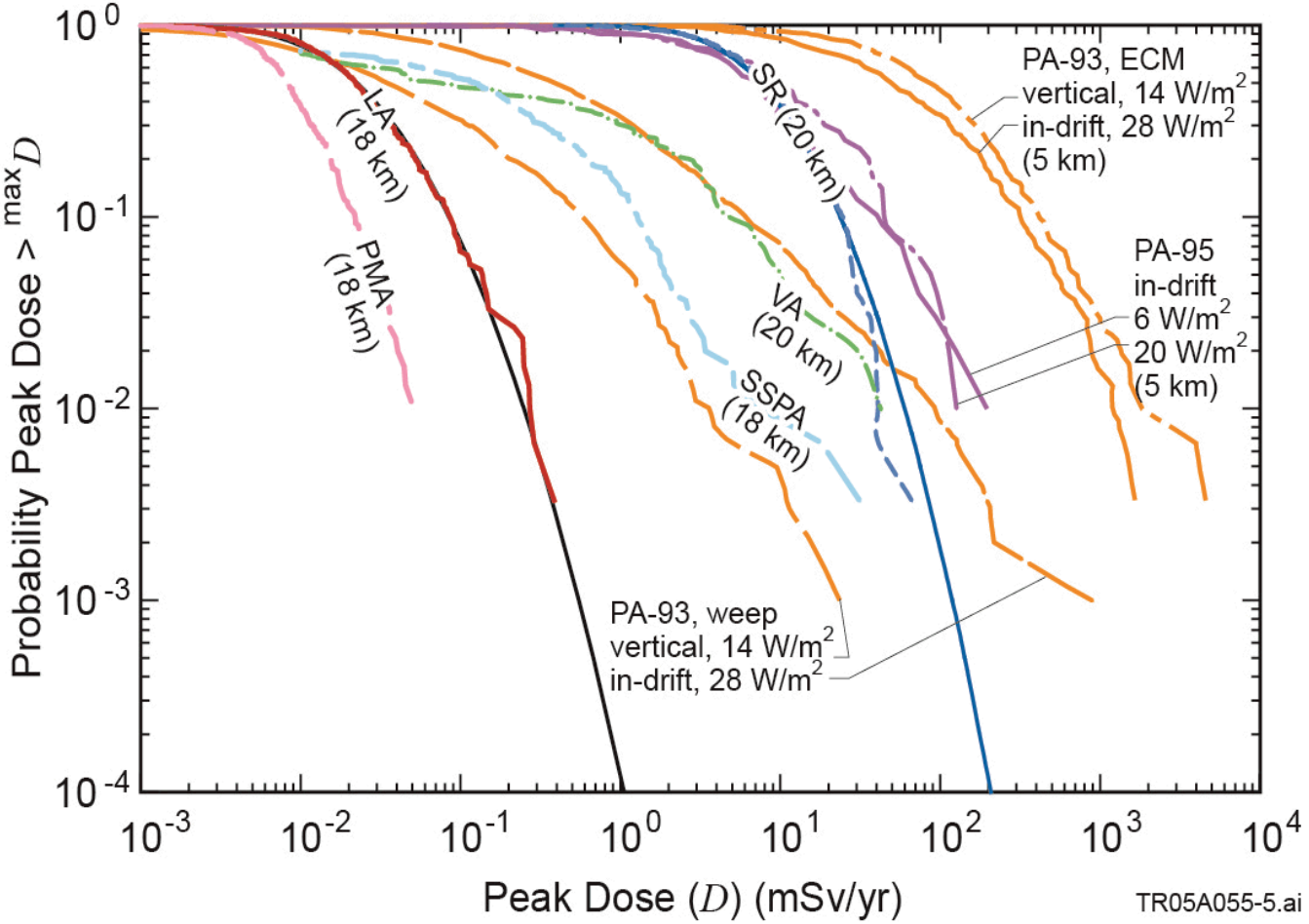
- **Here displaying a distribution of the peak dose from multiple simulations**
- **Mean of distribution of peak doses twice as large as maximum of mean dose (0.038 vs 0.020 mSv/yr)**

Additional dose measure is distribution of maximum peak doses



General decrease of peak doses but uncertainty was not consistently reduced

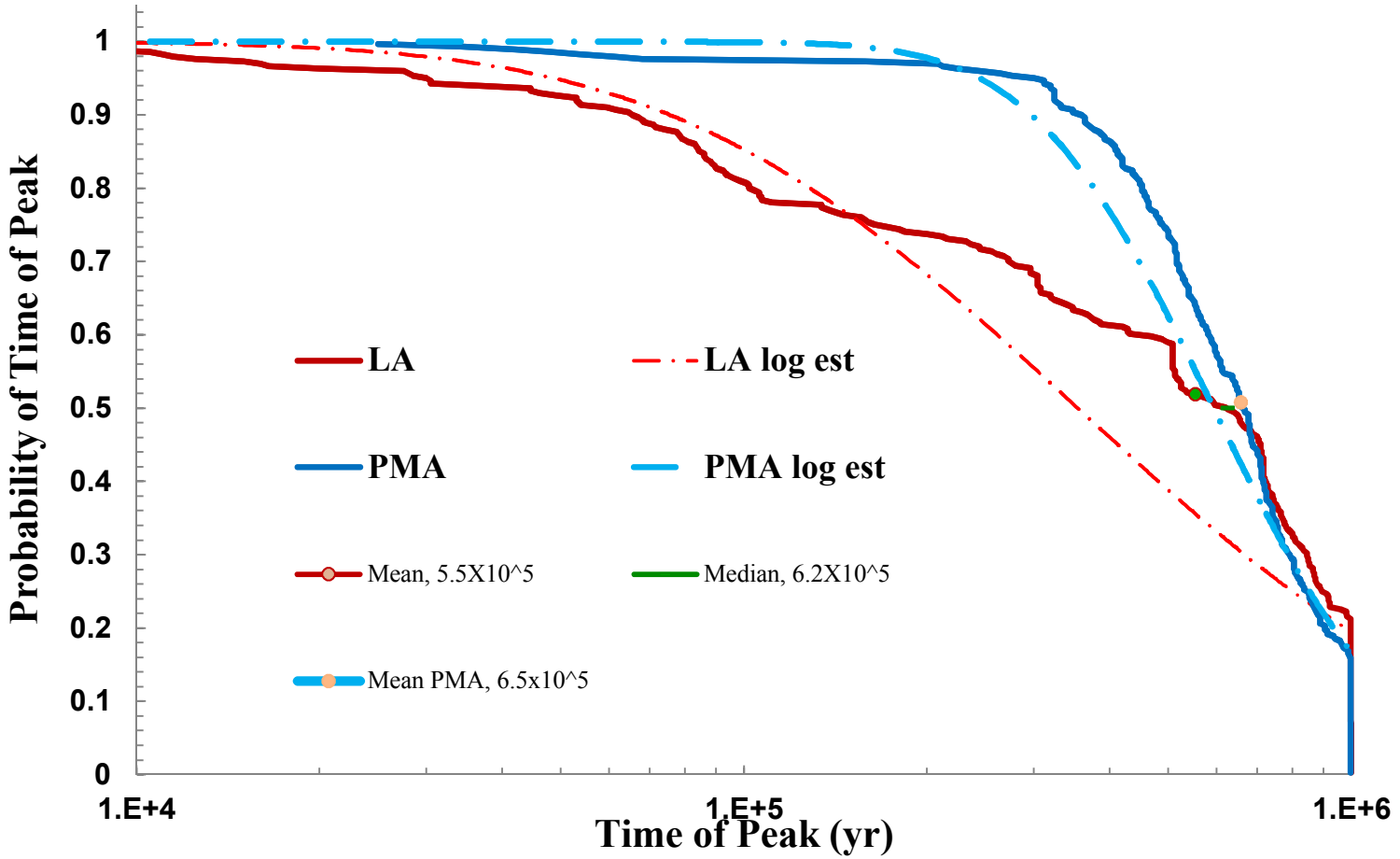
Total dose PA-LA greatly reduced from PA-SR and below range of PA-93



Conservatism introduced in PA-SR according to NRC reasonable assurance

Undisturbed mean doses similar for PA-VA and PA-EIS

Time of peak dose generally between 10^5 and 10^6 years



Times of PMA represented well by lognormal distribution (one phenomenon, volcanism, dominates dose

Times of PA-LA not represented well by lognormal distribution

Take-Away Points

- Much progress occurred when developing site specific standards and regulations for volcanic tuff repository
- Need to move forward on developing generic regulations for mined and deep borehole repositories
  - Previous work provides guidance for siting
  - Important for consent-based siting process
- Here proposed additional dose measure of distribution of peak doses
  - Convenient for relative comparison such as discerning differences in conceptual models and design options
  - Readily shows the range of uncertainty in the peak dose and the probability that the peak dose with be exceeded
- Mean dose as function of time
  - Readily shows when the maximum dose occurs
  - greatly enhanced by displaying various quantiles (e.g., 5^{th}, 50^{th}, and 95^{th}

Comments and Questions?