National Risk Assessment Partnership

NRAP leverages DOE's capabilities to help quantify uncertainties and risks necessary to remove barriers to full-scale CO_2 storage deployment.

Building toolsets and improving the science base to address…

- Potential impacts related to release of CO_2 or brine from the storage reservoir
- Potential ground-motion impacts due to injection of CO_2

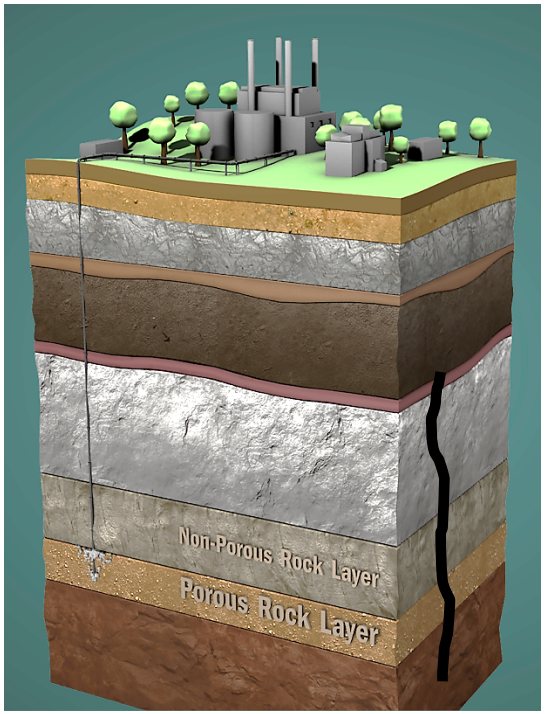
Technical Team

NETL

Berkeley Lab

Los Alamos National Laboratory EST.1943

Pacific Northwest National Laboratory



Stakeholder Group

AEP American Electric Power

Blue Source

bp

EPA United States Environmental Protection Agency

ExxonMobil

Sleaghg

IEc

MIT

NRDC

Schlumberger

Southern States Energy Board

Stanford University

Texas Railroad Commission

University of Utah

Wade, LLC

Whiting

Zurich

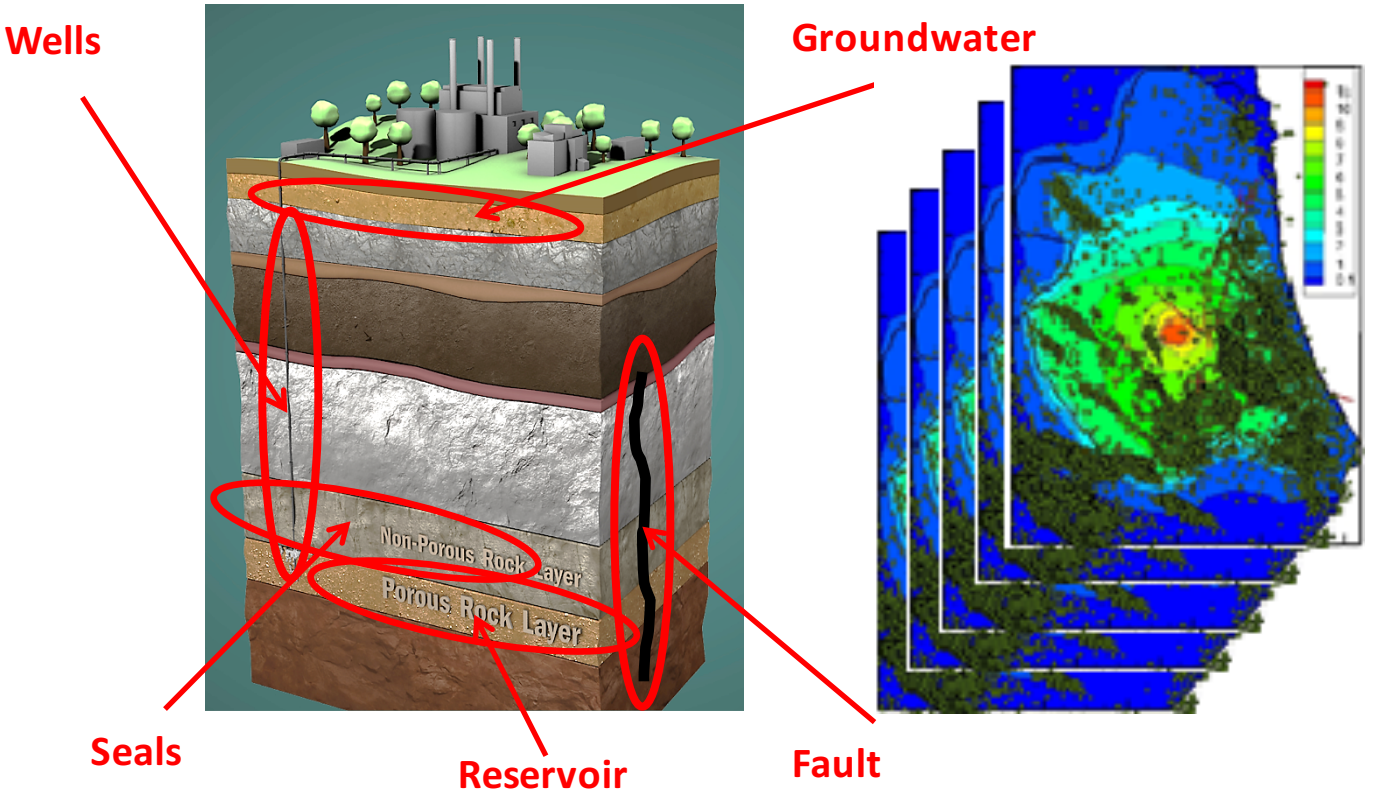
National Risk Assessment Partnership

NRAP leverages DOE's capabilities to help quantify uncertainties and risks necessary to remove barriers to full-scale CO_2 storage deployment.

Building toolsets and improving the science base to address…

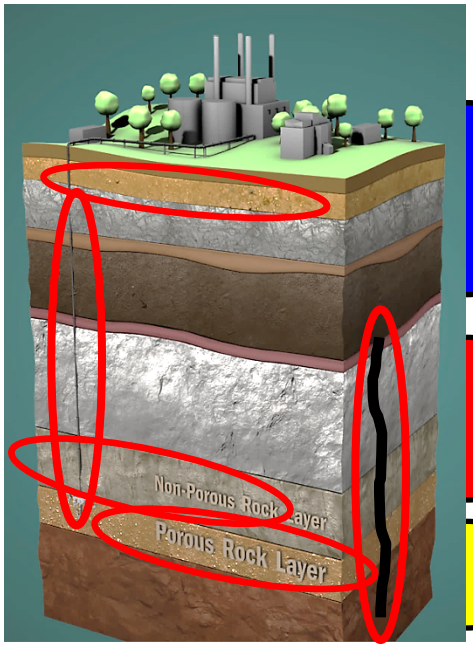
By simulating risk across the entire carbon storage system;

And generation thousands of realizations to quantify uncertainties.

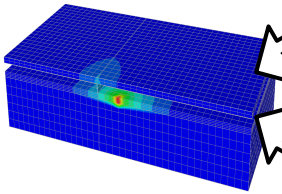


NRAP's approach to quantifying performance relies on reduced-order models to probe uncertainty in the system.

A. Divide system into discrete components



B. Develop detailed component models that are validated against lab/field data



C. **Develop reduced-order models (ROMs) that rapidly reproduce component model predictions**

IAM

Energy Data eXchange (edx.netl.doe.gov)

Data from RCSPs etc.

calibrate

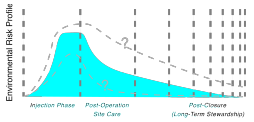
validate

validate

New Data from NRAP

calibrate

NRAP Integrated Assessment (System) Models



Potential Receptors or Impacted Media

Release and Transport

Storage Reservoir

D. **Link ROMs via integrated assessment models (IAMs) to predict system performance & risk; calibrate using lab/field data from NRAP and other sources**

E. Develop strategic monitoring protocols that allow verification of predicted system performance

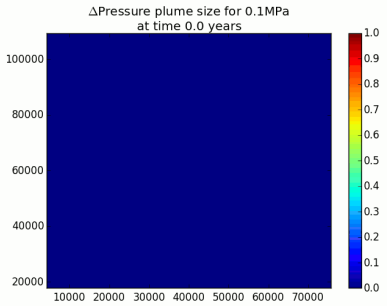
Several NRAP products will be released for beta testers this month.

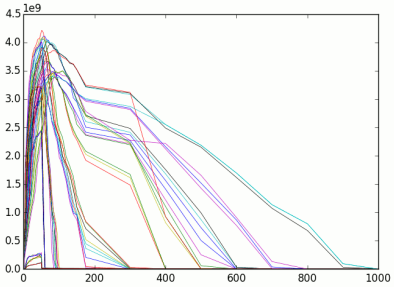
Integrated Assessment Model – Carbon Storage (NRAP-IAM-CS)

- Simulates long-term full system behavior (reservoir to aquifer/atmosphere)
- Generates risk profiles (time-lapse probability of leakage and GW impact)
- Estimates storage permanence quantitatively amidst system uncertainty
- Identifies key drivers of risk amidst system uncertainty

Reservoir Evaluation and Visualization (REV) Tool

- Generates pressure and CO_2 plumes sizes over time
- Suitable for Area of Review (AoR) determination
- Visualizes reservoir behavior probabilistically





Wellbore Leakage Analysis Tool (WLAT)

- Evaluate existing wells for leakage potential
- Explore leakage response as a function of well disposition
- Evaluate the implications of permeable overburden zones

Natural Seal ROM (NSealR)

- Estimate flux through a fractured or perforated seal
- Account for storage outside of primary target zone

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Several NRAP products will be released for beta testers this month.

Aquifer Impact Model (AIM)

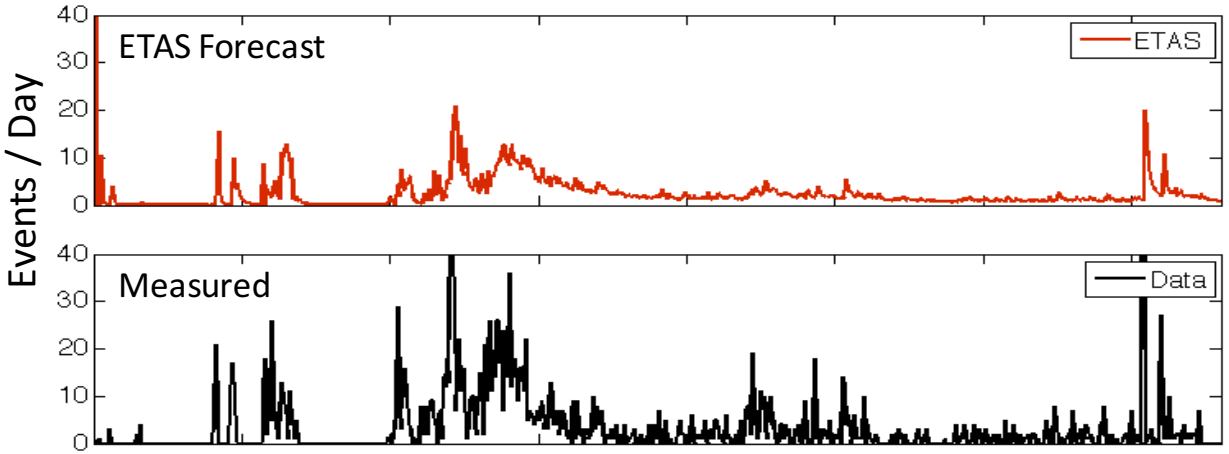
- Rapid estimation of aquifer volume impacted by a leak
- Distinguishes between impact of CO_2 and brine leaks
- Used to determine impact of threshold criteria.

Design for Risk Evaluation and Monitoring (DREAM)

- Estimate time to detection for a monitoring system
- Evaluate and select optimal monitoring designs

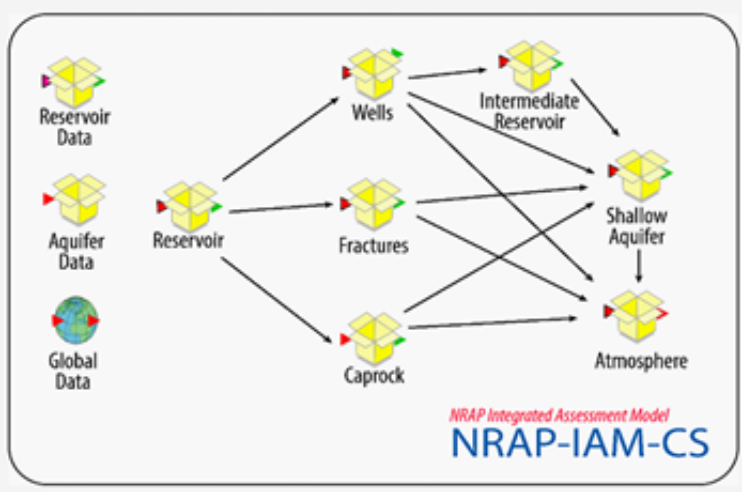
Short Term Seismic Forecasting (STSF)

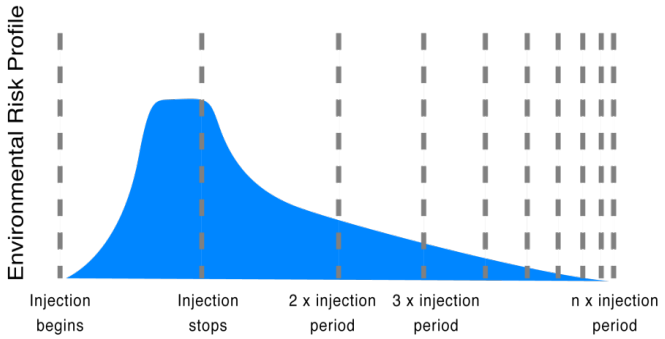
- Forecasts seismic event frequency over the short term
- Potential to complement stoplight approach for induced seismicity planning and permitting



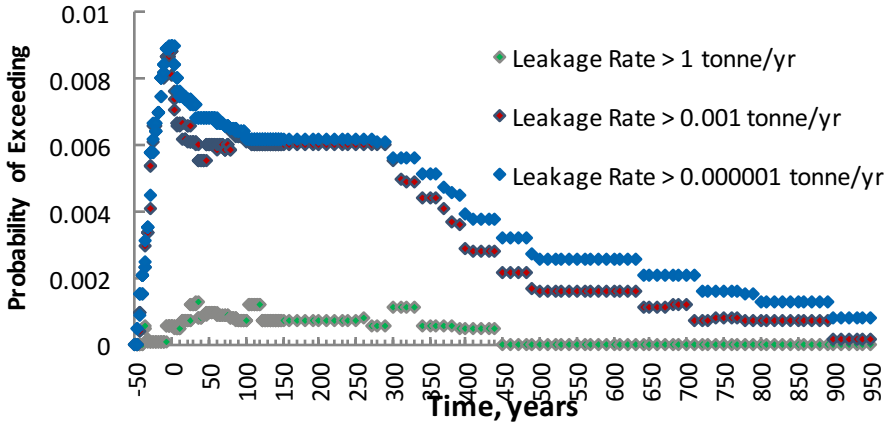
NRAP's integrated assessment model simulates carbon storage system behavior.

- **Simulates the entire storage containment system**
  - Reservoir
  - Wellbore and fracture flow
  - Thief zones
  - Groundwater aquifer
  - Release to atmosphere
- **Calculates probability of leak events**
  - For threshold values of choice
  - Over 100s to 1000s of years
- **Thousands of runs to quantify uncertainty**
- **Quantitative risk profiles with realistic storage conditions**





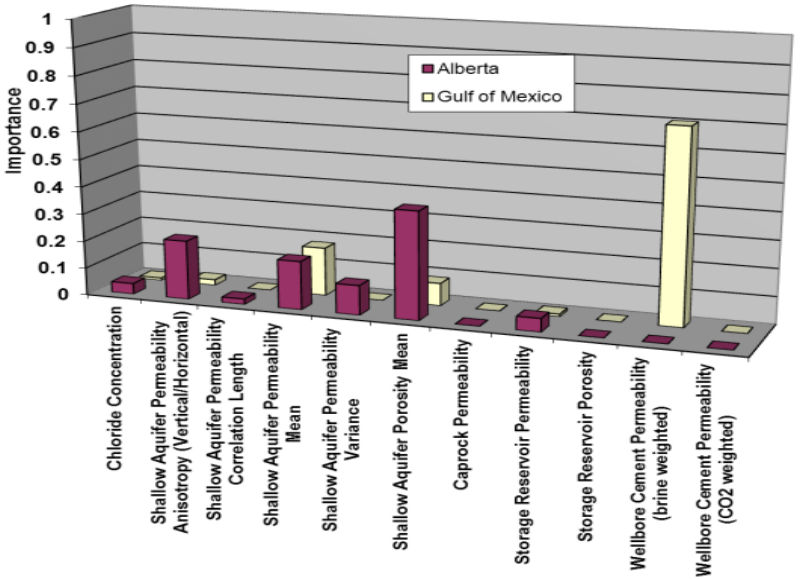
Benson, 2007

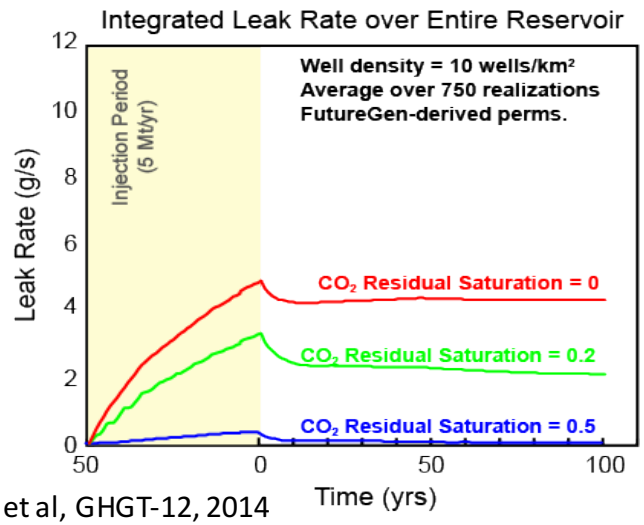


Ref: Bromhal et al, IEAGHG, 2013

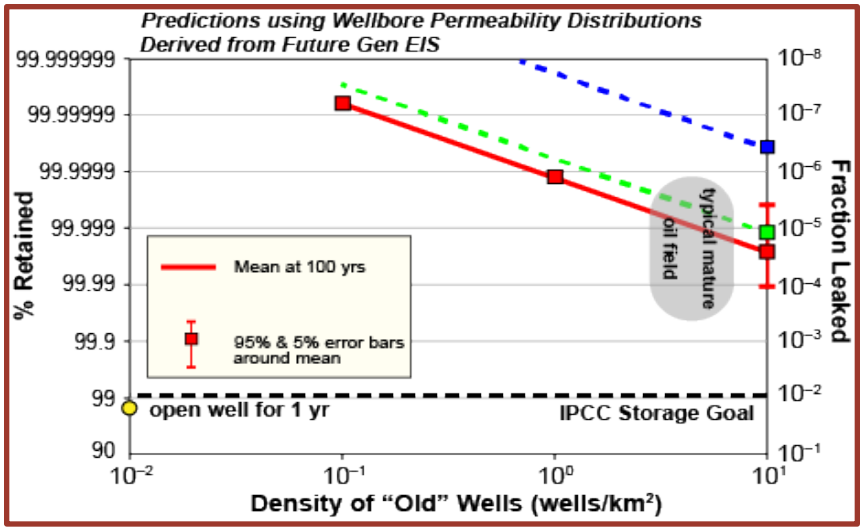
Many system-wide variables can be studied to determine impact on risk.

- **Importance diagrams identify parameters that do and don't have an impact on leakage**
- **Can evaluate impacts in any part of the storage-containment system**
  - E.g., on average, leak rate depends on residual saturation
  - E.g., wellbore transmissivity statistics influence parameter ranking
- **Greenfield vs. brownfield conditions influence likelihood of failure**
  - Open wellbores significantly increase probability of leak



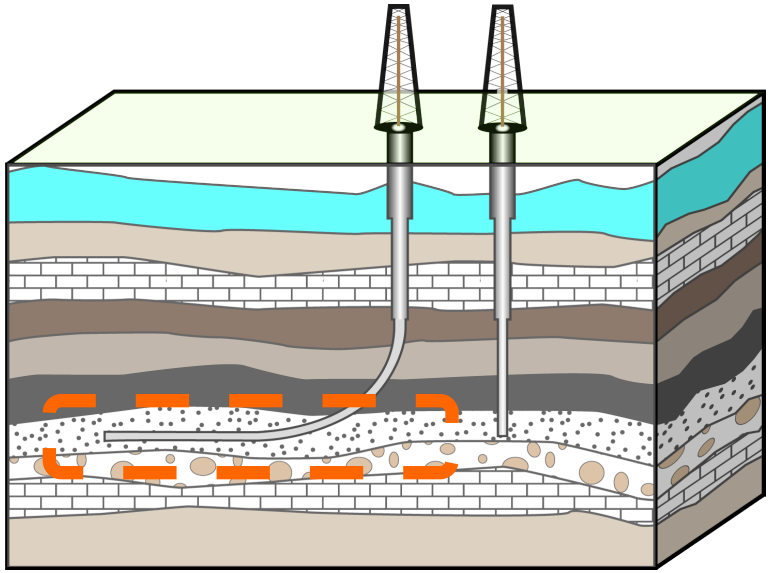


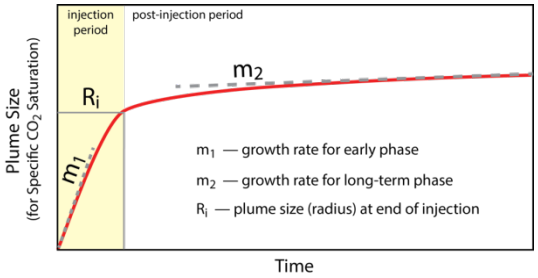
Ref: Pawar et al, GHGT-12, 2014



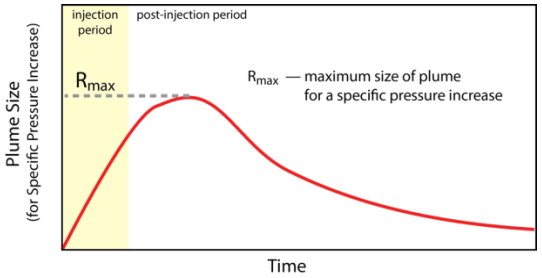
Using Science-Based Prediction to Probe Reservoir Behavior

- **Size of CO_2 plume injection**
  - Rate of growth for early phase
  - Rate of growth for long-term phase
  - Plume radius at end of injection
- **Size of pressure plume**
  - Maximum size of plume
  - Various pressure thresholds, relevant
    - Brine rise
    - Fault-slip criteria
- **Pressure at a location**
  - Maximum pressure increase

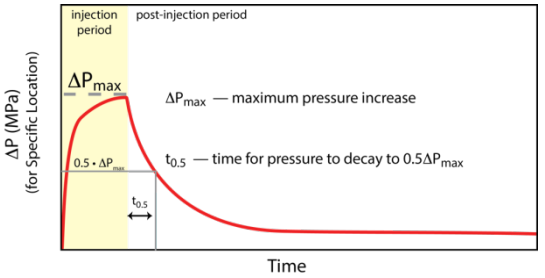




Size of CO_2 Plume



Size of Pressure Plume



Pressure at at a Location

Phase I of NRAP will end in FY16.

- Focus has been on Risk Assessment and Uncertainty Quantification
- Major products:
  - Simulation Tools
    - Integrated and components
    - Release of final Phase I tools in Summer 2016
  - Methodologies
  - Series of reports/papers
    - Addressing key questions
    - Explaining methodologies
    - Manuals for completed tools

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NRAP Phase II

- Focus has been on Risk Management and Uncertainty Reduction
- Begins mid-late FY16
- Key topics for Phase II:
  - Integration of monitoring and mitigation
  - Induced Seismicity and probabilistic hazard/risk
  - Conformance between models and data

Thank you.

Schedule of NRAP Products Demos for this afternoon's session.

Time	Station A	Station B
5:30 – 6:00pm	Short-Term Seismic Forecasting Tool (STSF)	Reservoir Evaluation ad Visualization Tool (REV)
6:00 – 6:30pm	Designs for Risk Evaluation and Management (DREAM)	Wellbore Leakage Analysis Tool (WLAT) and Seal Leakage model (NSEALR)
6:30 – 7:00pm	Aquifer Impact Model (AIM)	Integrated Assessment Model – NRAP-IAM-CS

For more information and to become a beta tester:

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