Task 3 – Induced Seismicity Risk Management

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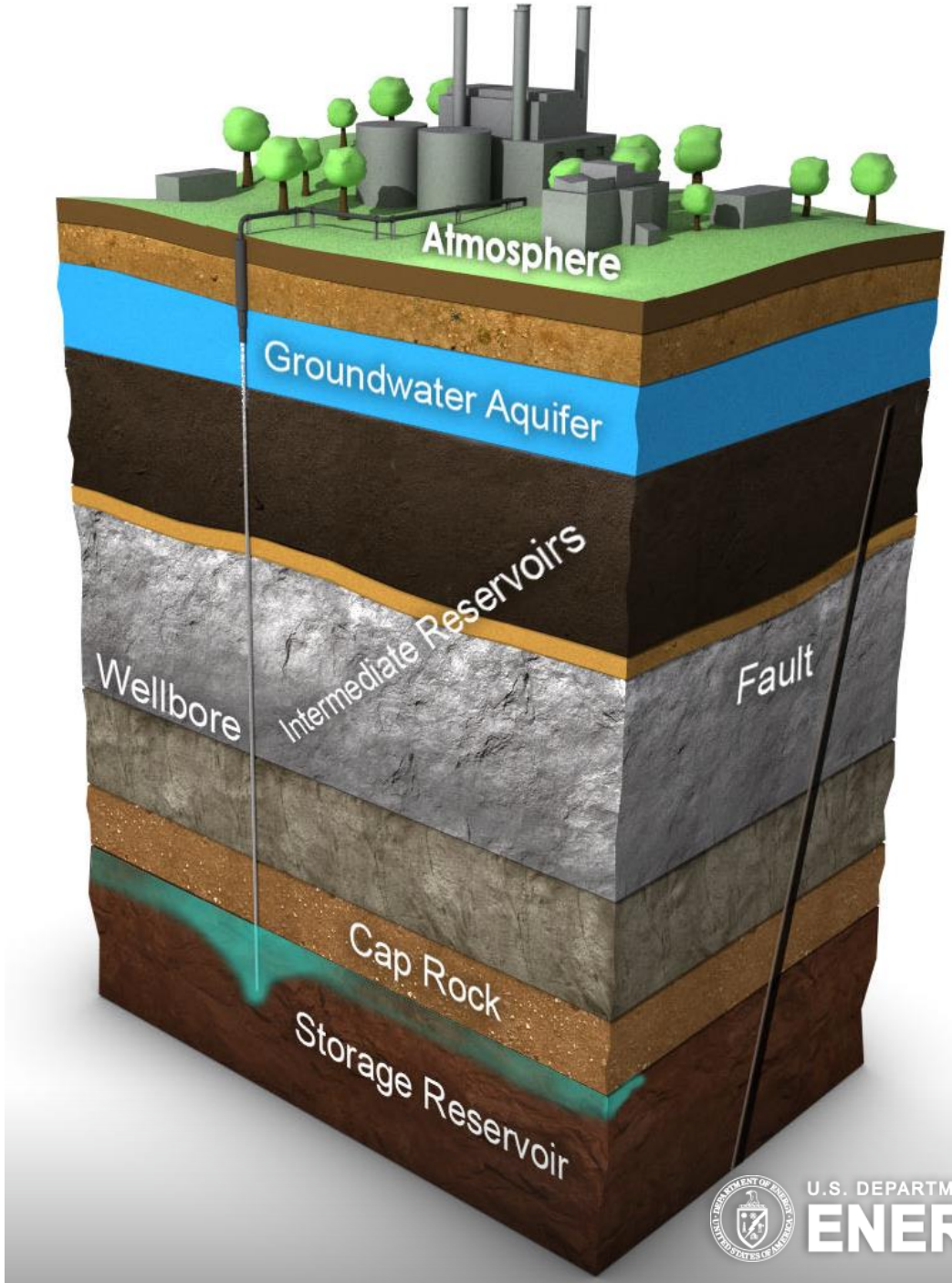

U.S. DEPARTMENT OF ENERGY

Task 3 Contributors

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U.S. DOE's National Risk Assessment Partnership

NRAP
National Risk Assessment Partnership

NRAP leverages DOE's capabilities to quantitatively assess and manage long-term environmental risks amidst significant geologic uncertainty and variability.

Technical Team

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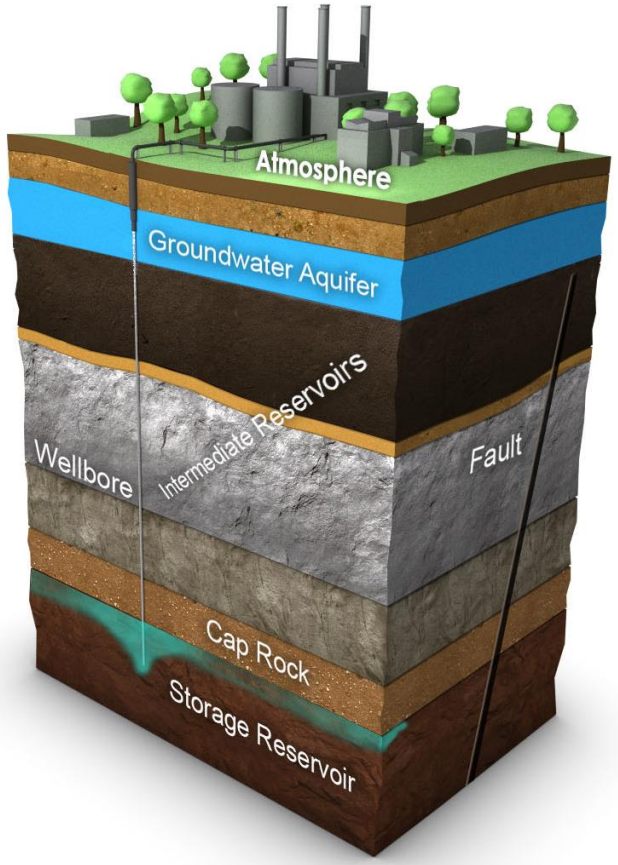

Stakeholder Group

PRINCETON UNIVERSITY

THE UNIVERSITY OF UTAH

ILLINOIS

BATTELLE

USGS
science for a changing world

bp

GLOBAL CCS INSTITUTE

Southern Company

ieaghg

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

CARBON SEQUESTRATION COUNCIL

NRDC

UNITED STATES Carbon Sequestration Council

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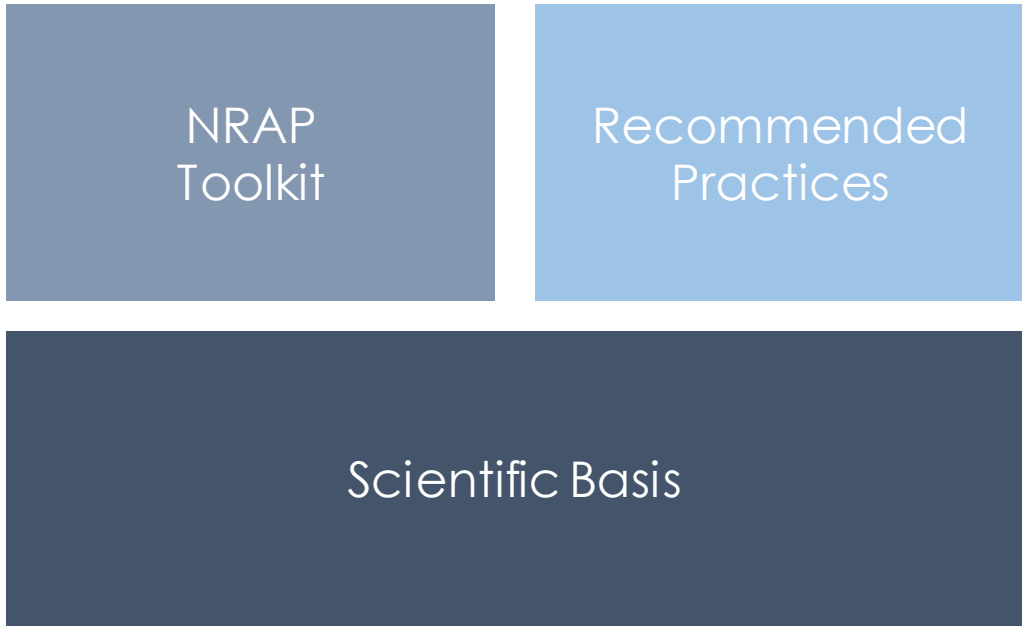
Working Group Goals

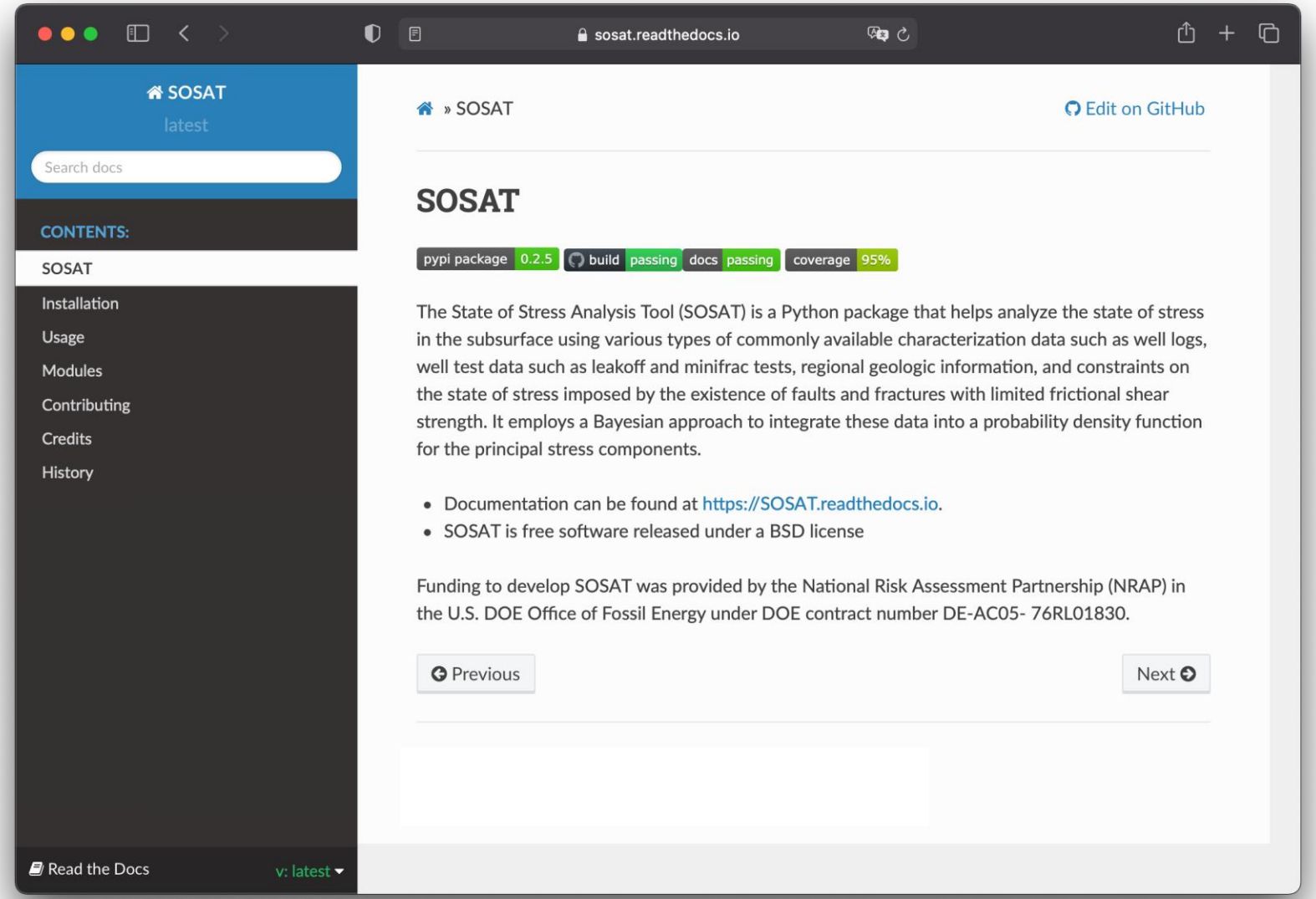
- Identify sites and operations that lead to low-risk—i.e. minimal hazard, minimal damage.
- Develop techniques to quickly identify and manage seismicity problems if they should appear.
- Share recommended practices with the broader CCS community



Tools, Products, and Capabilities

Tools	**Short-term seismic forecasting tool** ***	Available on EDX
	Ground motion prediction tool	Available on EDX
	State-of-stress assessment tool ***	Available on EDX
	Probabilistic seismic risk assessment (PSRA) tool	Available on EDX
Reports	**CO_2 seismic risk assessment review**	IJGGC Special Issue
	Numerous technical papers	NRAP Publication List
	Seismicity Recommended Practices ***	Draft for Public Comment
Capabilities	**Induced seismicity simulator (RSQSim)**	Mature
	Coupled hydromechanical reservoir simulators	Mature
People	**Broad discipline expertise**	Seismicity Working Group

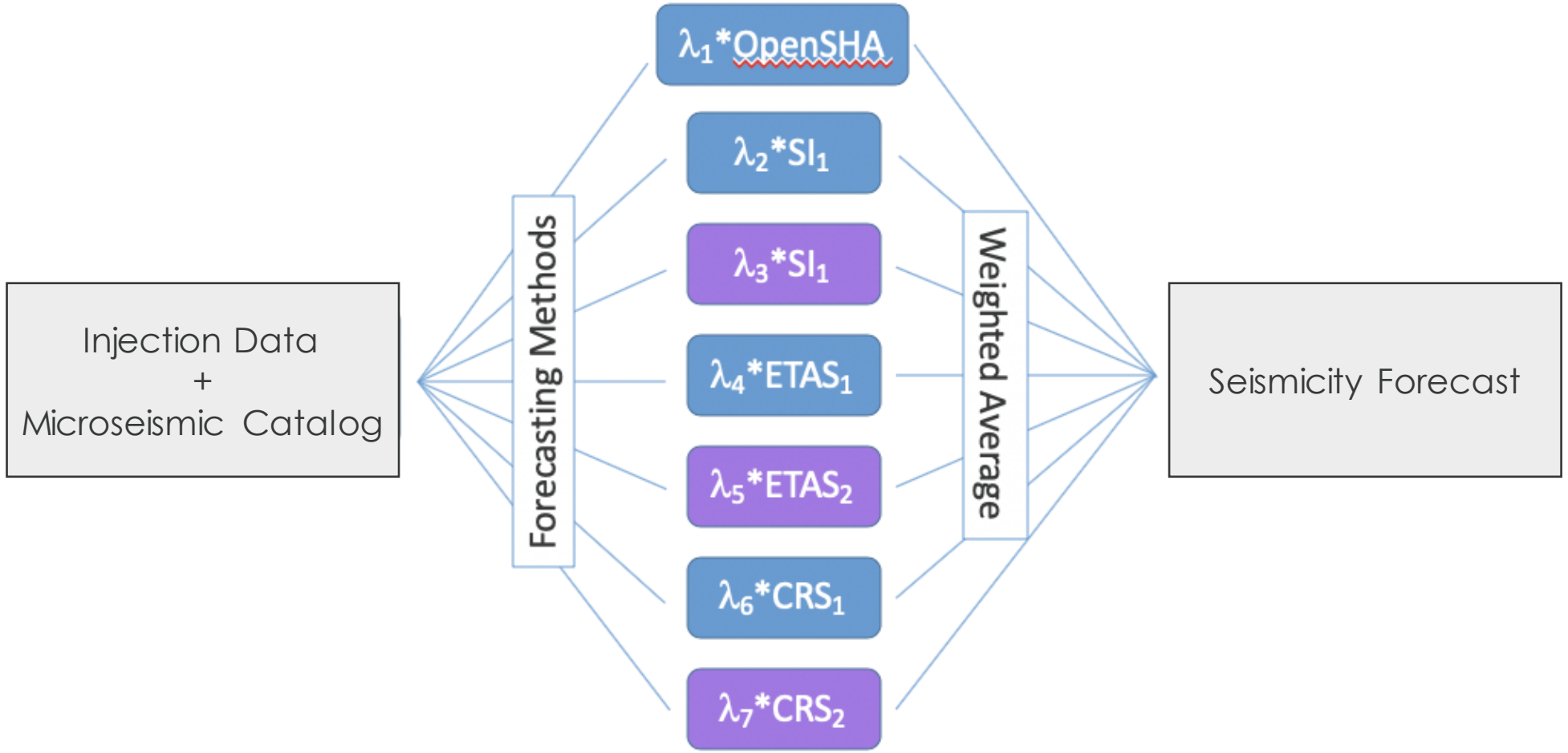
State-of-Stress Assessment Tool



- New Python-based version now available on Github
- Easy installation via Python Package Index
- Improved documentation
- Improved test coverage

Short-Term Seismic Forecasting Tool

New release planned for end of Phase II



Induced Seismicity Recommended Practices

- **Team:** Templeton (LLNL), Schoenball (LBNL), Bachmann (LBNL), Foxall (LBNL), Kroll (LLNL), Burghardt (PNNL), White (LLNL), Guglielmi (LBNL)
- **Overall Goal:** Help facilitate the successful deployment of domestic geologic carbon sequestration projects
- **The Document:** A set of recommended practices which would proactively address and mitigate potential problems with induced seismicity due to subsurface injection. Living document
- **The Audience:** Subsurface injection operators, regulators, and the public
- **The Approach:** Both technical and non-technical; Project-wide and project-lifetime

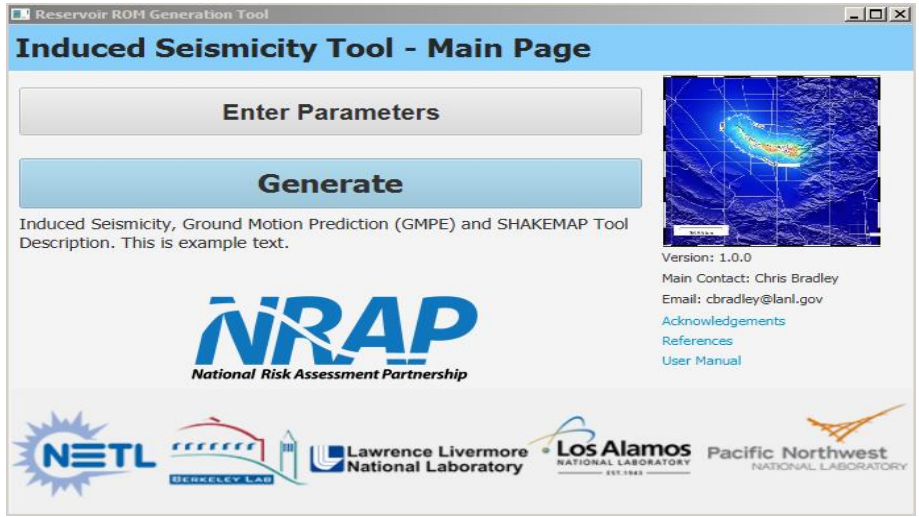
The Steps

- **Step 1:** Preliminary Seismic Risk Screening Evaluation
- **Step 2:** Outreach and Communication
- **Step 3:** Ground Motion Thresholds
- **Step 4:** Collection of Seismicity Data
- **Step 5:** Hazard Evaluation of Natural and Induced Seismic Events
- **Step 6:** Risk-Informed Decision Analysis
- **Step 7:** Operational Management of Induced Seismicity Risks

Recommended Practices Methodology: 7 Steps to Address and Mitigate Induced Seismicity

- **Step 1: Preliminary Seismic Risk Screening Evaluation**
  - **Goal**: Evaluate the merit of a candidate site using simple bounding methods and acceptability criteria
  - **Approach**: Review relevant laws and prior cases of IS, determine region of concern, identify impacts, engage stakeholders, classify risk based on upper and lower bound of potential damages, make assessment
  - **Result**: A Go/No-Go feasibility decision

Ground Motion Prediction for Potential Induced Seismicity Tool



Recommended Practices Methodology: 7 Steps to Address and Mitigate Induced Seismicity

- **Step 2: Outreach and Communication**

  - **Goal**: Create an IS component to a project's general outreach & communications program to facilitate communication and maintain positive relationships with all stakeholders, including the local communities

  - **Approach**: Create a tailor-made approach for each site based on stakeholder needs and concerns (public meetings, media interviews, site visits, website, email lists, etc.) across all stages of project planning, operation, and decommission

  - **Result**: A program to create long-term stakeholder support for the project through information exchange and trust

Recommended Practices Methodology: 7 Steps to Address and Mitigate Induced Seismicity

- **Step 3: Ground Motion Thresholds**

  - **Goal**: Determine site-specific ground motion thresholds to minimize nuisance and damage risks due to induced seismicity

  - **Approach**: Review local ordinances, building damage criteria, interference with community industrial activities, human perception of ground vibrations, stakeholder tolerance

  - **Result**: Development of criteria for monitoring, risk assessment, and operational management plan

Recommended Practices Methodology: 7 Steps to Address and Mitigate Induced Seismicity

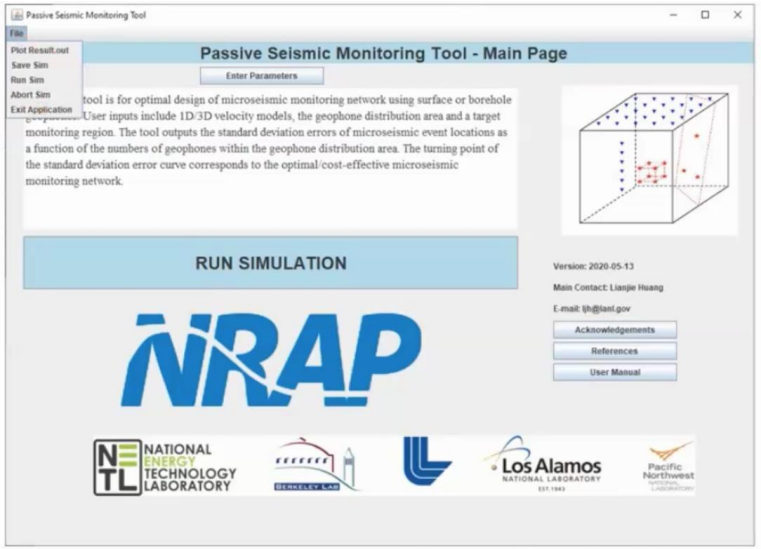
- **Step 4: Collection of Seismicity Data**

  - **Goal**: Create a seismic network and information database for induced seismicity mitigation and reservoir management purposes

  - **Approach**: Determine site-specific optimal network design; data processing needs, public reporting and engagement; data storage and longevity requirements

  - **Result**: Seismic data to aid in design and operation of the overall project (e.g., optimal station locations, seismic hazard evaluation, operational management plan)

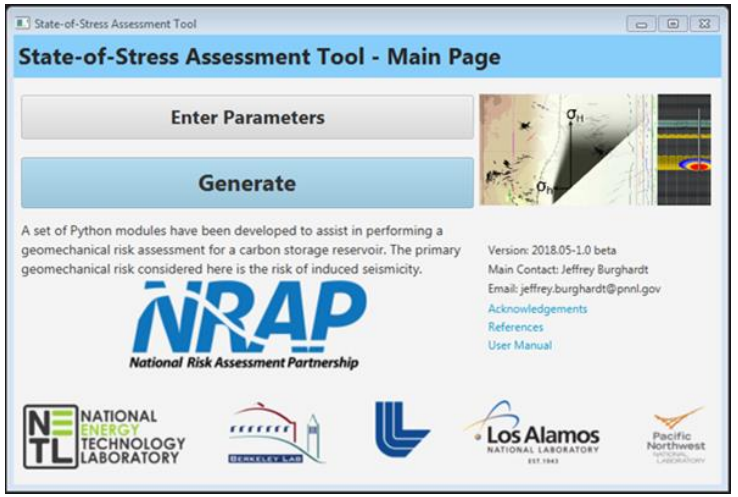
Passive Seismic Monitoring Tool



Recommended Practices Methodology: 7 Steps to Address and Mitigate Induced Seismicity

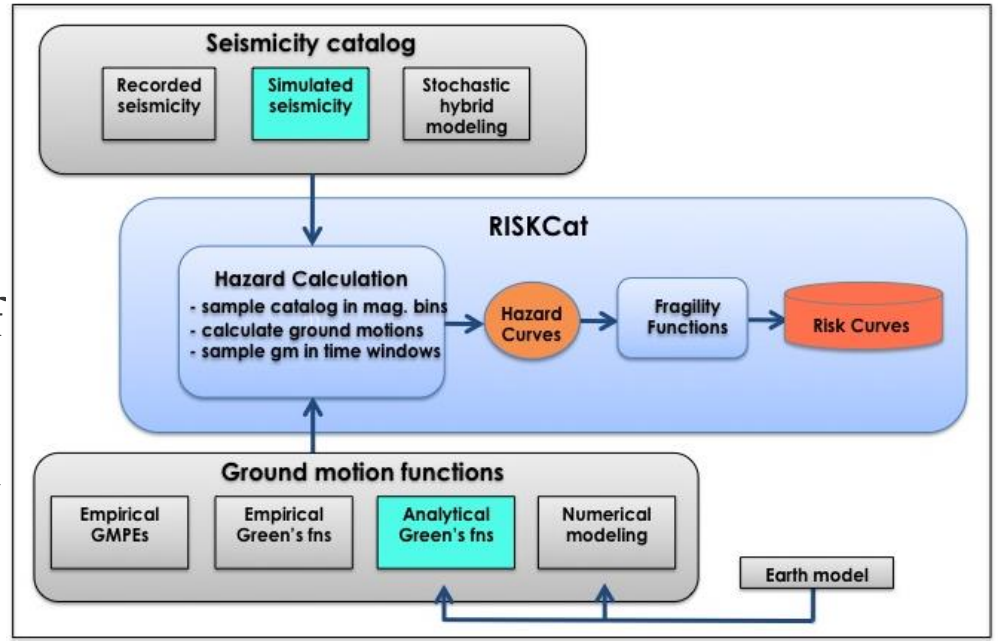
- **Step 5: Hazard Evaluation of Natural and Induced Seismic Events**
  - **Goal**: Estimate the ground shaking due to natural and induced seismicity at a proposed site
  - **Approach**: Determine both long-term and short-term seismic hazard forecasts
  - **Result**: Evaluation of the existing hazard and potential increase in seismic hazard due to site activities

State-of-Stress Assessment (SOSAT) Tool



Recommended Practices Methodology: 7 Steps to Address and Mitigate Induced Seismicity

- **Step 6: Risk-Informed Decision Analysis**
  - **Goal**: Rigorous quantitative estimate of the time-dependent induced seismicity risk associated with the design, operation, and closure of the proposed geologic carbon storage site
  - **Approach**: Estimate the risk based on probable damage of particular assets (building, sleep depravation, socioeconomic impact, etc.) for a given seismic ground motion, and the probability that this ground motion would occur (using the previous estimates of seismic hazard)
  - **Result**: Determination if the potential future negative effects of the operation are within the tolerance range of the stakeholders



Recommended Practices Methodology: 7 Steps to Address and Mitigate Induced Seismicity

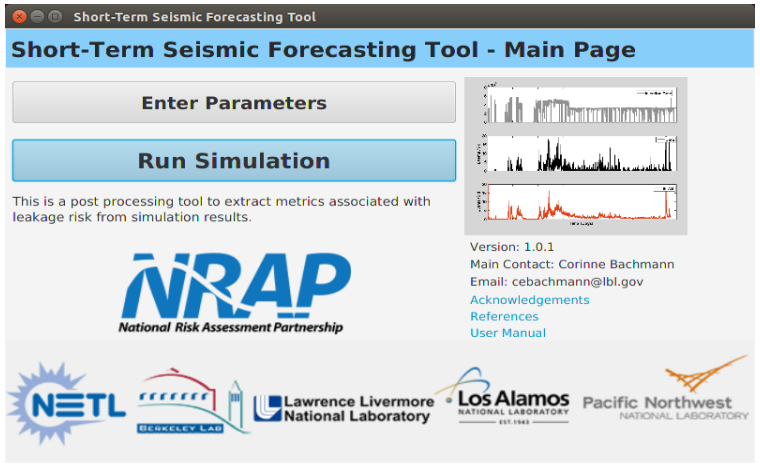
- **Step 7: Operational Management of Induced Seismicity Risks**

  - **Goal**: Create a site-specific, real-time plan to monitor, assess, control, and mitigate the risks associated with induced seismicity during and after fluid injection.

  - **Approach**: Establish plan describing direct mitigation actions (e.g., injection modifications) and indirect mitigation actions (e.g., damage compensation) to be implemented and under what conditions (e.g., traffic light systems based on levels of ground shaking or observed event magnitudes)

  - **Result**: A clear set of procedures, known and approved by all the stakeholders ahead of time, to be followed in the event that certain seismic thresholds are reached

Short Term Seismic Forecast (STSF) Tool



Recommended Practices Summary

- **Goal:** Recommended Practices document describes project-wide, project lifetime approach to address and mitigate potential problems with induced seismicity

- **Process:** A general 7 step program to promote the safe and economic implementation of geologic carbon sequestration, with respect to induced seismicity

- **The Path Forward:**
  - Currently open for public comment. Additionally, 12 domestic/international reviewers from academia, industry, and government have agreed to review the document
  - Living document: Sharing of lessons learned, recent case studies, and best practices

Task 3 Summary

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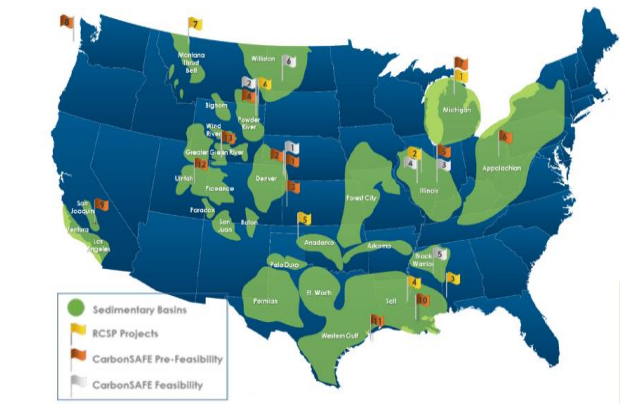
People	**Broad discipline expertise**	Seismicity Working Group

Engaging with Key Stakeholders

DOE CarbonSAFE



DOE-FE Regional Initiatives

DOE-FE SMART Initiative

SMART

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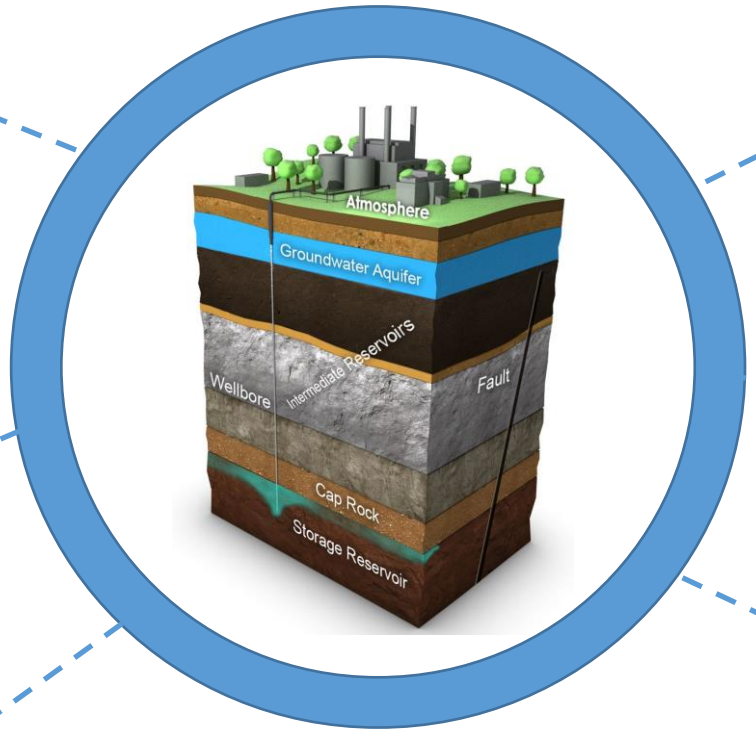
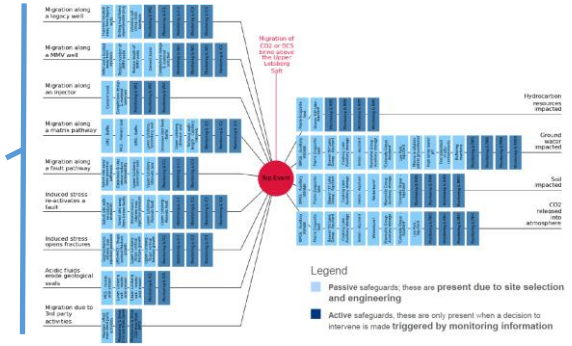


Industry Best Practices



Bourne et al., 2014

International CCUS RD&D Community

ieaghg

Regulatory Context

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

NORTH DAKOTA OIL AND GAS DIVISION

DEQ

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Acknowledgements

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Thank you!

Comments and Questions:

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