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Performance Based Earthquake Engineering and Assessment Tool for Gas Storage and Transmission Systems

OpenSRA Workshop - January 11, 2022

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Outline

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Project Goals

- ❑ **Develop open-source seismic risk analysis software for natural gas infrastructure (*OpenSRA*) to provide regulators and owners a tool to analyze seismic risk in California**
- ❑ **Utilize recent advances in seismic hazard analysis and incorporate focused research on gas infrastructure capacities**
- ❑ **Ensure the tool can accommodate regions and infrastructure where there is little-to-much site-specific information to provide efficient, reliable estimates of risk based on the information available**

Tiered Assessment Approach

Data availability drives uncertainty of the estimate

Level 1 – Statewide

- Statewide maps: Geologic units (2010, CGS), Vs30 (Wills et al., 2015)
- Do not utilize subsurface or site-specific geotechnical data

Level 2 – Regional

- Maps/datasets available at the regional scale (Bay Area) with higher resolution than Level 1 data
- May use limited/generic subsurface data specific to a region

Level 3 – Site-Specific

- Site-specific geotechnical data (groundwater, CPT/SPT, index tests)

Level 4 – Advanced Analysis (not part of project scope)

Seismic Demand



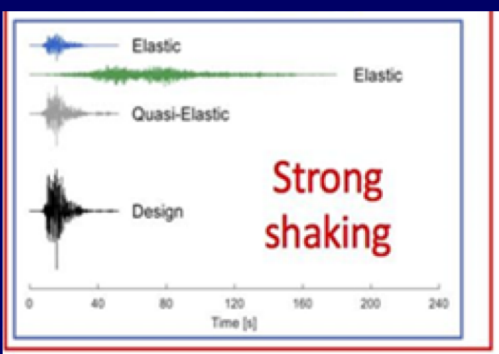
Landslides



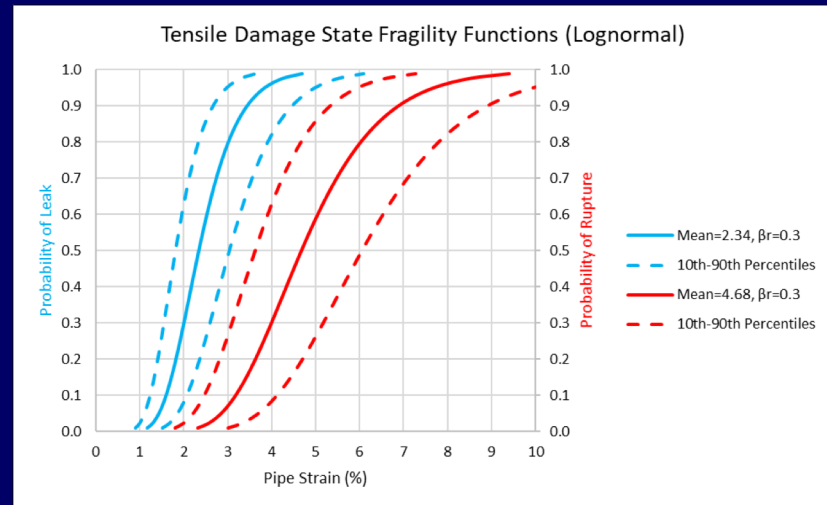
Liquefaction



Fault Rupture



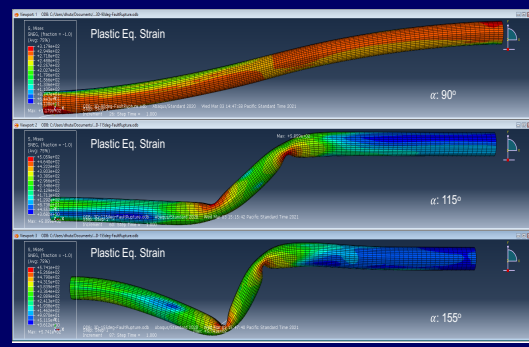
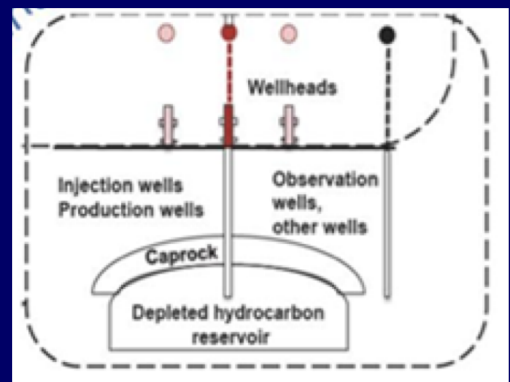
Component and System Fragilities



Capacity



Surface Elements



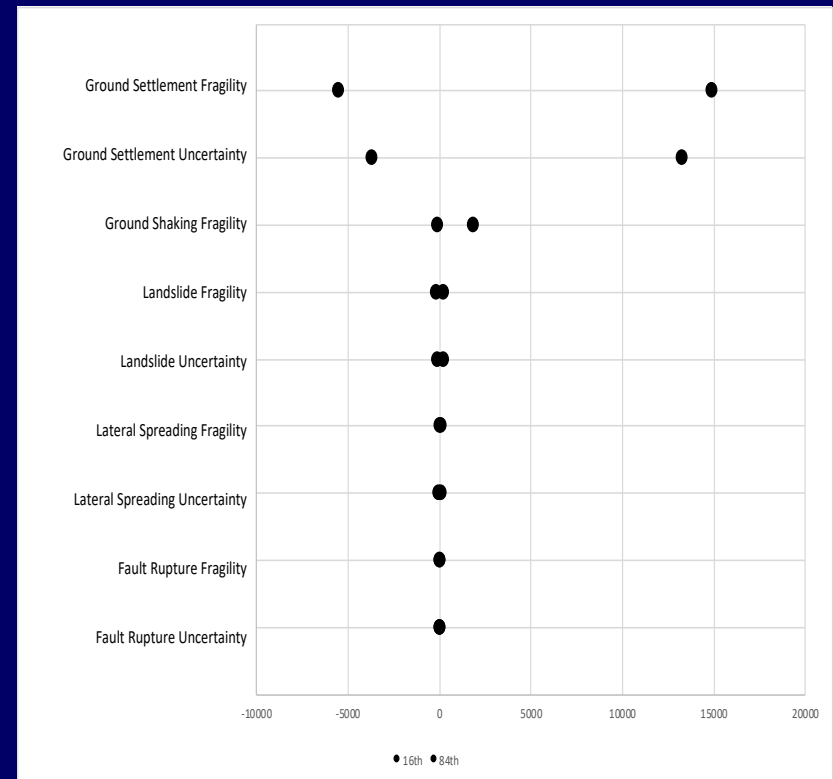
Subsurface Interface

Task 2 – Sensitivity Analyses

- Performed sensitivity analyses using preliminary version of OpenSRA
- Results were used to focus efforts in Task 4 – Targeted Research

Task 2 – Sensitivity Analyses Findings

- Fragility curves have a greater impact than demand parameter models
- Epistemic uncertainty in ground shaking fragility model is larger than other demand parameters
- Epistemic uncertainty from liquefaction-induced lateral spreading can lead to catastrophic failures
- Surface fault rupture has little impact statewide but can have a significant impact at a site.



Task 3 – OpenSRA Development

- ❑ OpenSRA is based on the PEER PBEE methodology and incorporates results from:
 - ❑ UCERF3 Seismic Source Characterization
 - ❑ NGA-West 2 Ground Motion Characterization
 - ❑ Polynomial Chaos Calculation Scheme
- ❑ Results of Task 4 have been integrated into the code
- ❑ Preliminary executable software is available and can be refined over the next 2 months

Task 3 – OpenSRA Development

- **Straightforward** – Analyses are performed using a graphical user interface
- **Visual** – Can visualize infrastructure, demand parameters and results
- **Fast** – minutes not hours
- **Flexible** – User can add new infrastructure and new or site-specific fragility curves

Task 3 – OpenSRA Development

The screenshot displays the OpenSRA (Open-Source Seismic Risk Assessment Tool) interface. The main window is titled "OpenSRA: Open-Source Seismic Risk Assessment Tool". On the left, a sidebar contains a "Visualization" panel with a list of layers: "Pipelines" (expanded), "California_Natural_Gas_Pipeline", "1994_Northridge", "Google Road", and "Open Street Map". Below the list are buttons for "Identify", "Select", "Add selected assets to analysis list", "Add Assets", "Clear all selected assets", and "Clear". The main map area shows a geographic view of California with the selected layers overlaid. At the bottom, a status bar shows the current stage as "PREPROCESS" and a "Program Output" window with the following log entries:

- 13:11:29 - ShakeMap 1994_Northridge loading complete.
- 13:14:33 - Loading visualization for 277716 assets
- 13:14:37 - Done loading assets

Much Thanks to Barry Zheng of Slate

Task 4 – Targeted Research

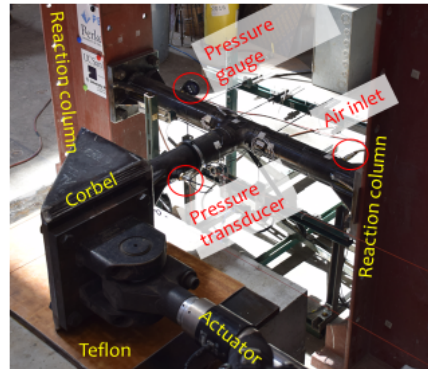
Some Highlights:

- ❑ Fragility curves developed for underground pipelines (UCB et al.), above-ground storage facility infrastructure (UCSD/UNR), and wells/caprocks (LBNL)
- ❑ Developed fast polynomial chaos calculation procedure (UCB)
- ❑ Component and system pipeline tests performed (UCSD & UNR)
- ❑ Recommendations on sensors and monitoring (UCB)
- ❑ Models for subsurface fault & shaking effects on wells (LBNL)
- ❑ New lateral spread procedure & soil-pipeline response models developed (UCB et al.)
- ❑ All subtasks supported implementation into *OpenSRA*

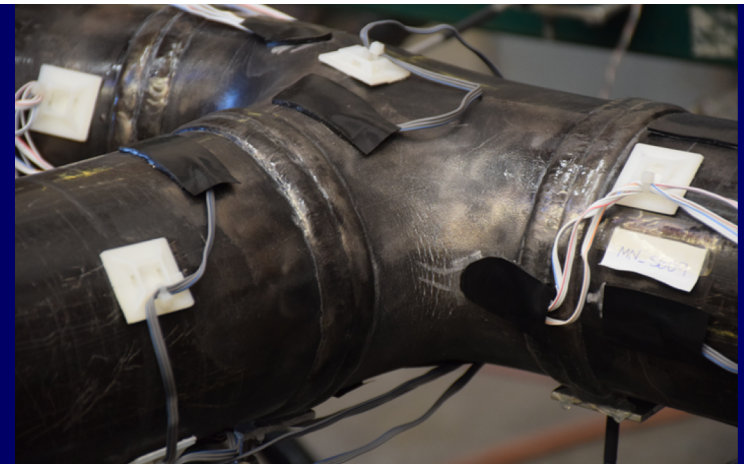
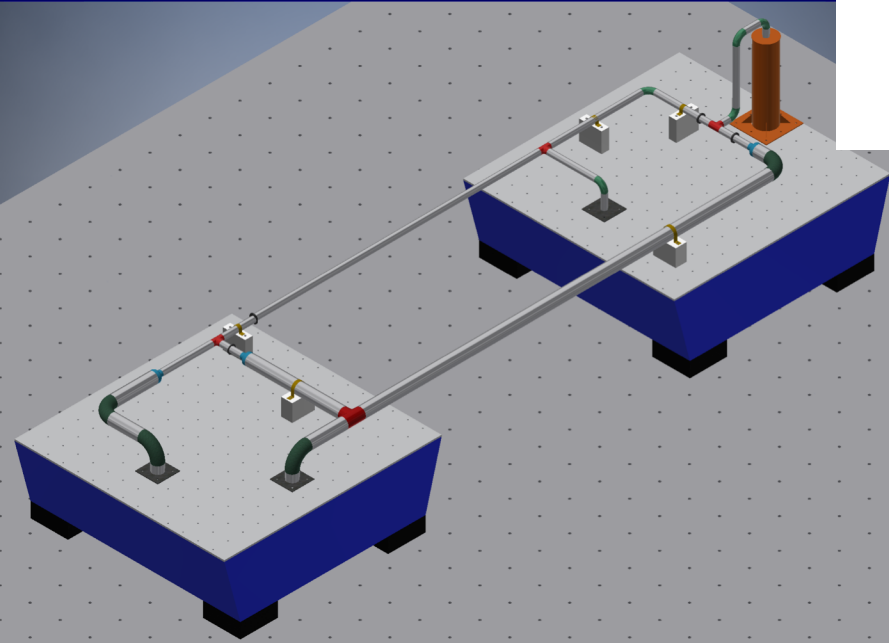
Task 4d – Laboratory Testing

Test setup

In-plane (IP) test



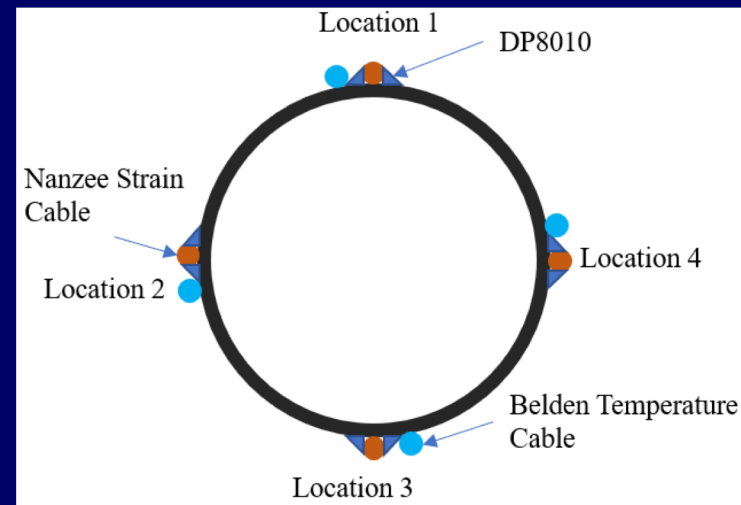
In-plane (OP) test



Task 4e – Field Tests



(A) Before and (B) During the bending test



TAC Comments Helpful

EXAMPLES:

- ❑ Focus on transmission lines, not distribution
- ❑ Evaluation of service laterals is of minor importance
- ❑ Focus on well trees and vertical tanks at storage facilities
- ❑ Remove Java from OpenSRA
- ❑ Software security review will be extensive

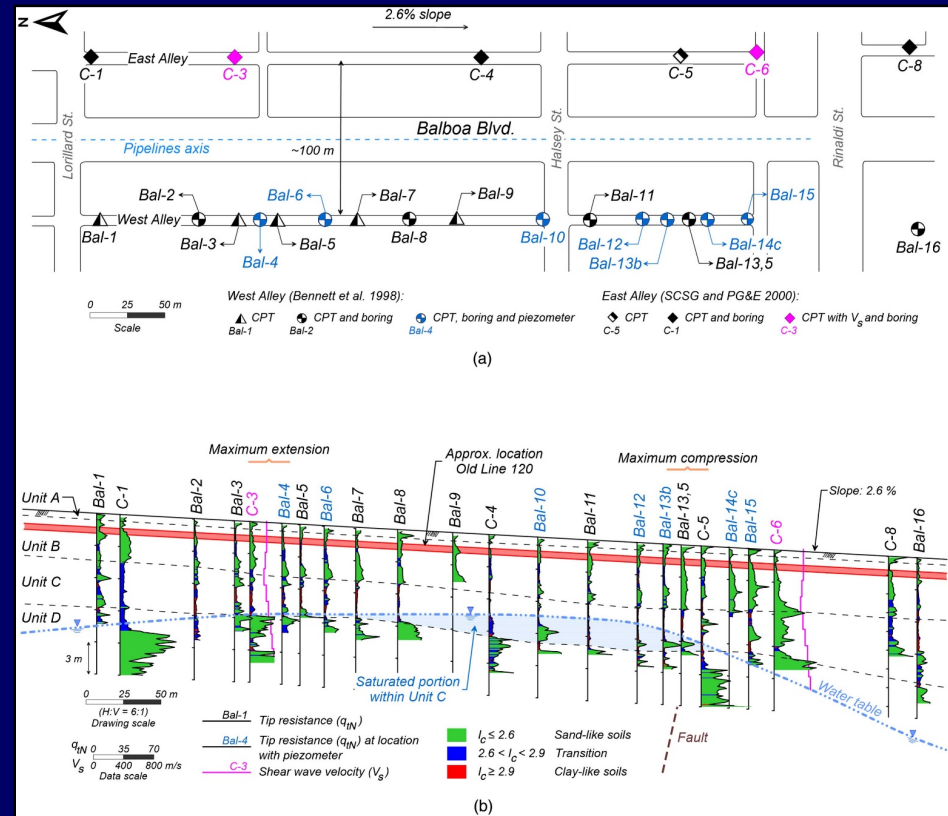
Task 5 – Validation & Demonstration Sites

- Used 4 demonstration sites to evaluate and to validate demand and capacity models:
 - Balboa Blvd
 - McDonald Island
 - Cordelia Junction
 - Honor Rancho

Balboa Blvd Demonstration Site

□ Simplified geotechnical inputs at Level 1 (i.e., ground water table) underestimate response to 1994 Northridge EQ

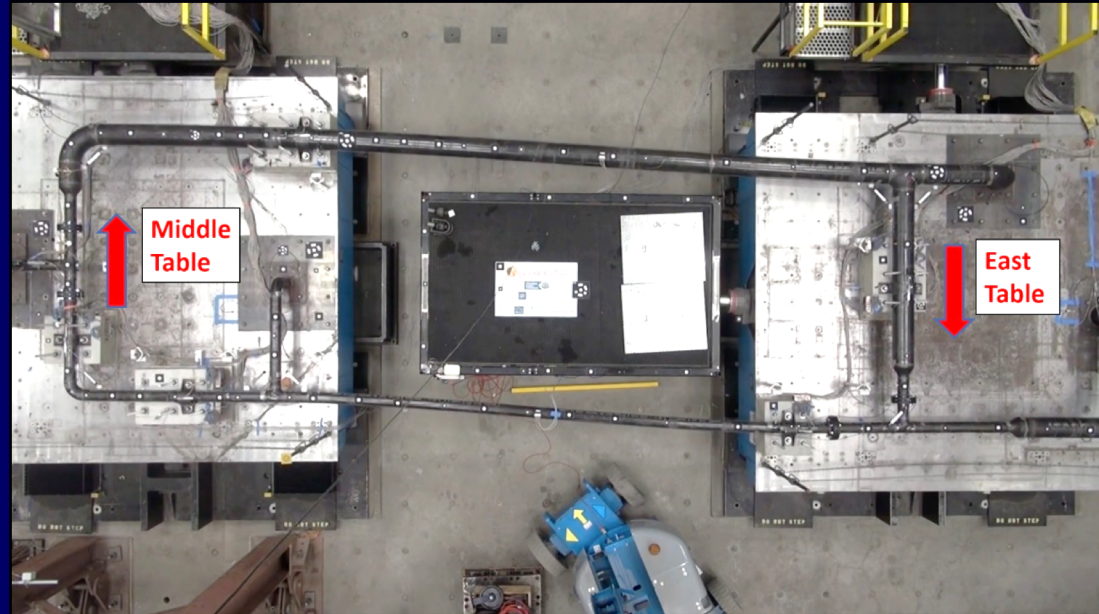
□ Level 3 inputs are more detailed and result in much closer estimates of response to 1994 Northridge & 1971 San Fernando EQ



(from Ziotopoulou, Davis & Pretel 2021)

McDonald Island Demonstration Site

- Assessment of McDonald Island subsystems showed negligible probabilities of failure, consistent with observations



Honor Rancho Demonstration Site

- ❑ **Negligible damage to wells was calculated for 1971 San Fernando and 1994 Northridge, consistent with observations**

Cordelia Junction Demonstration Site

- ❑ **Negligible probabilities for compressive and tensile rupture for 1989 Loma Prieta earthquake, consistent with observations**

Task 6 – User Workshop

□ January 11, 2023

Thank you for joining us

Task 7 – Project Benefits

- ❑ System-wide fragilities and prioritization of mitigation will provide greater reliability of the system.
- ❑ Mitigation decisions based on robust quantitative data can focus efforts, resulting in effective disbursement and lower overall costs.

Performance Metric	Metric Category	Performance Metric Unit	Benchmark Performance	Current Project Performance	Minimum Target Performance	Goal Target Performance	Evaluation Method	Significance of Metric
OpenSRA website hits	Programmatic - Goals related to data collection, outreach, and project execution	number of hits	NA	845 per quarter	50 per year	100 per year	website tracking	Demonstrate broad project exposure
OpenSRA workshop participants	Programmatic - Goals related to data collection, outreach, and project execution	participants	NA	31	10	20	workshop registration	Demonstrate interest and broad use of OpenSRA
Accuracy	Technology - Industry standards and barriers being advanced		NA	-				Demonstrate improvement in accuracy when using the advanced capabilities in OpenSRA
Number of pipeline component lab tests	Technology - Industry standards and barriers being advanced	test	NA	8 tests	3 tests	6 tests	completion of test	Demonstrate improvement of fragility calculation.

Task 8 – Knowledge Transfer

Conference Presentations

OpenSRA Website

PEER Social Media

PEER Newsletters

PEER Website

PEER Reports

Fact Sheets

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OpenSRA

OpenSRA - Performance-Based Earthquake Engineering Assessment Tool for Natural Gas Storage and Pipeline Systems

OPENSRA

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Demand

- Ground Motions
- Landslides
- Liquefaction

Capacity

- Surface elements
- Surface-subsurface interface
- Subsurface
- Hypocenter
- Observation wells
- Other wells
- Estimated fault rupture

Fragility expert working group

Advise on: Testing plans and protocols, standards of practice, fragilities, earthquake scenarios

Component & System Fragilities

System Performance Model
SERA → OpenSRA

The project "Performance-Based Earthquake Engineering Assessment Tool for Natural Gas Storage and Pipeline Systems," henceforth referred to as the "OpenSRA Project," is a multi-year study to develop open-

PEER News Digest
PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

Dear Jennie Watson-Lamprey,
Thank you for subscribing to PEER news!

2022 IMD Blind Prediction Contest Closes on October 31, 2022

PEER is organizing a Blind Prediction Contest for predicting the experimental results of a study at the UC Berkeley shaking table at the Piedmont Park Station, performed in collaboration with the University of Toronto, Italy.

Tests were performed on a steel Moment Resisting Frame with the goal of examining the effectiveness of a novel device for seismic energy dissipation called Impact Glass Coupler (IGC). Deadline for submissions is **October 31, 11:59 PM PDT**.

More details about the contest are available on the 2022 Blind Prediction Contest website.

OpenSRA Report – Enhanced Liquefaction and Ground Deformation Report

The California Energy Commission has published "Performance-Based Earthquake Engineering Assessment Tool for Natural Gas Storage and Pipeline Systems, Task B Final Report – Enhanced Liquefaction and Ground Deformation Report." It was written by Chris Bain, UC Berkeley; David Haberman, UC Berkeley; Jonathan D. Bray, UC Berkeley; Norman Abrahamson, UC Berkeley; Thomas D. O'Rourke, Cornell University; and Scott Lindell, Lethis Consultants.

This publication is an interim project report for the OpenSRA project. OpenSRA is a new open-source seismic risk assessment software tool for gas utility regulators and owners that will enable them to strategically assess challenges posed by the risk from earthquake-induced hazards. OpenSRA includes existing and new methods to assess the risk to buried pipelines from ground displacements due to surface fault rupture, liquefaction-induced lateral spreading and ground settlement, and seismic slope displacement. The pipe strain response to permanent ground displacements is estimated and fragility curves are evaluated to estimate the probability of pipe rupture.

Access the report and see how you can contribute.

PEER CENTER @PEER_Center · Oct 31
New interim #OpenSRA project report "Seismic Response of Pipeline and Gas Storage Surface Infrastructure." [bit.ly/3CsbRPv](#) #riskassessment #infrastructure #naturalgas #testing #CalEnergy @SlateGeotech @nevadareno @UCSDJacobs

OpenSRA
<https://peer.berkeley.edu/openSRA>

OpenSRA 2023 and Beyond

- ❑ Additional funding is being sought to advance research & OpenSRA software
- ❑ Will continue to work with owners to adapt and refine for their systems