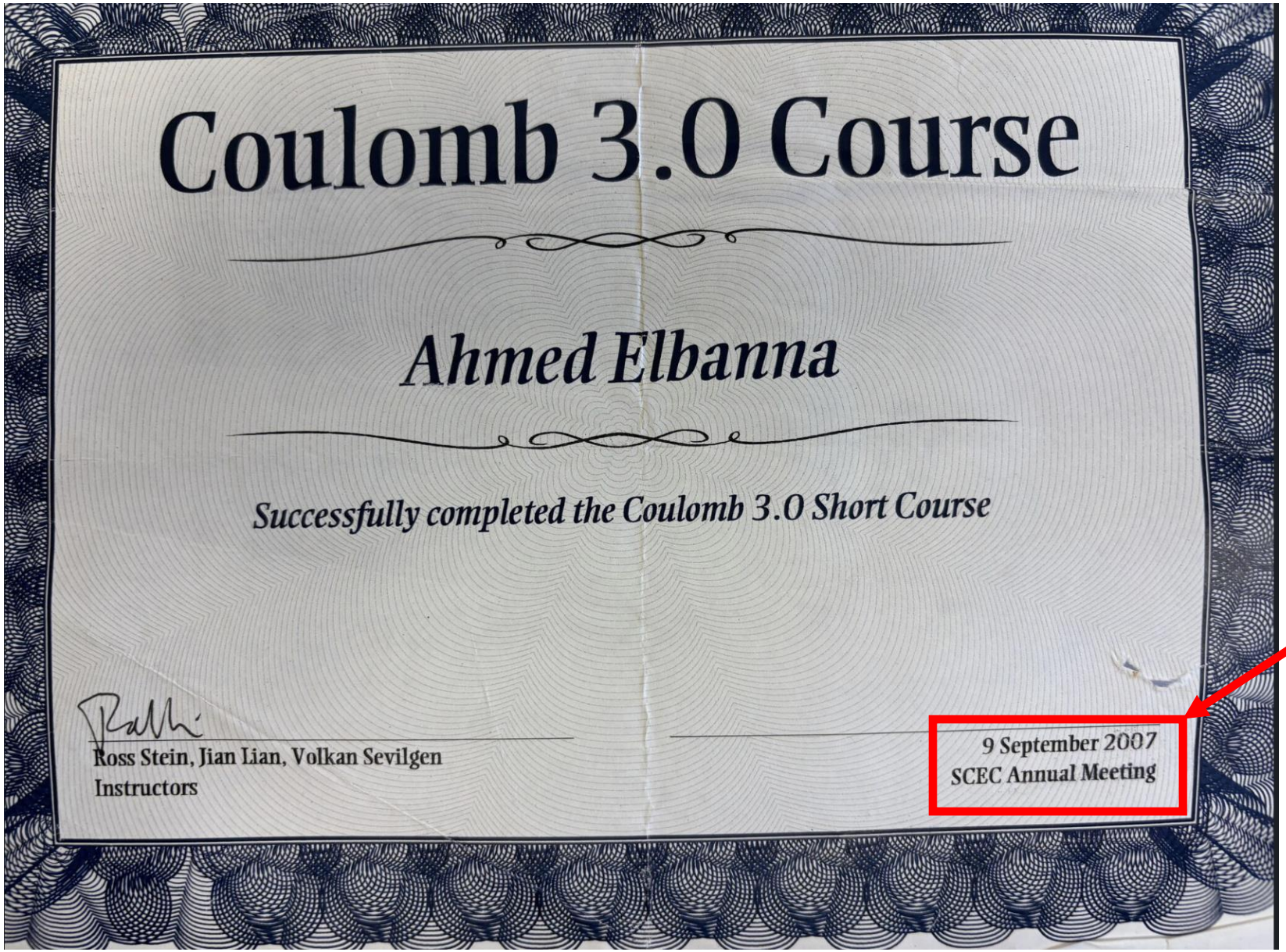
Charting SCEC's Future - Together!

Ahmed Ettaf Elbanna, PhD
Professor of Earth Sciences and Civil Engineering
University of Southern California
Director-Designate of SCEC (Statewide California Earthquake Center)

2007



Coulomb 3.0 Course

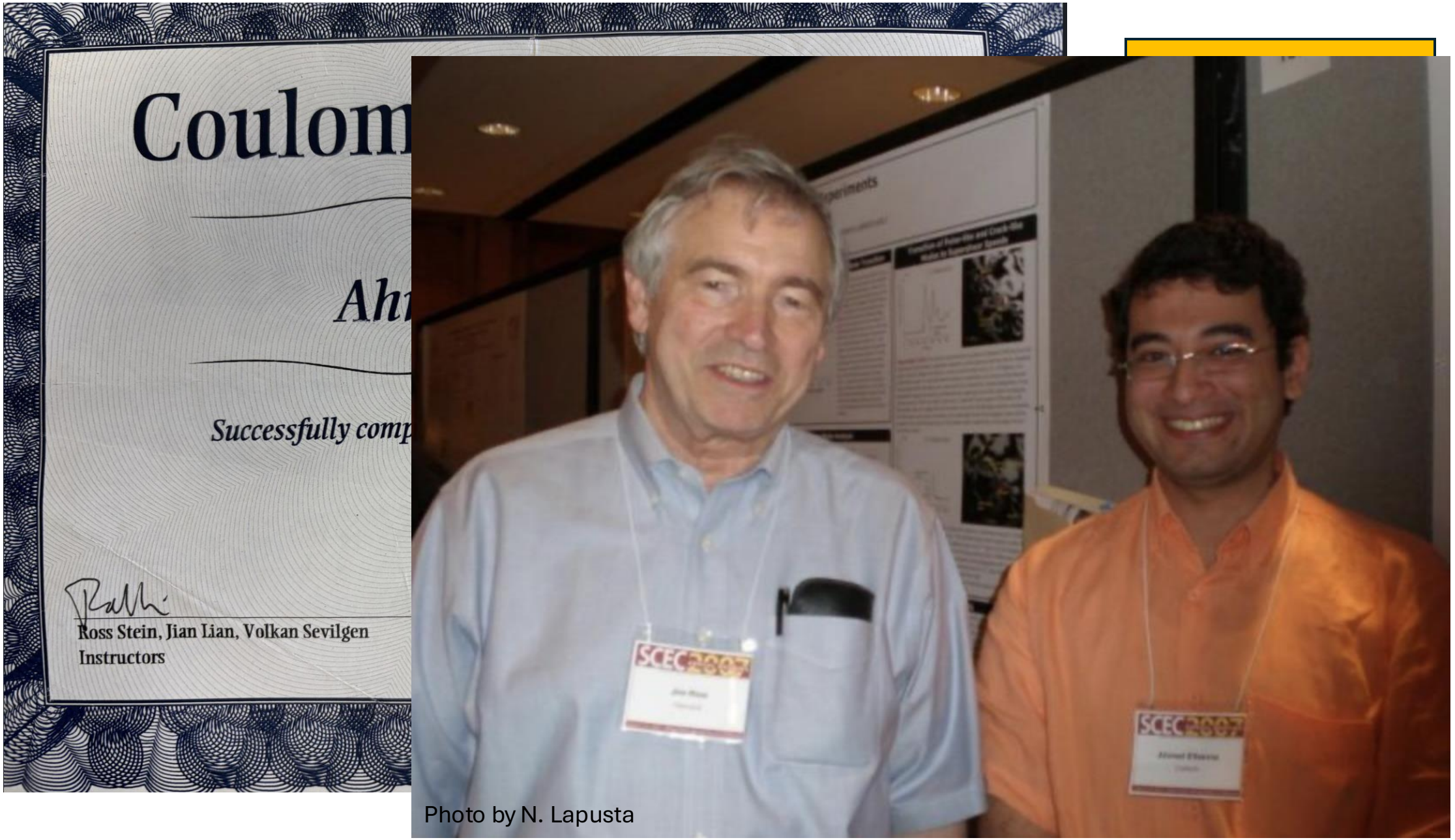
Ahmed Elbanna

Successfully completed the Coulomb 3.0 Short Course

Ross Stein, Jian Lian, Volkan Sevilgen
Instructors

9 September 2007
SCEC Annual Meeting

2007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Ross Stein, Jian Lian, Volkan Sevilgen
Instructors
Photo by N. Lapusta

Image is AI-generated

Image is AI-generated


EXIT 29
81
NORTH
MECHANICSBURG
MILE
COFFEE
EXIT
Image is AI-generated

For me, SCEC Is Personal

"The only constant in life is change"

- Heraclitus

But in times of rapid change, it’s the constants we should be seeking.

People do not want to die or get injured during an earthquake

People do not want to lose their homes

People want to feel safe during and after the earthquake

Businesses want to recover fast

People want to pay less insurance

Insurance companies want to reduce their losses

People adapt to technology

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We must be relevant and make the case that our science benefits the society!

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SCEC shall be a powerhouse for Earthquake System Science with a dual engine—driving scientific discovery while delivering tangible benefits to society

Example : Resilience by Design

Source: Los Angeles Times

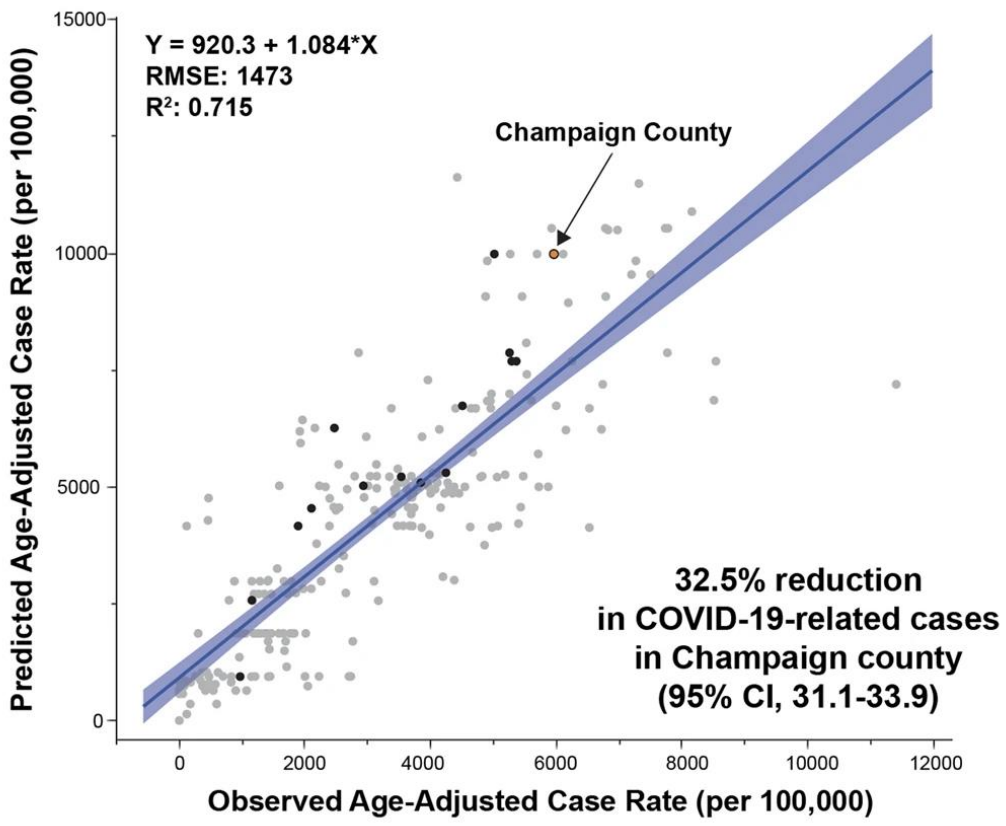
The 2008 USGS ShakeOut Scenario report (informed by SCEC CyberShake simulations) was the basis of the initial Great Southern California ShakeOut emergency response and preparedness exercise, inspired utility infrastructure improvements, and motivated LA Mayor Garcetti's ***Resilience by Design*** mandate for **smarter city planning** and retrofitting vulnerable buildings.

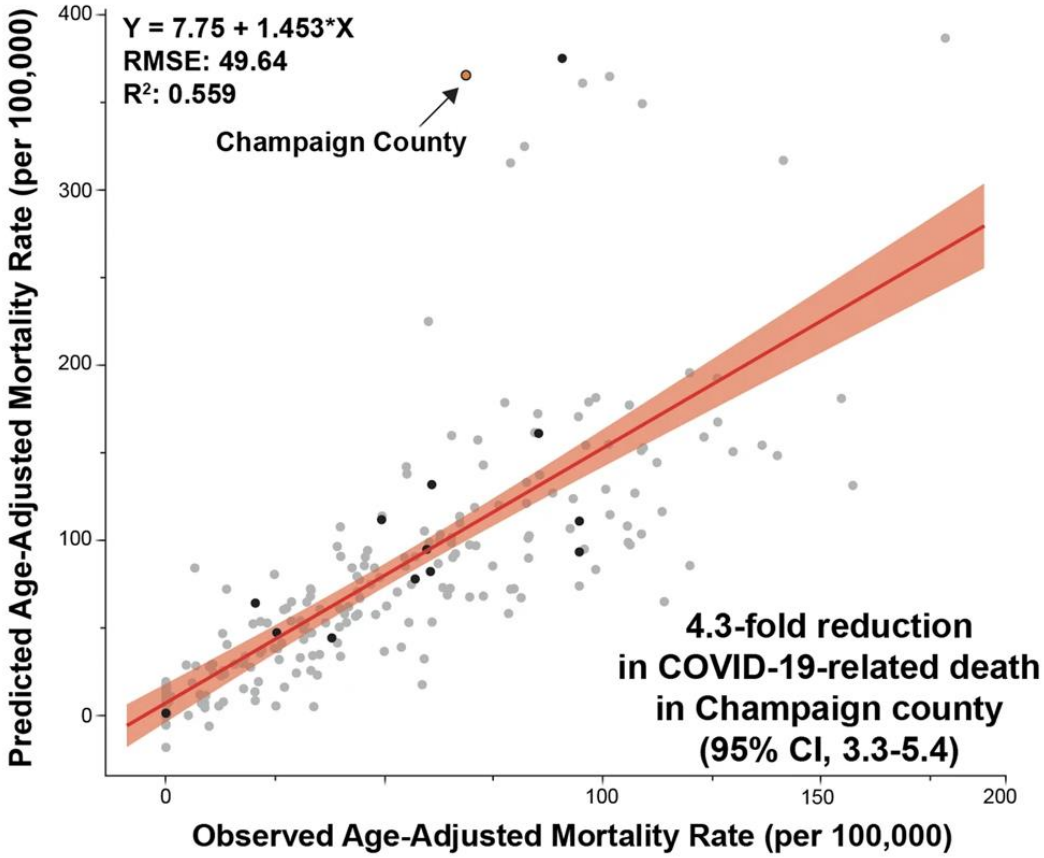
Covid19: Advancing Science and Affecting Societal Impact

Between 2020 and 2022: Co-led and then led UIUC Covid-19 Modeling and Data Analysis Group

Published fundamental mathematical epidemiology research: PNAS, PRX, eLife, and Nature Comm

But we remain most proud of one result in particular:

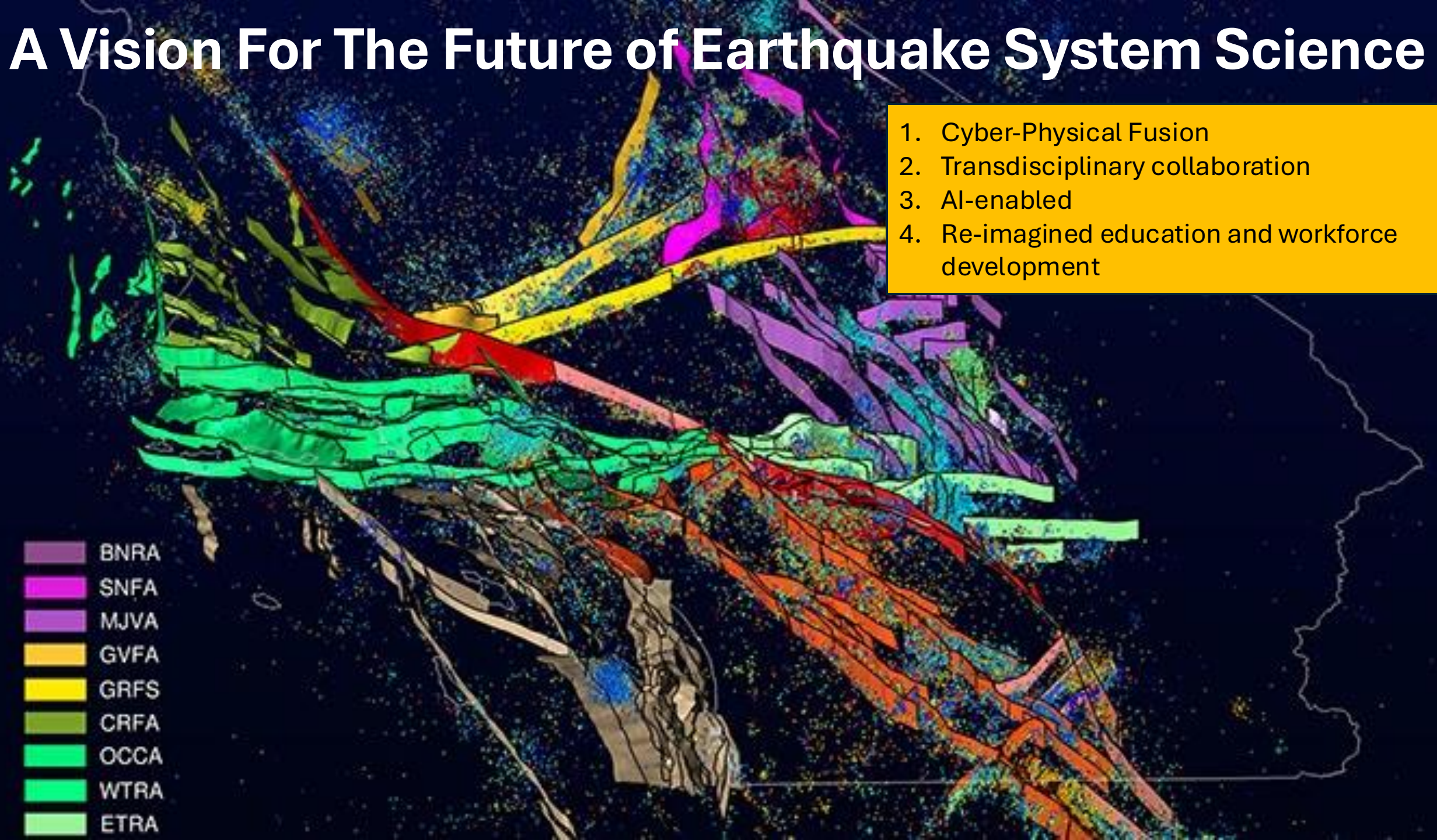




Ranoa et al., Nature Comm, 2022

A Vision For The Future of Earthquake System Science

1. Cyber-Physical Fusion
2. Transdisciplinary collaboration
3. AI-enabled
4. Re-imagined education and workforce development



I. Convergence of the Cyber and Physical Worlds

Earth science is data-driven

I. Convergence of the Cyber and Physical Worlds

Earth science is data-driven and model-guided

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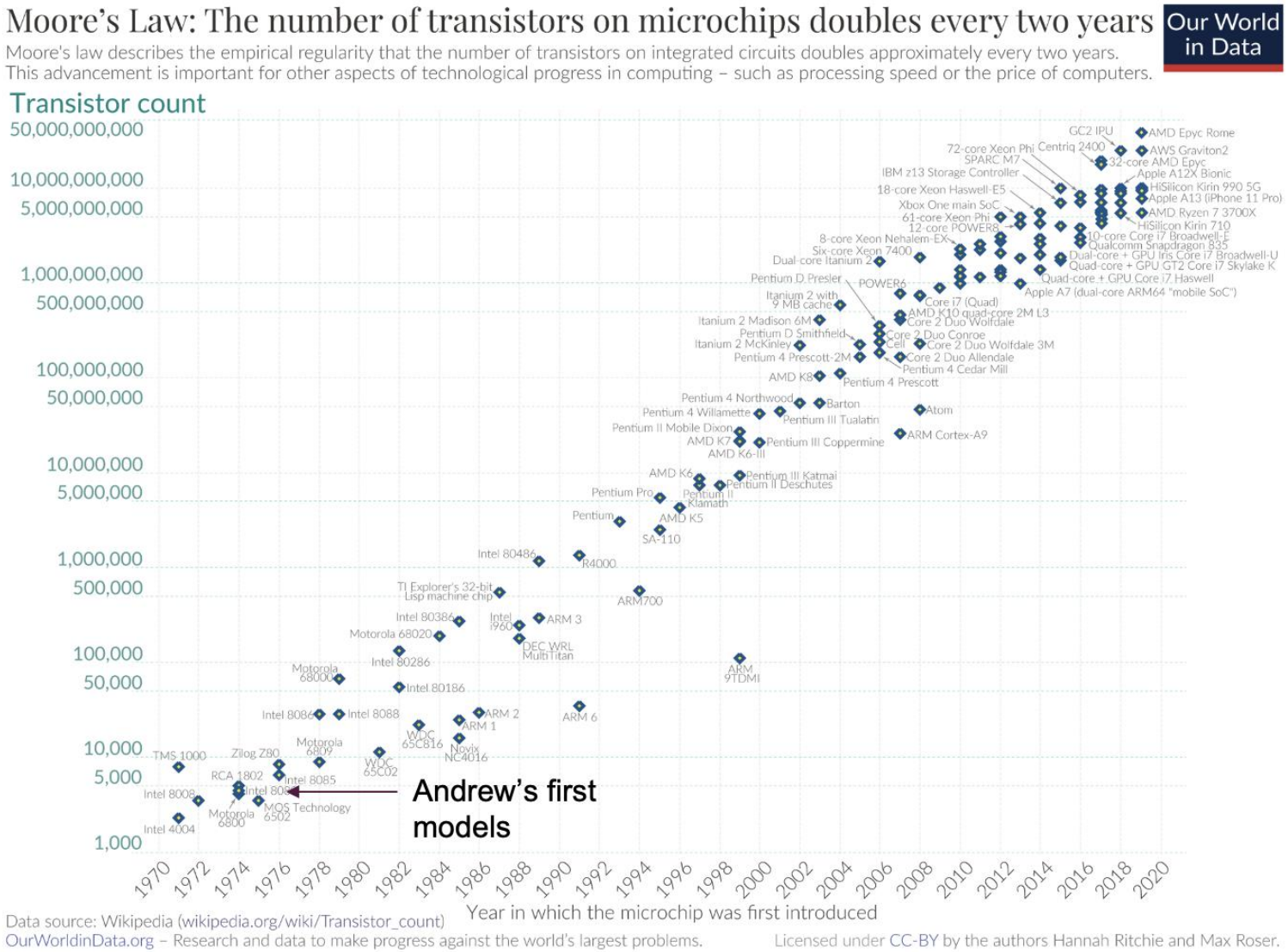
Earth science is data-driven and model-guided

But for the most part

Data has been limited

Models have been largely prescriptive not predictive

I. Convergence of the Cyber and Physical Worlds



100s Petaflops

$\times 10^9$

100s Megaflops

Computing power continues to rise exponentially!

Exciting new opportunities!

New algorithms + ML

I. Convergence of the Cyber and Physical Worlds

Seismic Wave Propagation and Inversion with Neural Operators

Yan Yang; Angela F. Gao; Jorge C. Castellanos; Zachary E. Ross; Kamyar Azizzadenesheli; Robert W. Clayton

FWI in seconds!

Instantaneous Physics-Based Ground Motion Maps Using Reduced-Order Modeling

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Hazard Maps on demand!

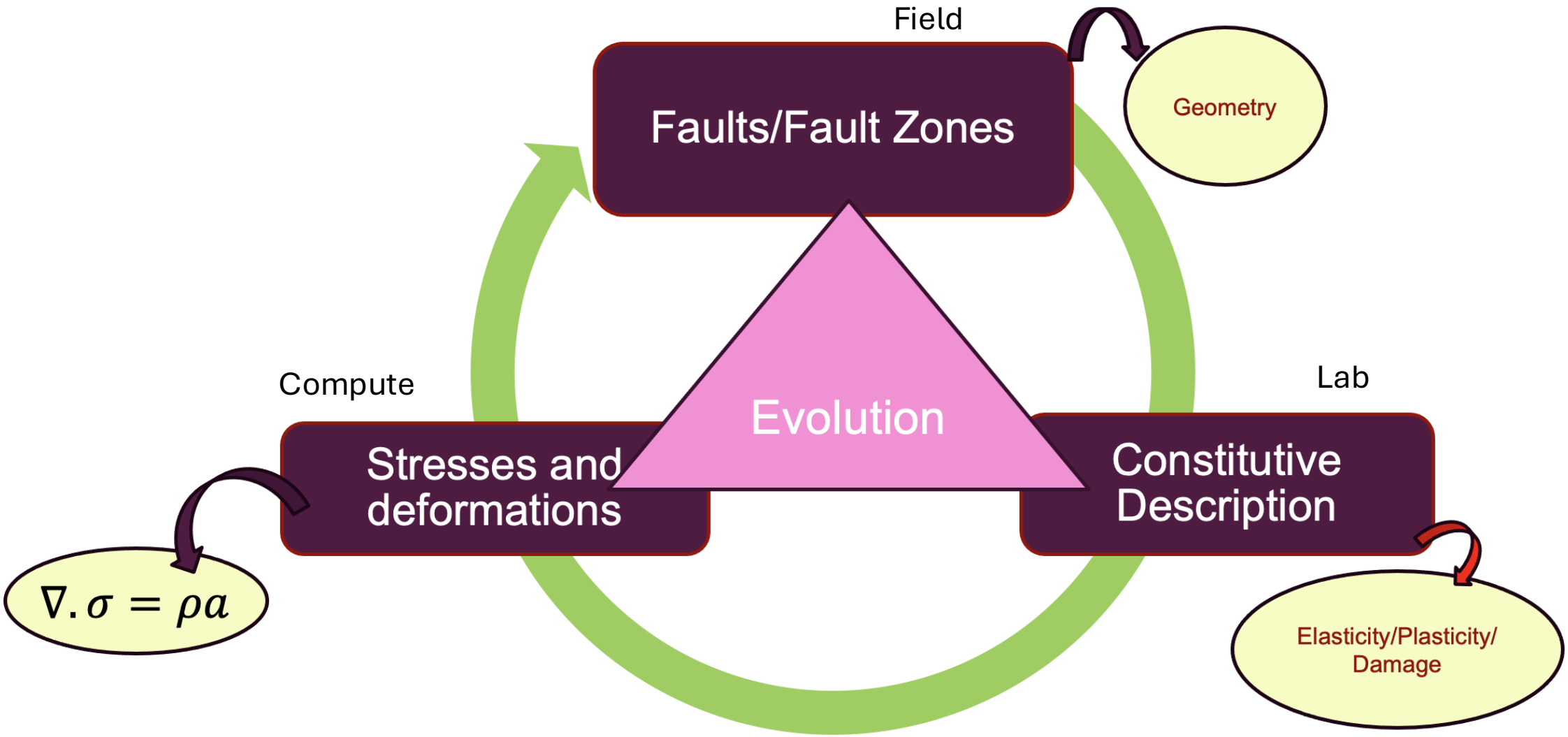
Fourier Neural Operators for Accelerating Earthquake Dynamic Rupture Simulations

GEOPHYSICS

Napat Tainpakdipat, Mohamed Abdelmeguid, Chunhui Zhao, Kamyar Azizzadenesheli, Ahmed Elbanna

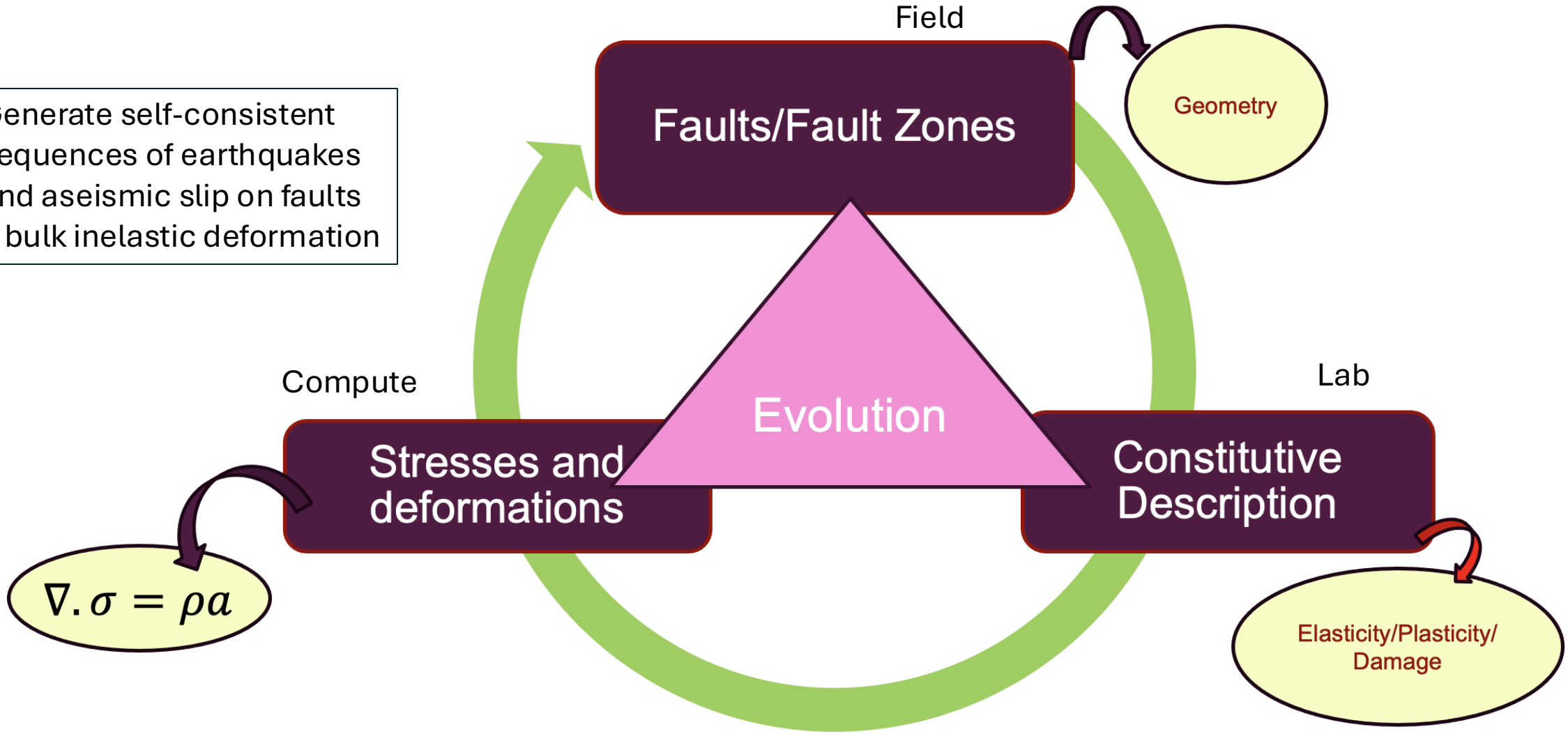
At least 10^5 x speed up!

I.A) A New Cyber Realm: The Virtual Earthquake Machine



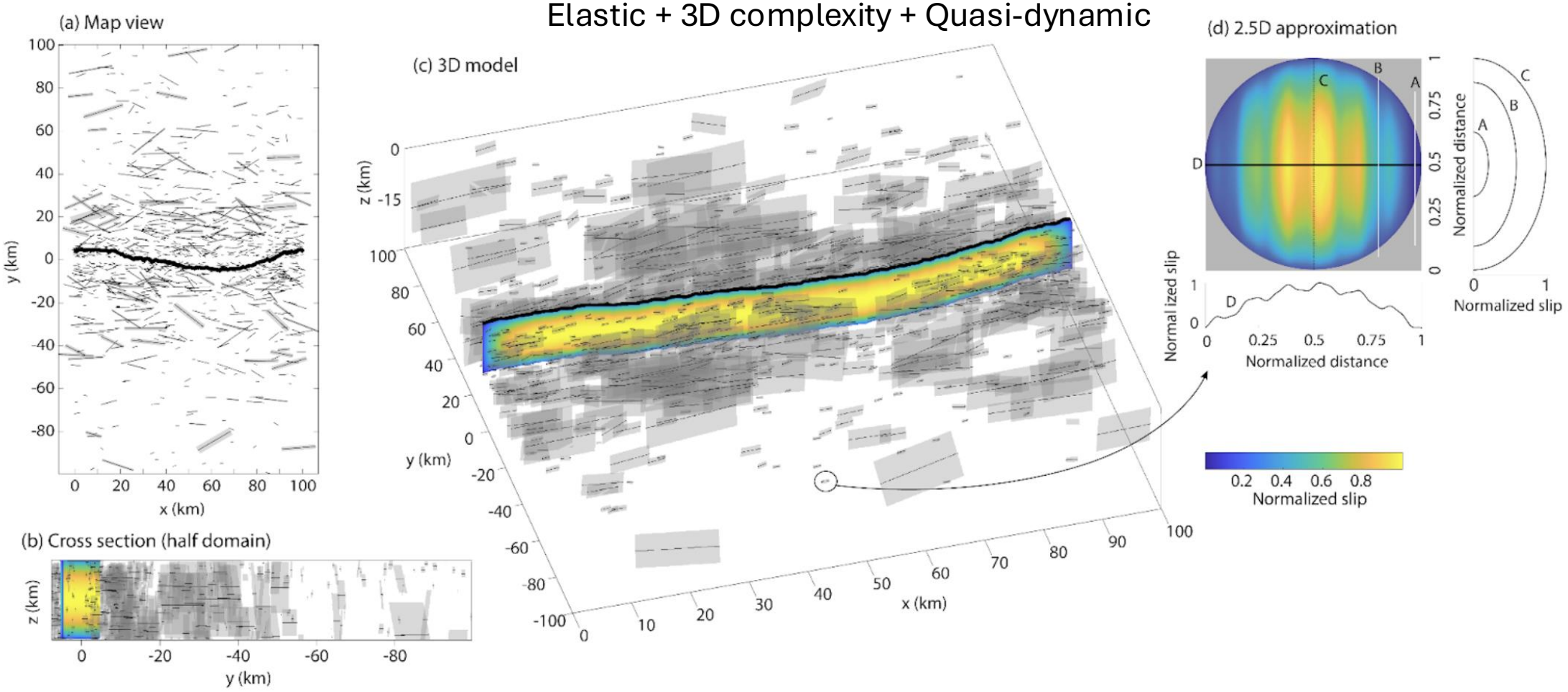
I.A) A New Cyber Realm: The Virtual Earthquake Machine

Generate self-consistent sequences of earthquakes and aseismic slip on faults + bulk inelastic deformation



I.A) Example: Physics-based multi-cycle simulations in Complex Fault Zones

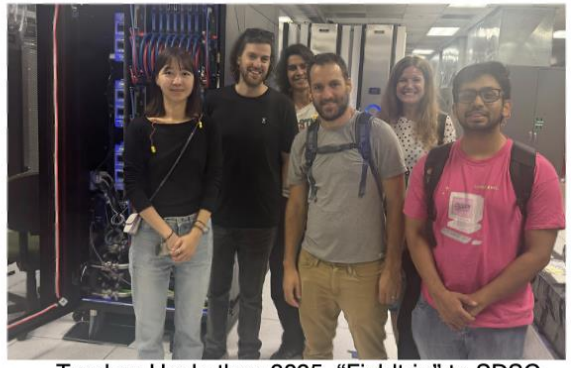
Elastic + 3D complexity + Quasi-dynamic



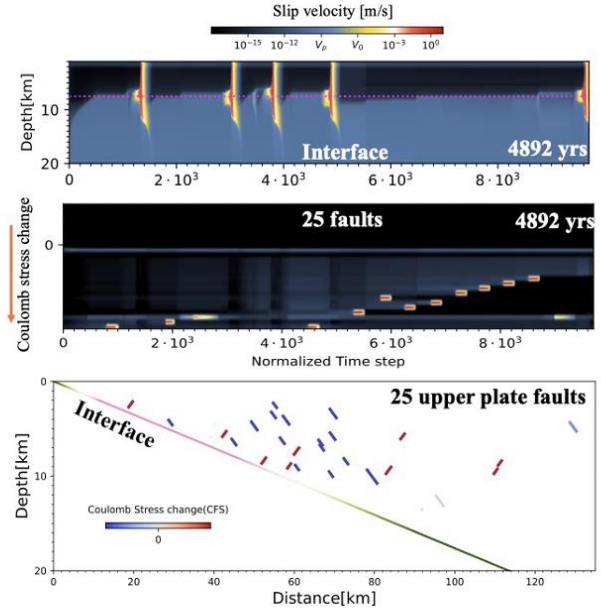
Courtesy of Camilla Cattania (MIT) 2025

I.A) Example: Physics-based multi-cycle simulations in Complex Fault Zones

Tandem - a symmetric interior penalty discontinuous Galerkin method for volumetric SEAS simulations using Supercomputers

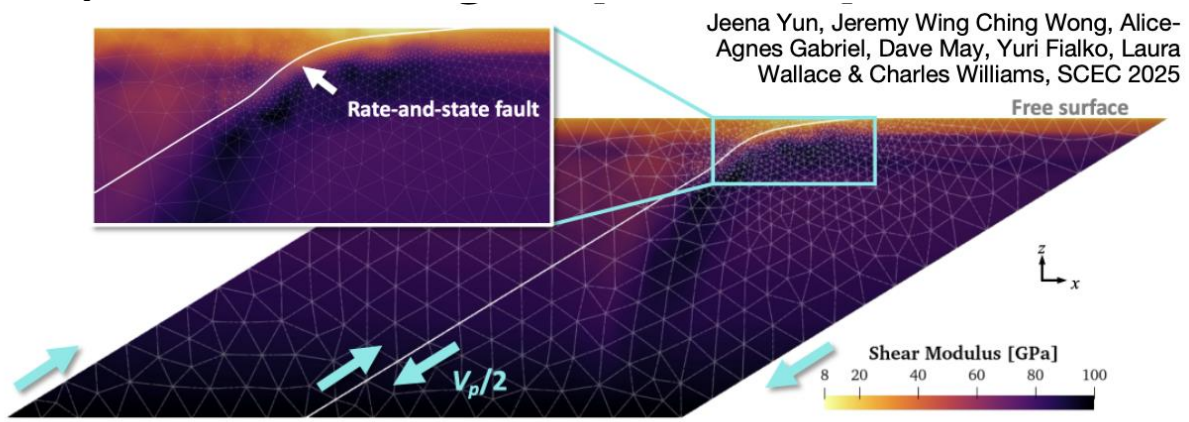


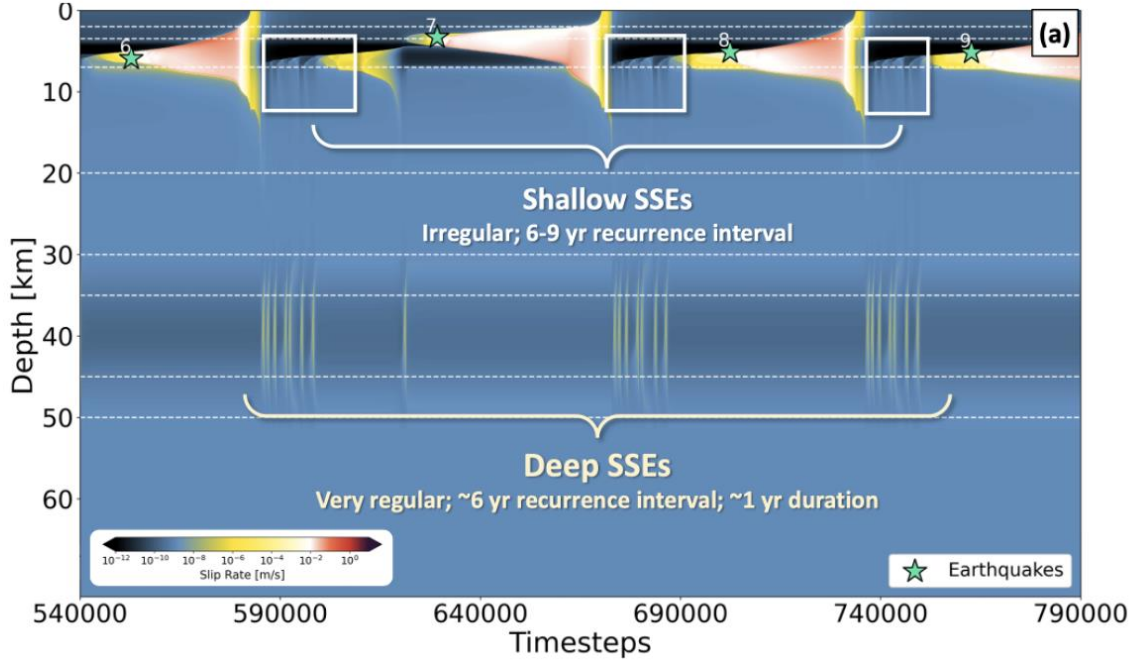
Tandem Hackathon 2025, "Fieldtrip" to SDSC



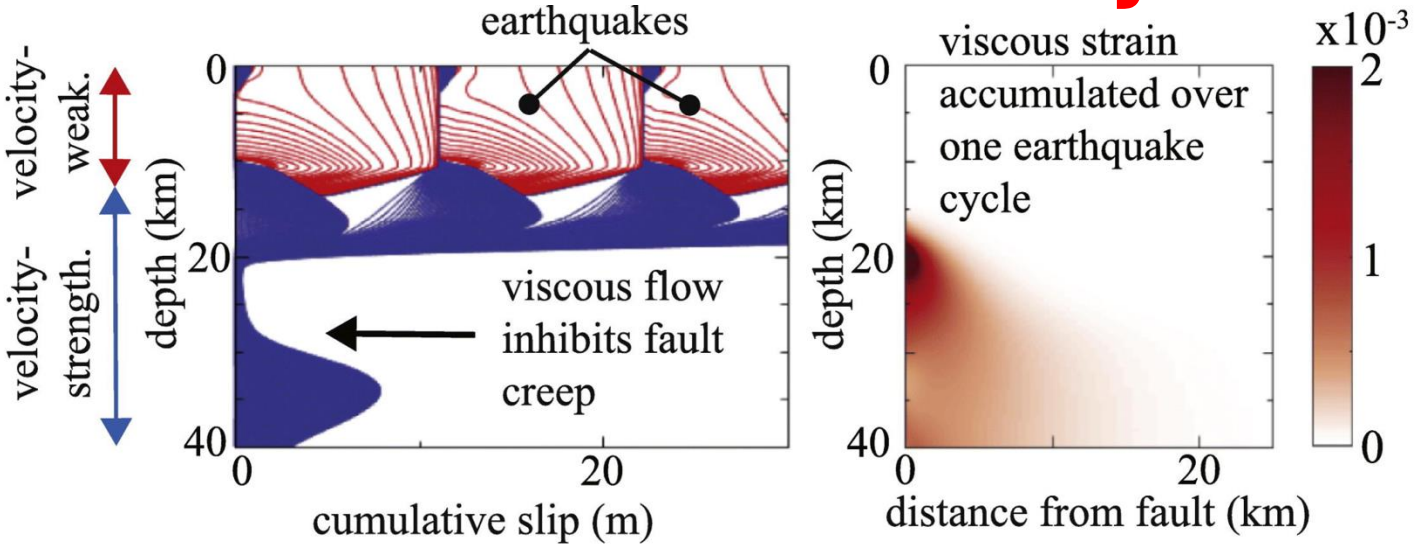
Bar Oryan, Dave A May, Alice-Agnes Gabriel, in prep.

Jeena Yun, Jeremy Wing Ching Wong, Alice-Agnes Gabriel, Dave May, Yuri Fialko, Laura Wallace & Charles Williams, SCEC 2025

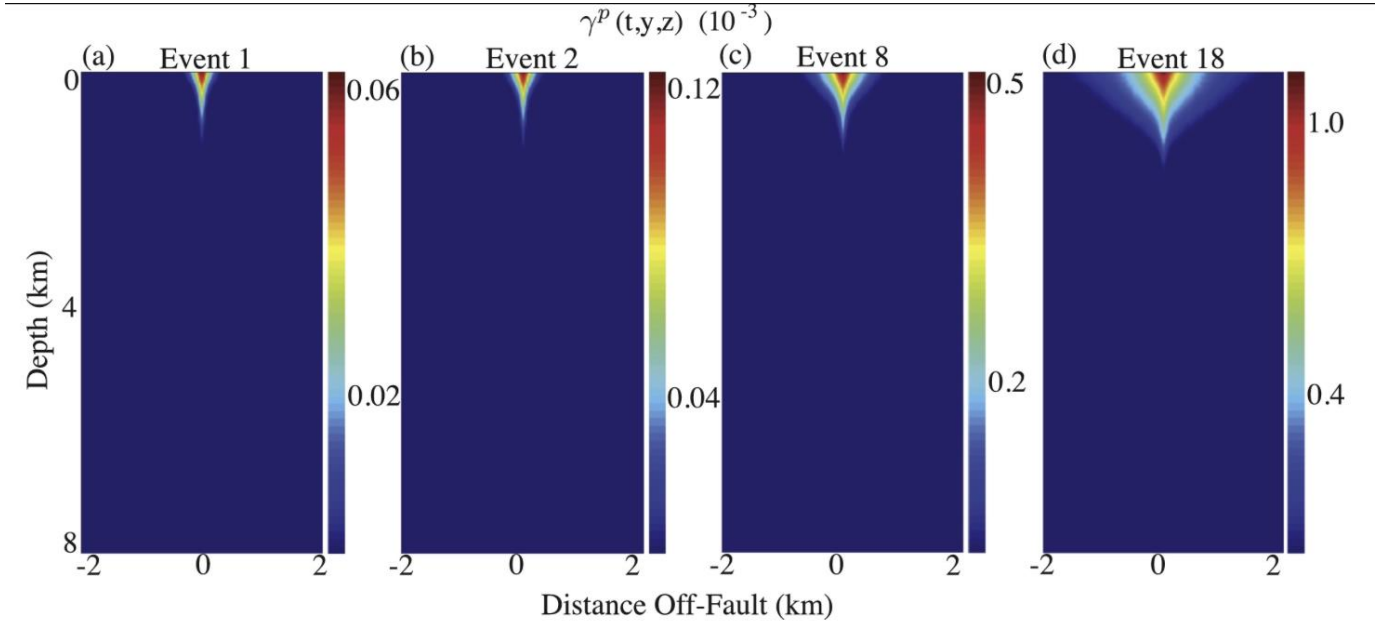




I.A) Example: Physics-based multi-cycle simulations with bulk inelasticity



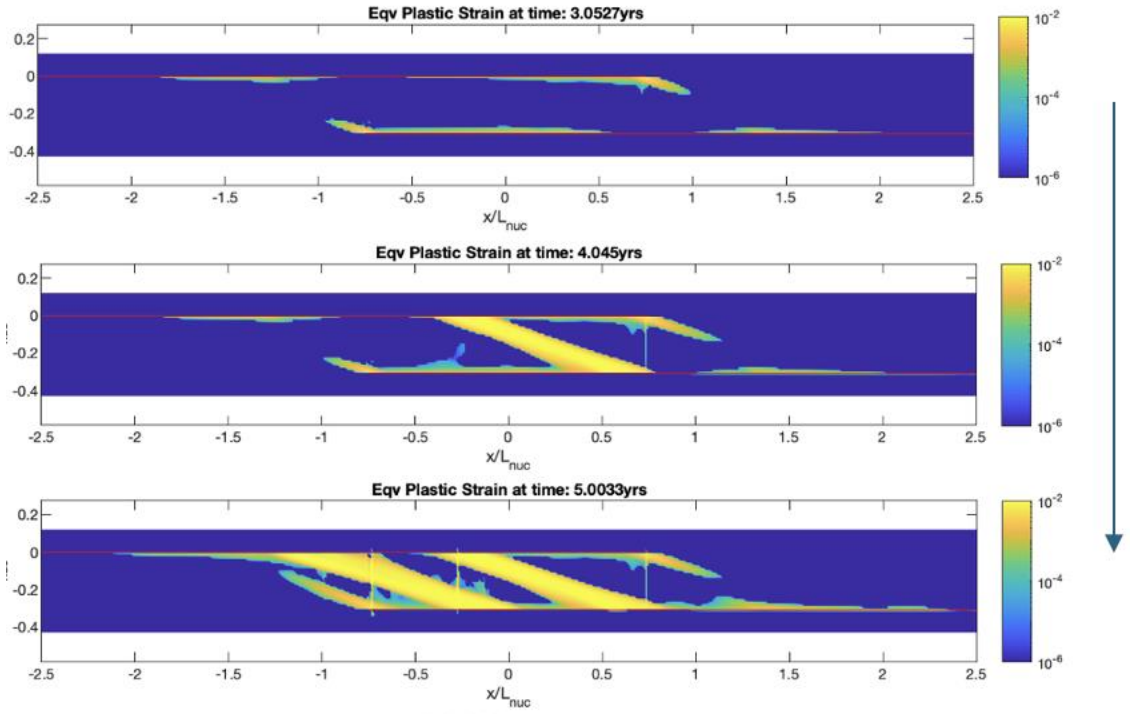
visco-elastic + Quasi-dynamic
Allison et al. 2017

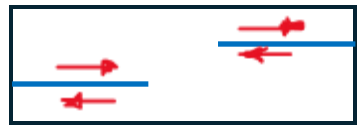


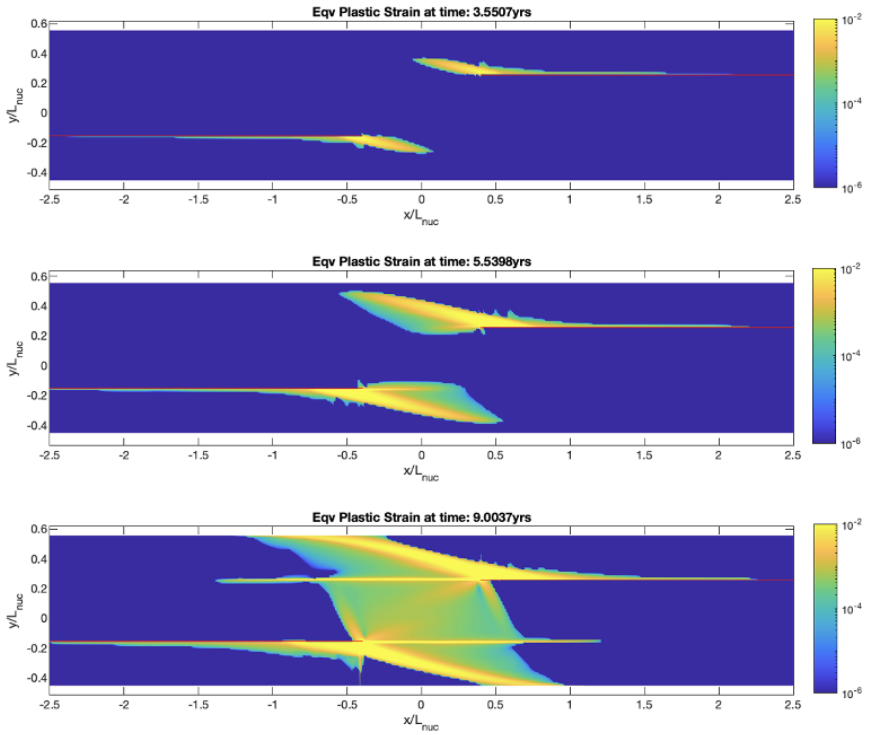
elastoplastic + Quasi-dynamic
Erickson et al. 2017

I.A) Example: Physics-based multi-cycle simulations in Fault step-overs with off-fault inelastic rheology

Elastoplastic
Fully Dynamic
Geometric Complexity





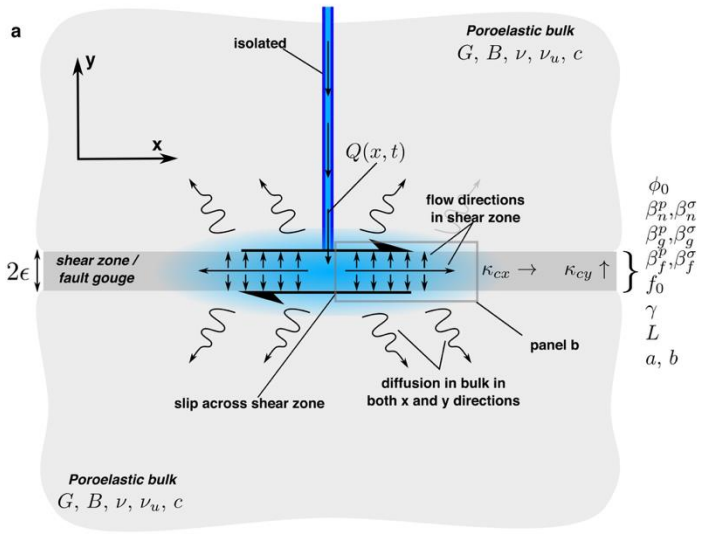


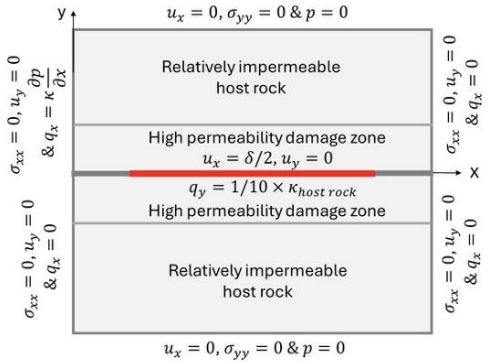
Tensile stepover (overlap). Developing multiple connecting faults over cycles that may be selectively get activated

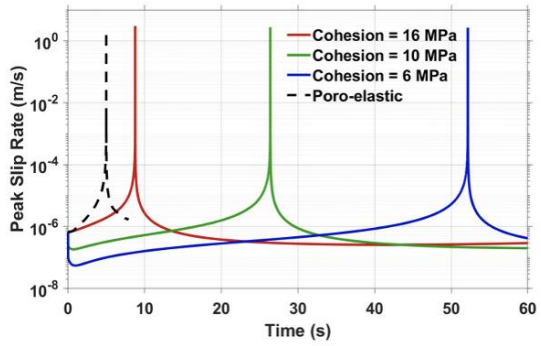
Compressive stepover (Underlap). Developing repulsive branched and complex connectivity.

Mia, Abdelmeguid, Ruth Harris, and Elbanna, BSSA 2024; Mia et al. (2025) to appear

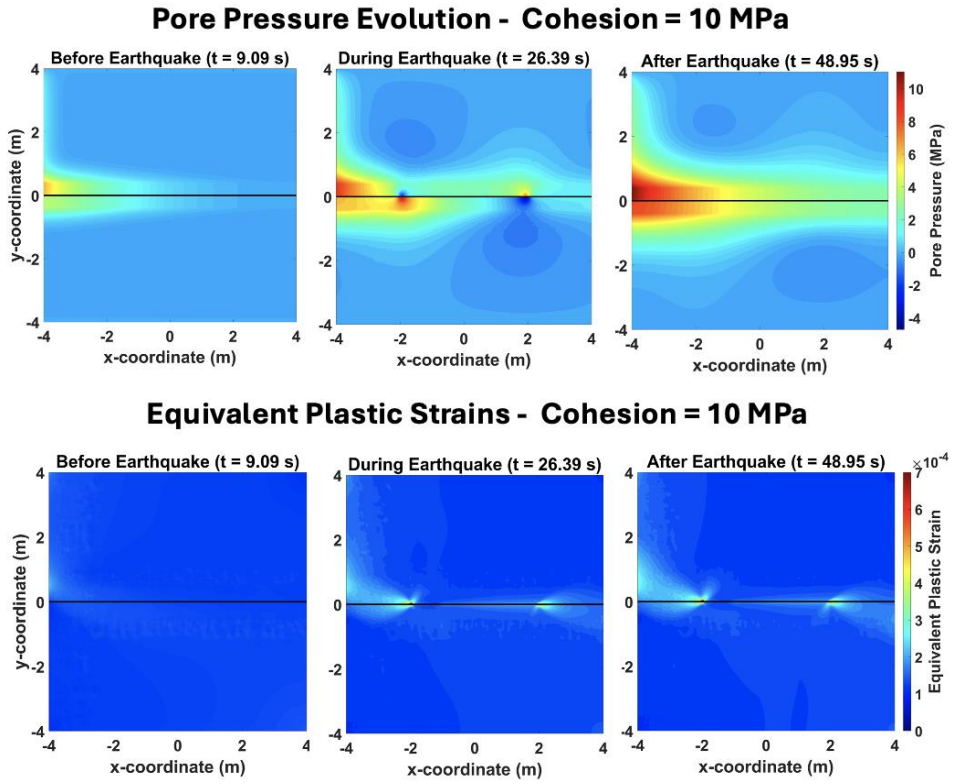
I.A) Example: Physics-based multi-cycle simulations with poro-mechanics







Poro-elastic + Quasi-dynamic
Heimisson et al. 2022



Poro-plastic + Quasi-dynamic
Ibrahim, Abdelmeguid, and Elbanna, (2025) to appear

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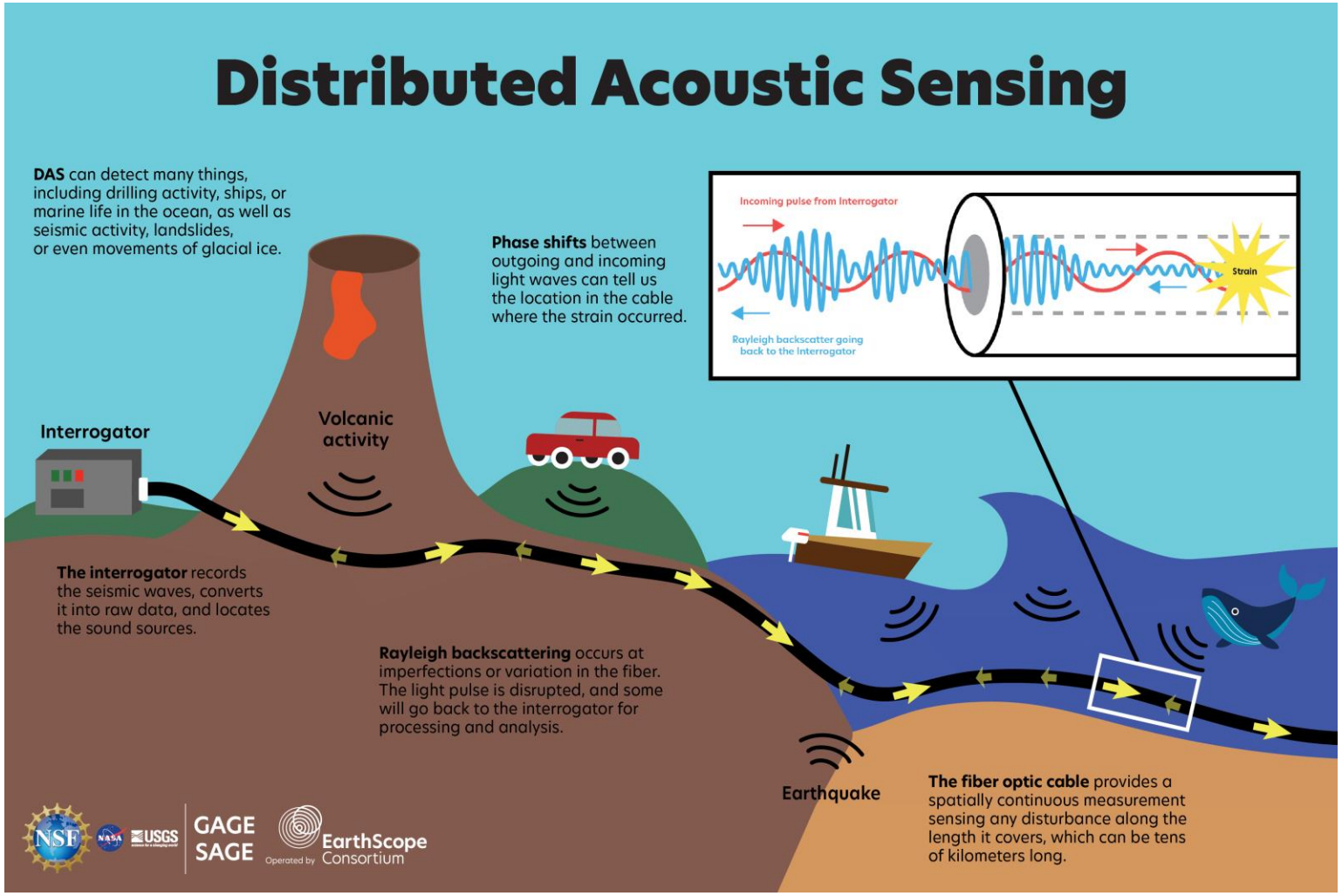
I.B)A New Age in the Physical World: Ubiquitous Geo-sensing - DAS



Credit: Davie Loria/EarthScope

I.B) A New Age in the Physical World: Ubiquitous Geo-sensing – Cell phones

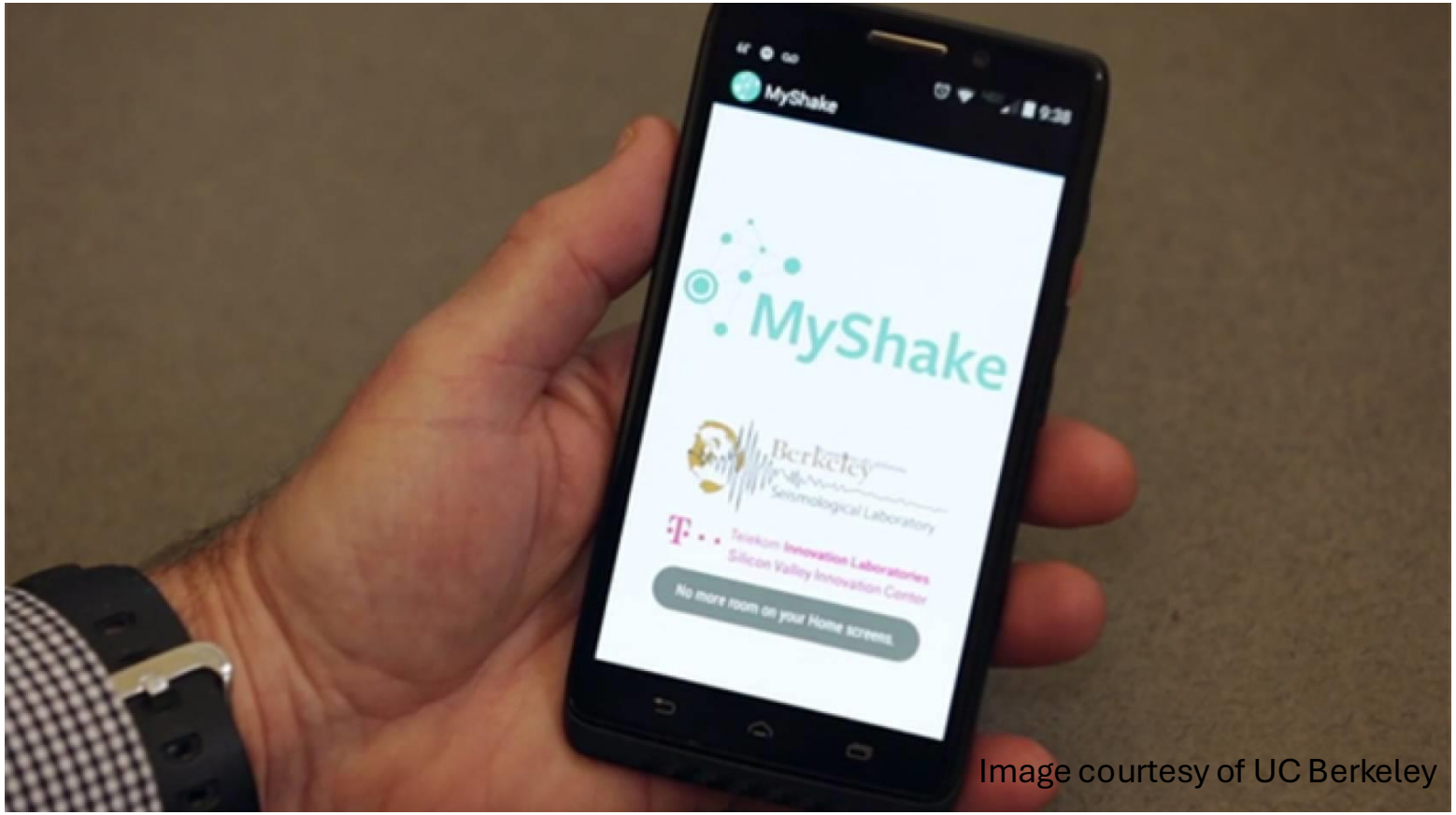
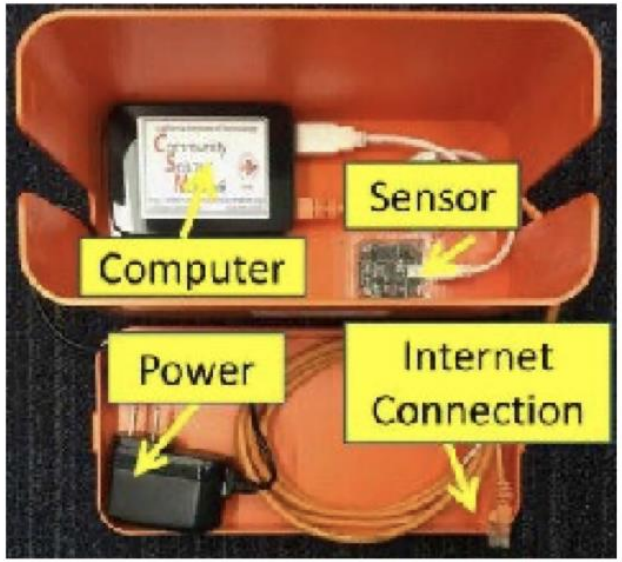


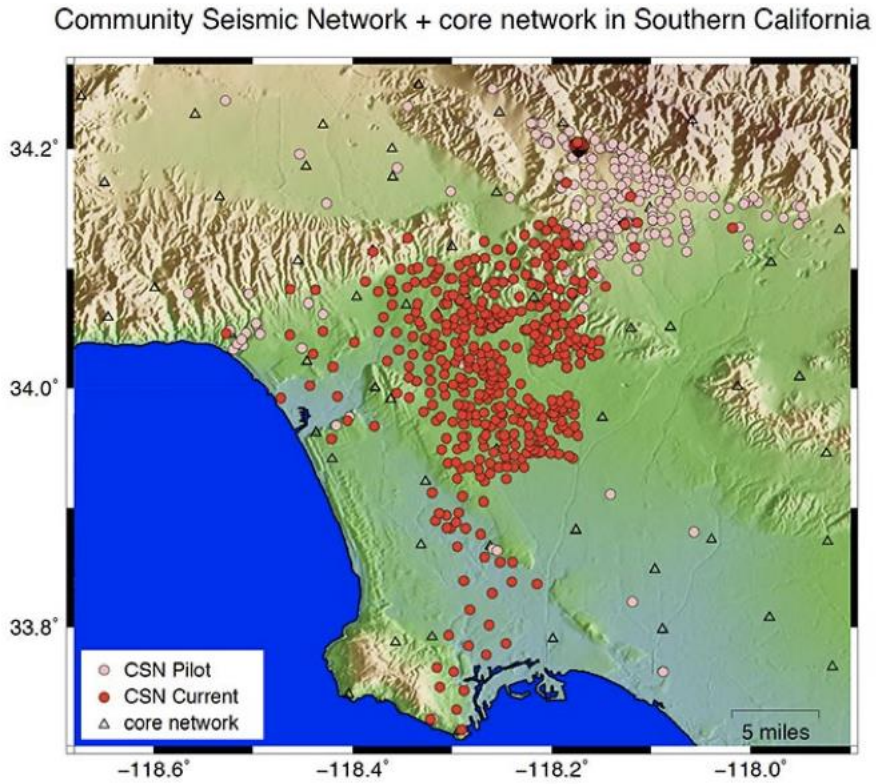
Image courtesy of UC Berkeley

Smartphone Seismology

I.B) A New Age in the Physical World: Ubiquitous Geo-sensing - CSN



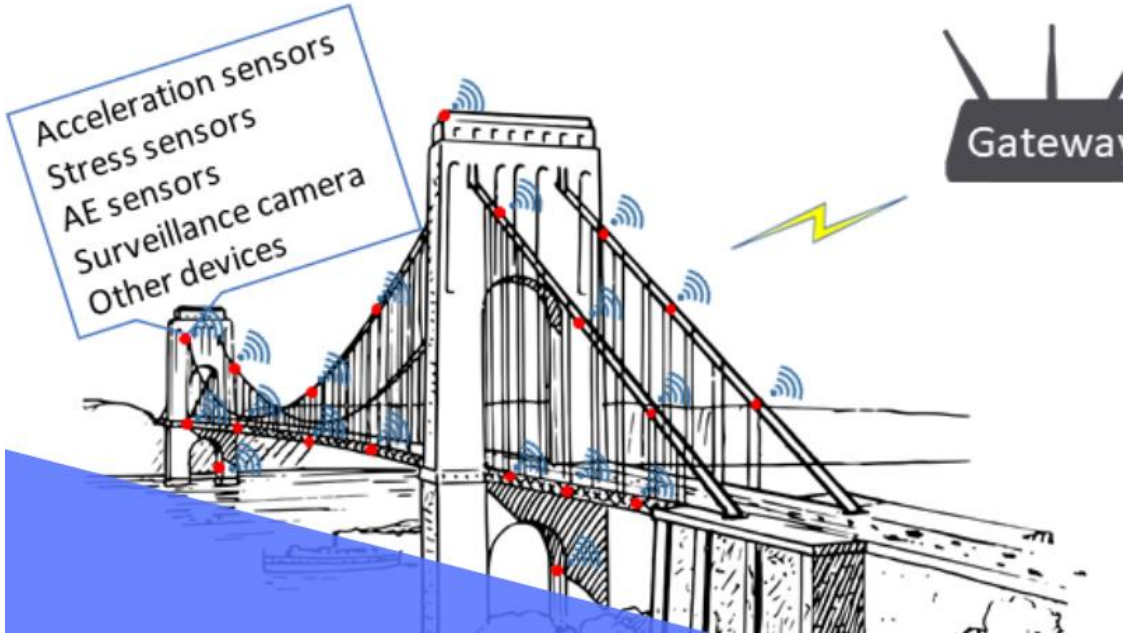
https://web.gps.caltech.edu/~clay/CSN_New_Web/Sensor-Detail.html



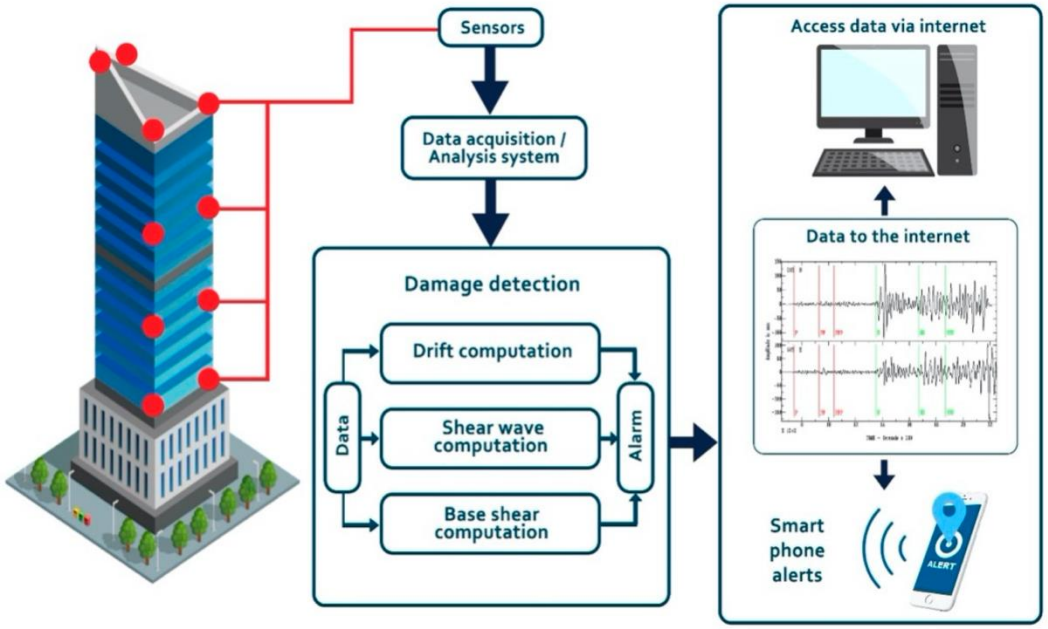
http://csn.caltech.edu/lausd/

Community Seismic Network: Expanding Dense Affordable Instrumentation

I.B) A New Age in the Physical World: Ubiquitous Geo-sensing – Leveraging SHM



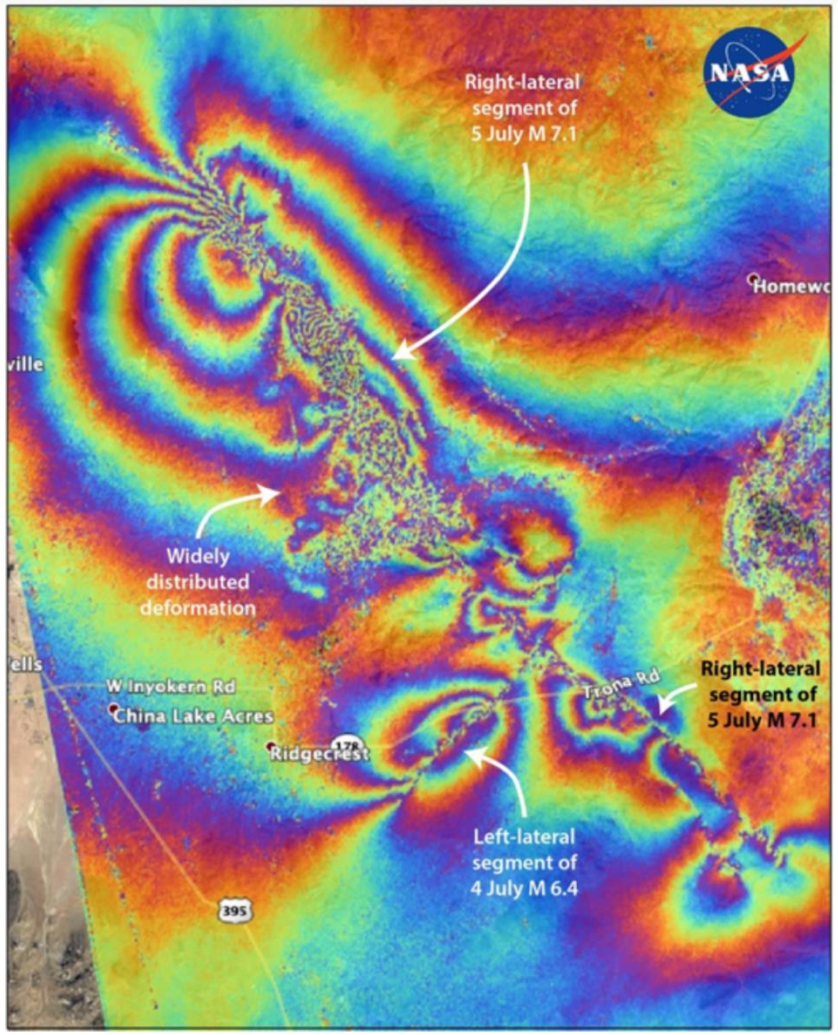
FPrimeC solutions



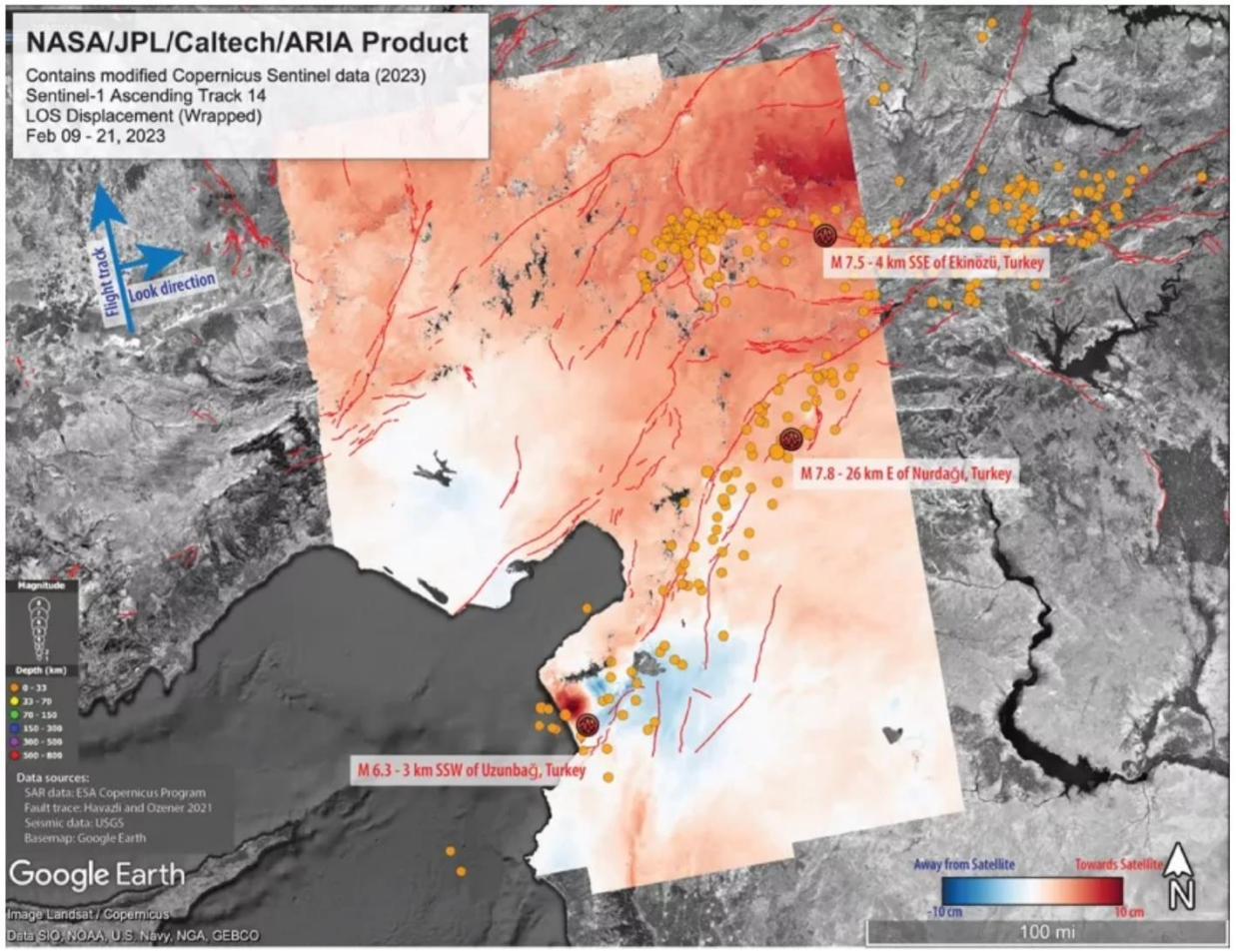
Sivasuriyan et al., Buildings, 2021

Structural Health Monitoring Sensors (Bridges and Buildings)

I.B) A New Age in the Physical World: Ubiquitous Geo-sensing- Lidar (faster, more accurate, and abundant)



The interferogram is derived from the ALOS-2 satellite, operated by the Japan Aerospace Exploration Agency (JAXA), with images taken before (16 April 2018) and after (8 July 2019) the earthquakes. Each color cycle represents 11.45 cm (4.5 inches) of ground displacement in the radar line-of-sight (28° from vertical and roughly east).



This unwrapped displacement map depicts changes to Earth's surface from the Feb. 20 earthquake. Blue areas show land movement away from the satellite, while red areas depict land movement toward the satellite. The epicenters of the three major earthquakes are shown by red icons, while the numerous aftershocks are shown in yellow. Credits: NASA's Jet Propulsion Laboratory. Copyright contains modified Copernicus Sentinel data (2023) processed by the ESA.

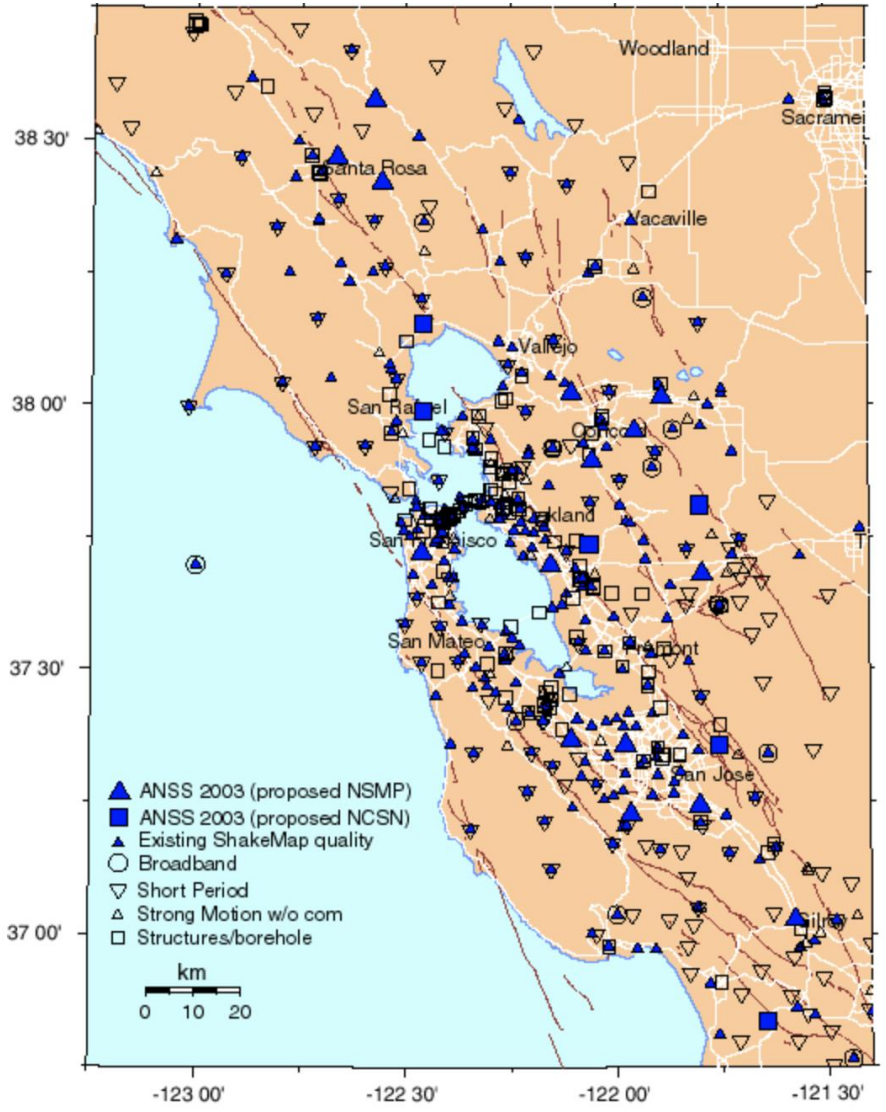
I.B) A New Age in the Physical World: Ubiquitous Geo-sensing - GNSS

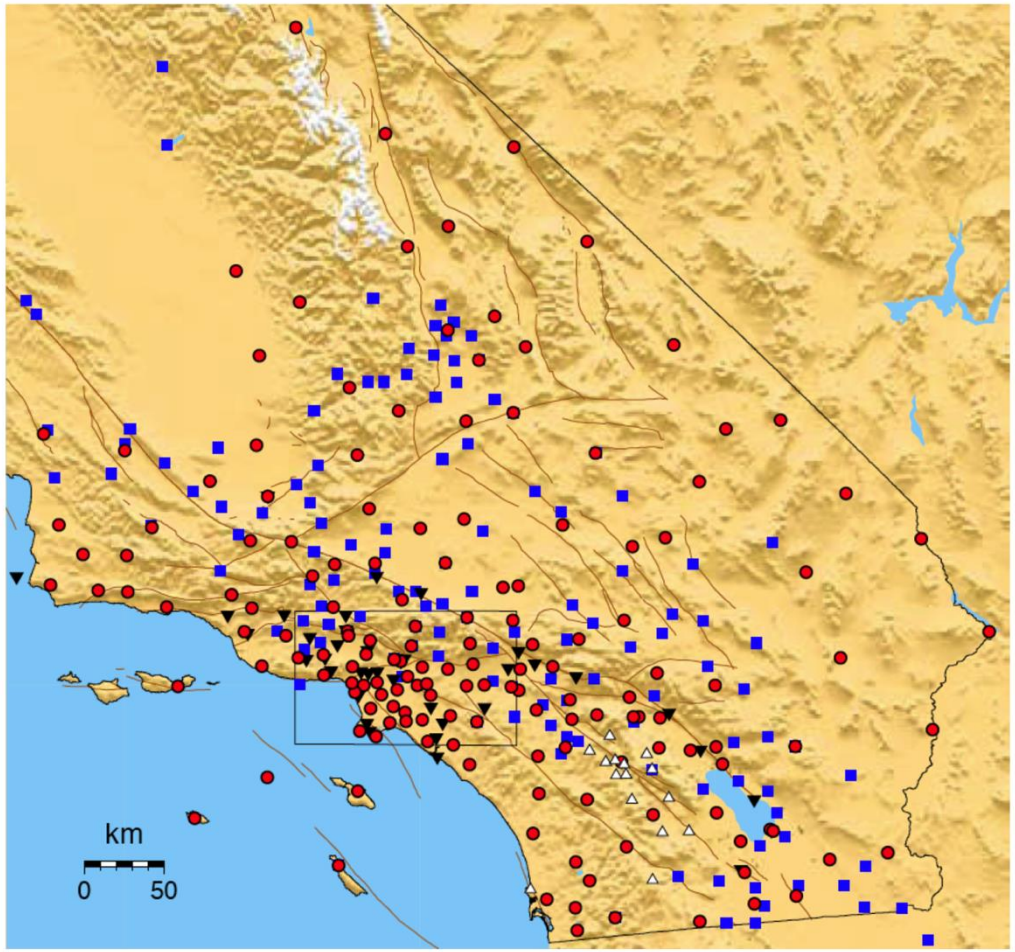
GNSS station - AB13
atop a cliff

Seismic station - S15K
2 km away; near a bed-and-breakfast

This GNSS station and seismic station are considered closely located at a distance of about 2 kilometers (about 1.2 miles) apart. Both stations collected data during the 2021 magnitude-8.2 Chignik earthquake in Alaska. They're located about 121 kilometers (about 75 miles) away from the hypocenter. Credit: Parameswaran et al. (2023)

I.B) A New Age in the Physical World: Ubiquitous Geo-sensing - Strong Motion and Broadband





Larger imageThe Southern California Seismic Network (SCSN) records data from more than 370 seismic stations. Each station records seismic waves from both near and distant earthquakes. All the data are transmitted automatically to Caltech/USGS in Pasadena for processing and distribution of information such as epicenters, magnitudes, and ShakeMaps. The SCSN is also part of the California Integrated Seismic Network (CISN) that coordinates earthquake monitoring statewide. The symbols indicate different types of seismic stations.

I.B) A New Age in the Physical World: Ubiquitous Geo-sensing - Internet of Things (IoT)

The Rise of Smart Cities

I.B)A New Age in the Physical World: Ubiquitous Geo-sensing - Geological Investigation

Trench across one of South Nappa rupture

Courtesy of Alexis Ault! (Field Trip 09/07 ☺)

Ubiquitous Geo-sensing: Obvious Benefits and Longterm Challenges

Obvious Benefits:

Multiscale coverage.
Complementary Data Streams
Measurement of multiple physical quantities

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Time is ripe to collaborate on addressing long term challenges

Cyberinfrastructure for Data Management and Sustainability
Data Fusion
Data Assimilation with Models
Optimal Design of Networks
Cross Validation by Different Streams of Data.
Identification of Data Gaps

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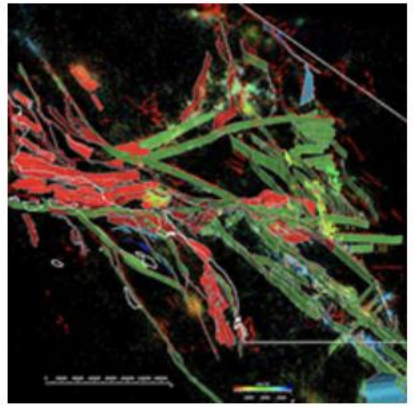
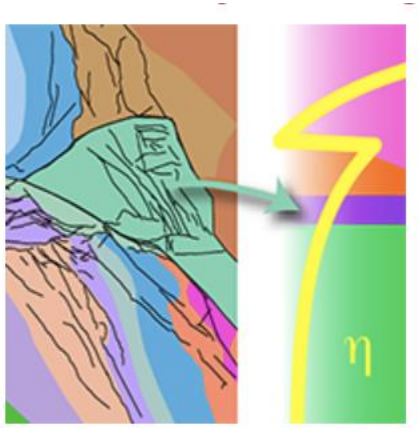
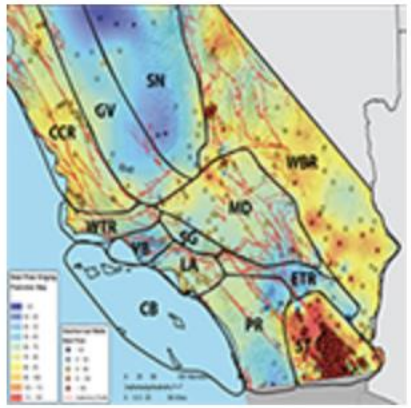
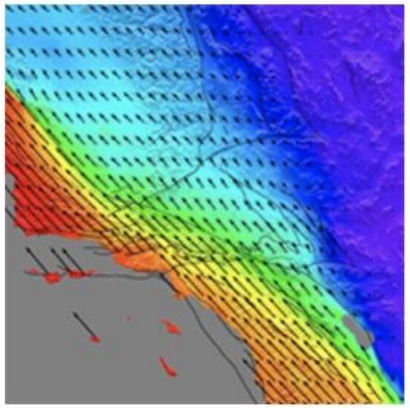
HPC, AI, Cloud, Science Gateways

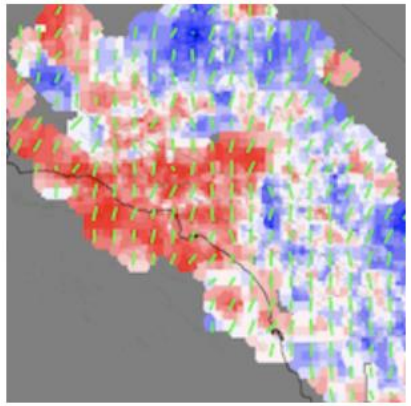
Ubiquitous Geo-sensing: Integrated CEMs

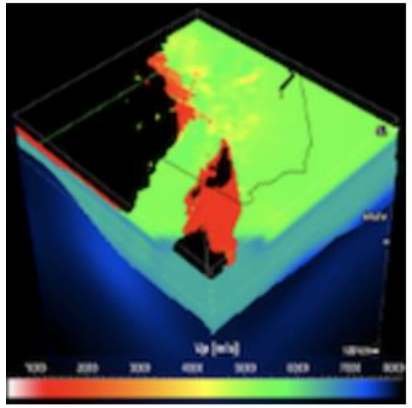




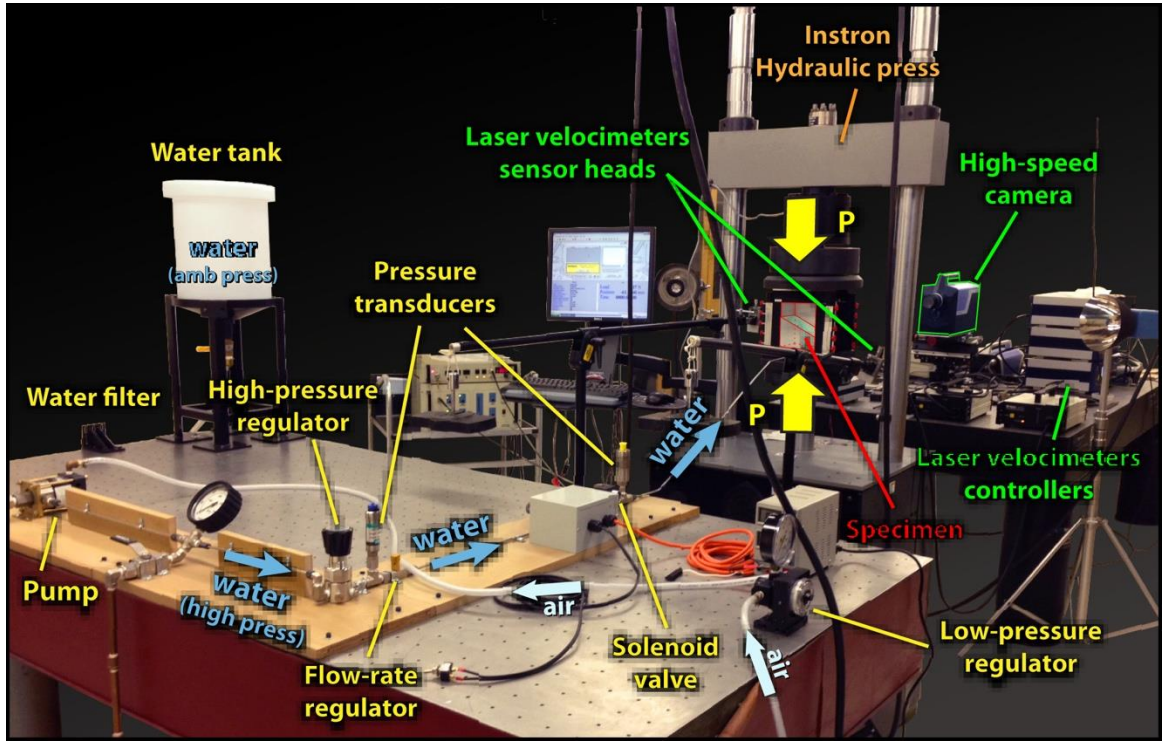




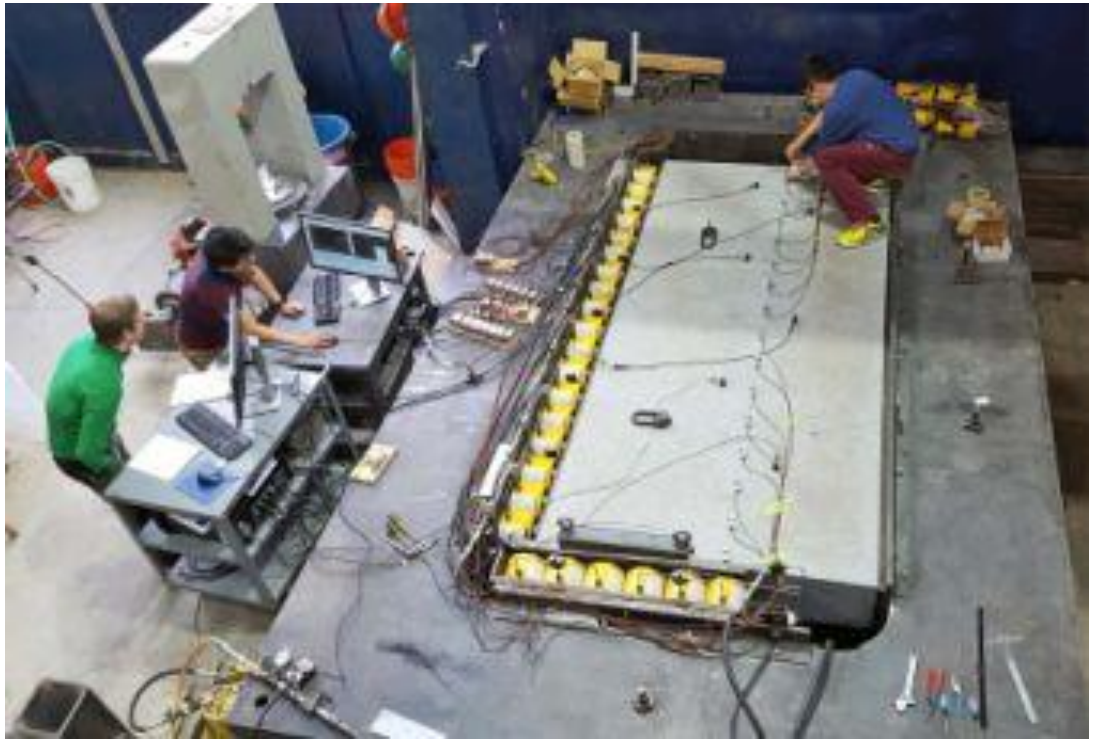




I.C) Lab quakes: A Venue for Discovery and Testing Digital Twins



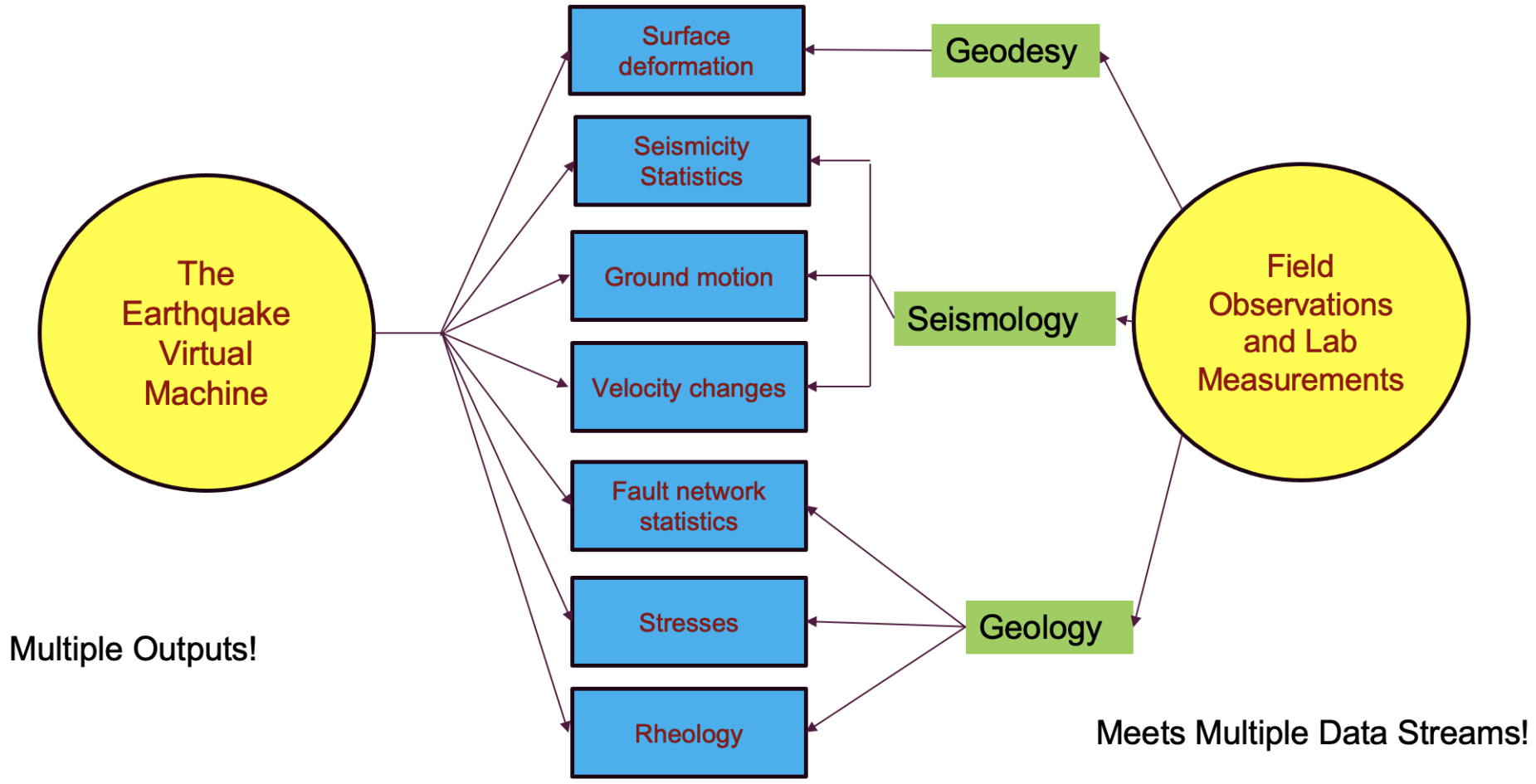
Rosakis Lab (Caltech)



McLaskey Lab (Cornell)

And a few other labs across the globe are also beginning to provide unprecedented, close-up insights into source processes that were traditionally unobservable

I. Convergence of the Cyber and Physical Worlds



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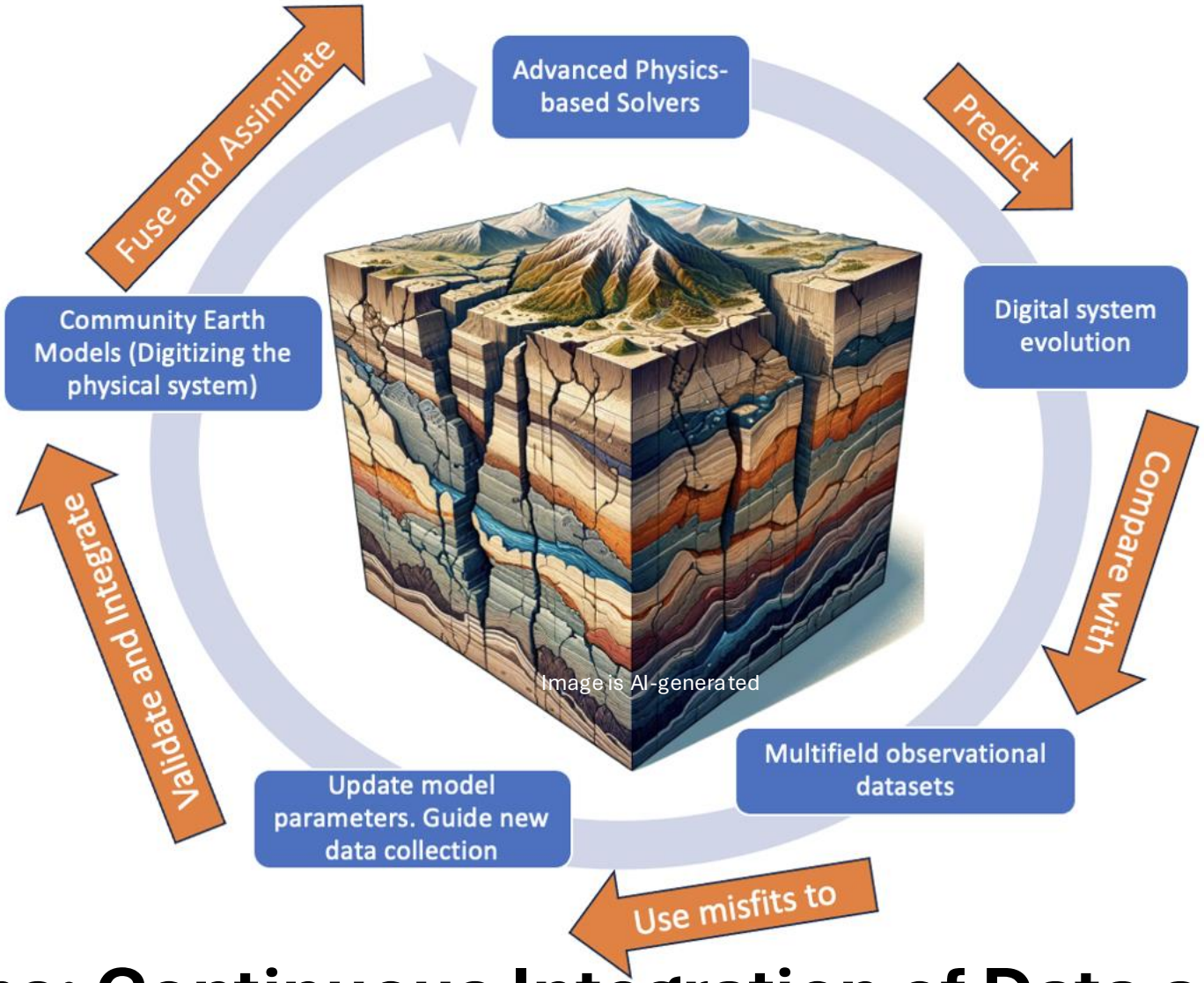


Discover missing physics

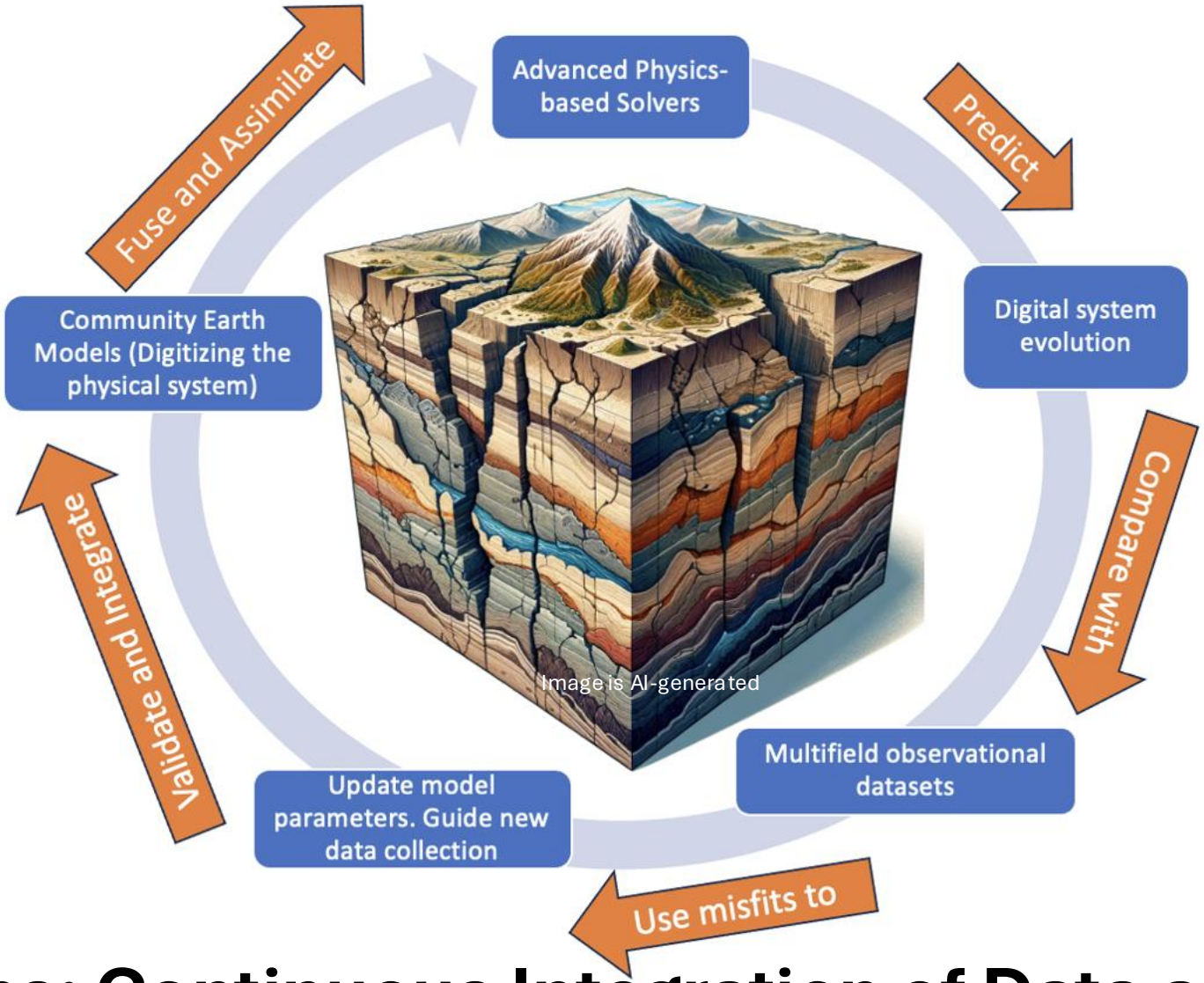
Improve forecasting

Enhance uncertainty bounds

Digital Twins: Continuous Integration of Data and Models

I. Convergence of the Cyber and Physical Worlds

?



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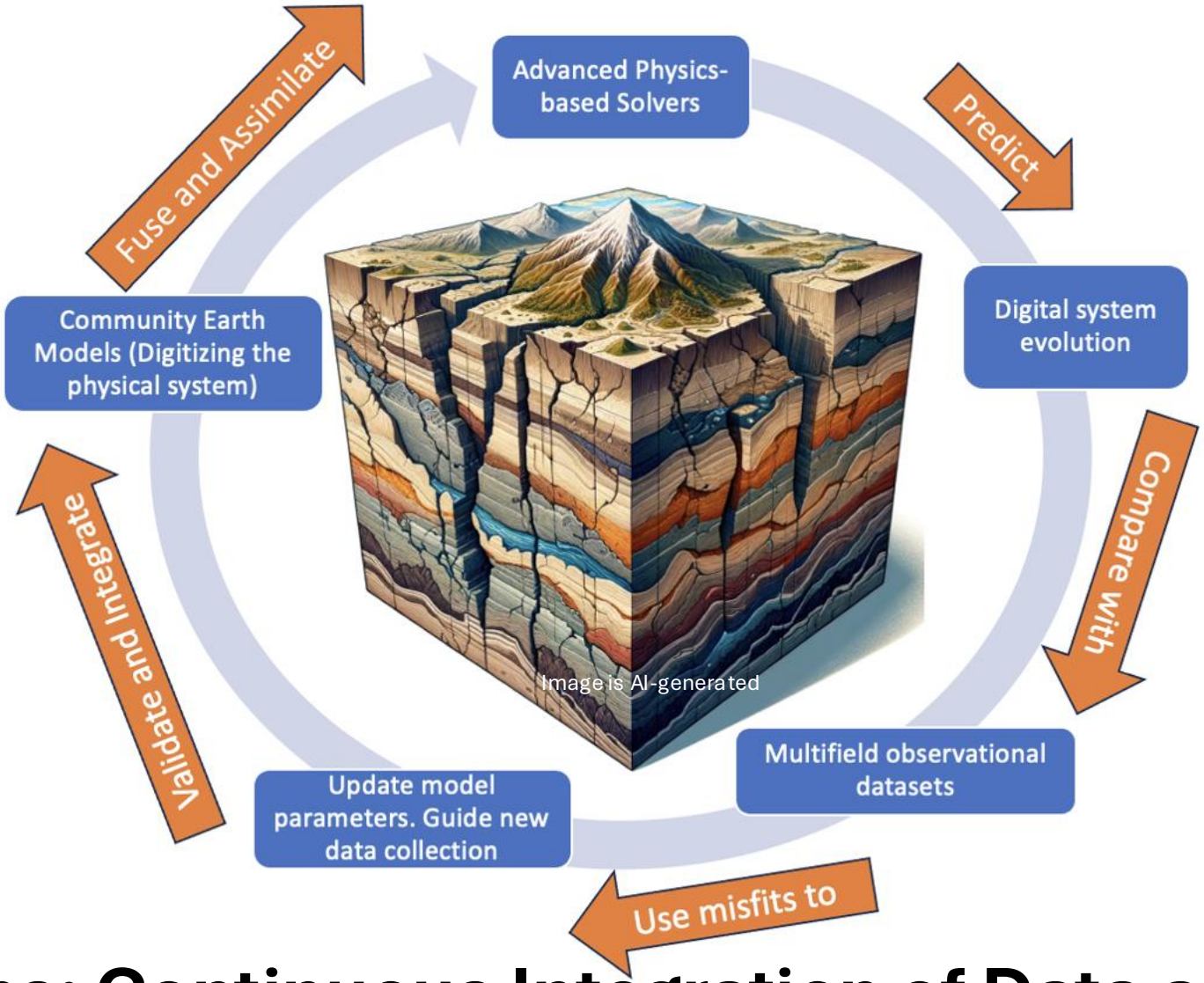
I. Convergence of the Cyber and Physical Worlds

NSHM 33 ?

Data-constrained physics-based multi cycle simulations



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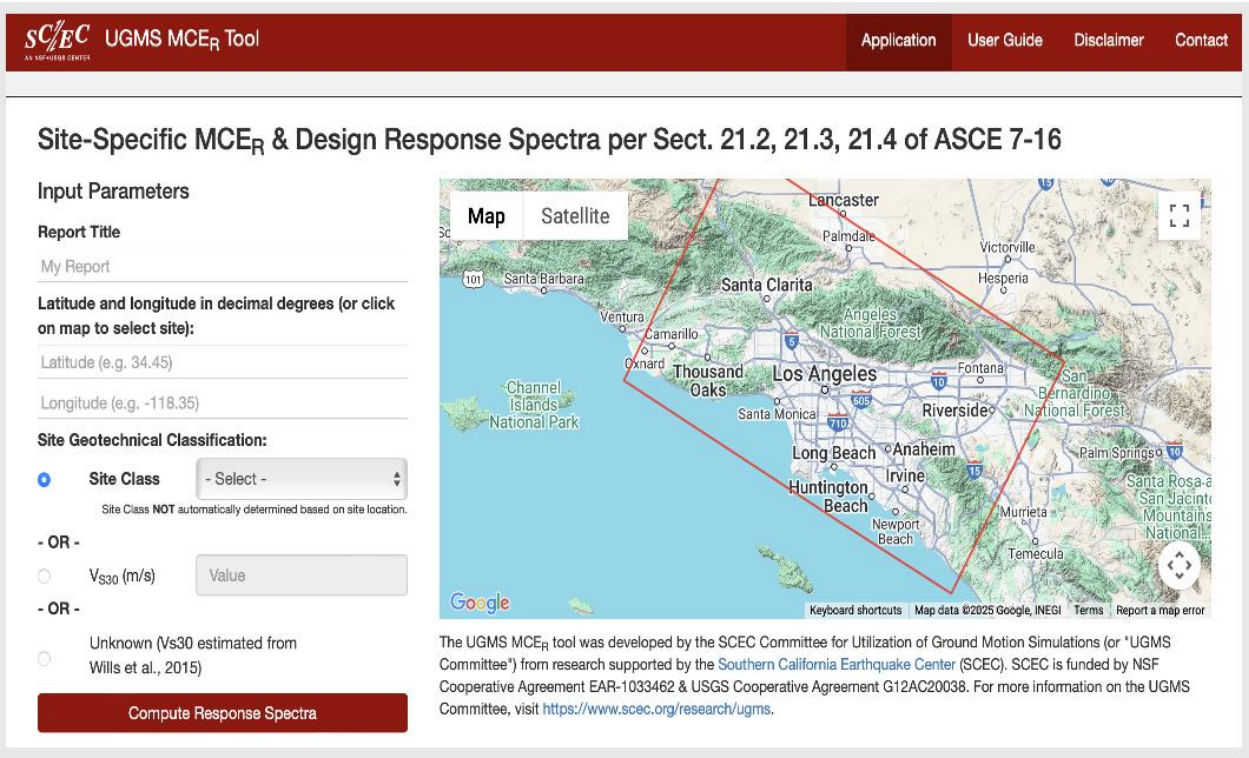
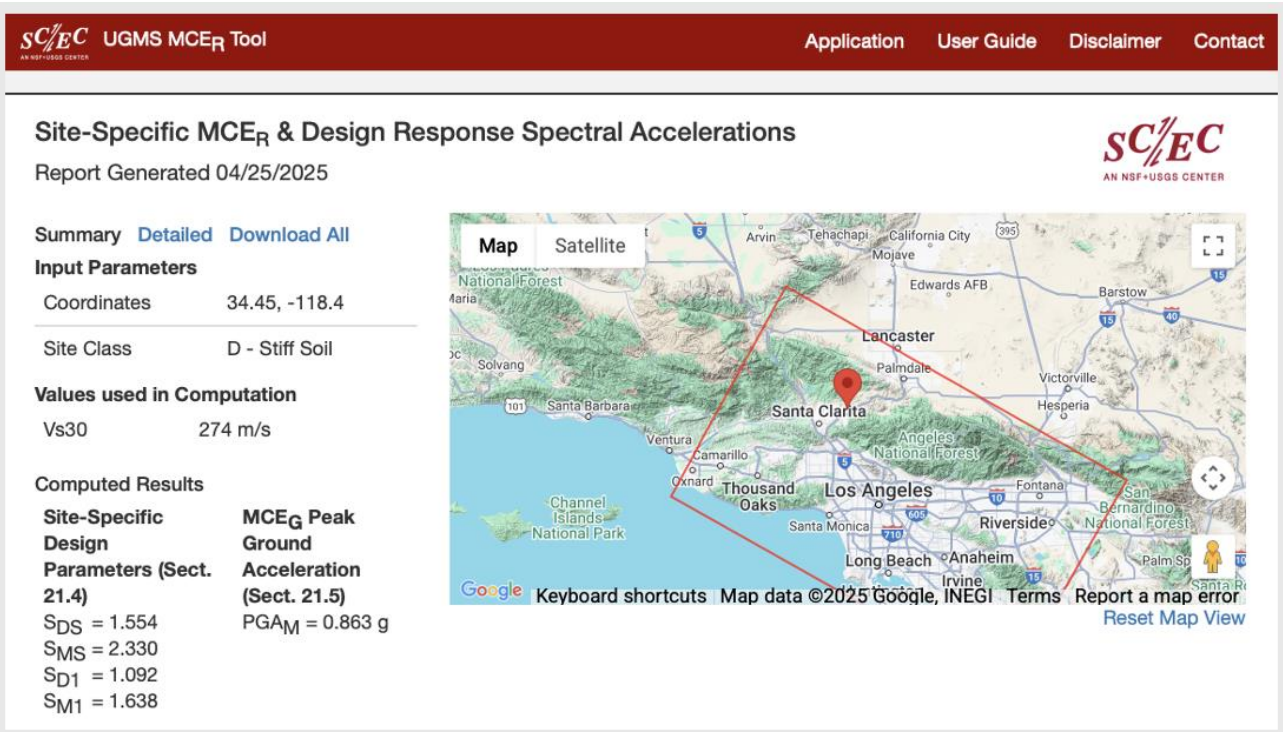
Digital Twins: Continuous Integration of Data and Models

II. Recharging the Alliance with Earthquake Engineers: We are in this Together!

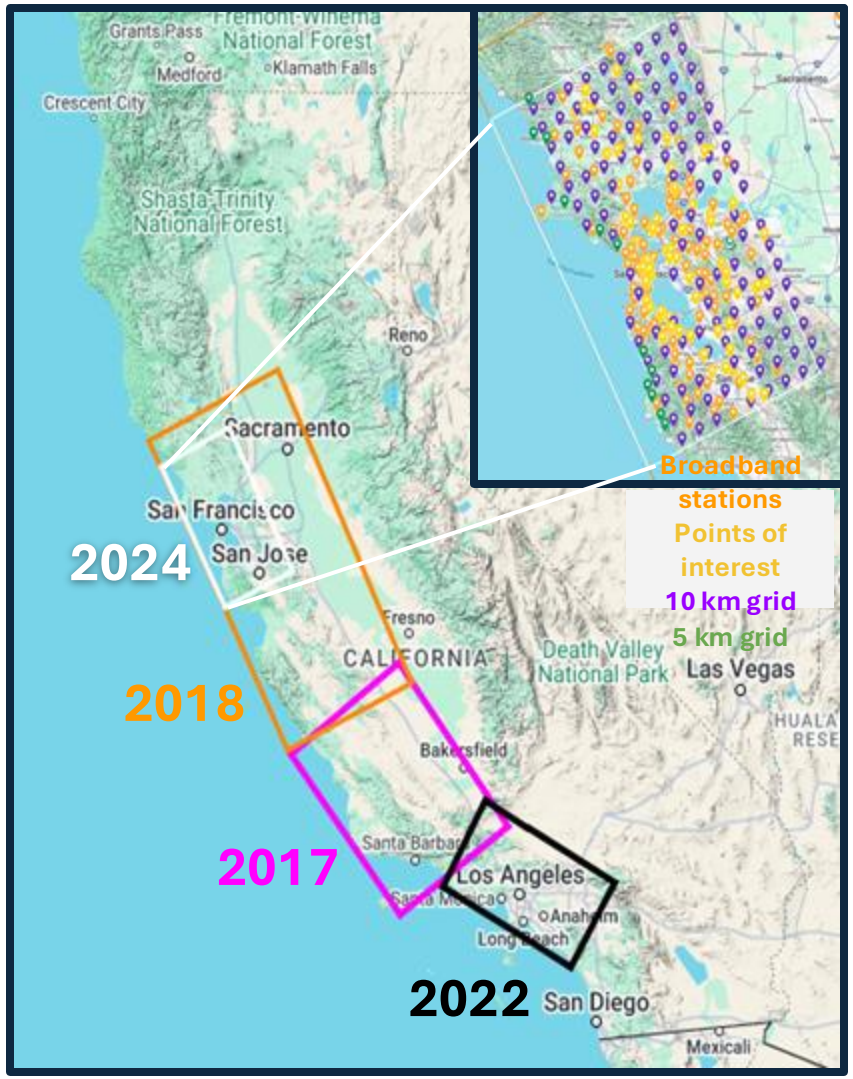




SCEC's Utilization of Ground Motion Simulations Committee demonstrated leadership in bridging science, engineering, and policy, driving changes that got codified in **ASCE 7-22** Seismic Provisions and the **Los Angeles City Building Code**—most notably through contributions to **MCE_R** and the integration of updated spectral acceleration values, especially at long periods

With currently available advanced tools, clearer science, and lessons from destructive earthquakes abroad, we can lead the world in critical updates to building standards

II. Recharging the Alliance with Earthquake Engineers: We are in this Together!



Ground Motion Simulation Validation (GMSV) Technical Activity Group (TAG)

Many outstanding questions require our close collaboration. For example:

- Near field ground motion characteristics (a critical data gap)
- Fault Displacement and Lifelines
- Displacement Demand on Base Isolation Systems
- Nonlinear site response
- Basin amplification and better 3D Velocity models
- Directivity!
- Supershear propagation (Effect of FP directivity)
- Vertical ground motion
- High-F and constraining multi-period spectrum in short periods
- Thresholds for triggering of secondary hazards.

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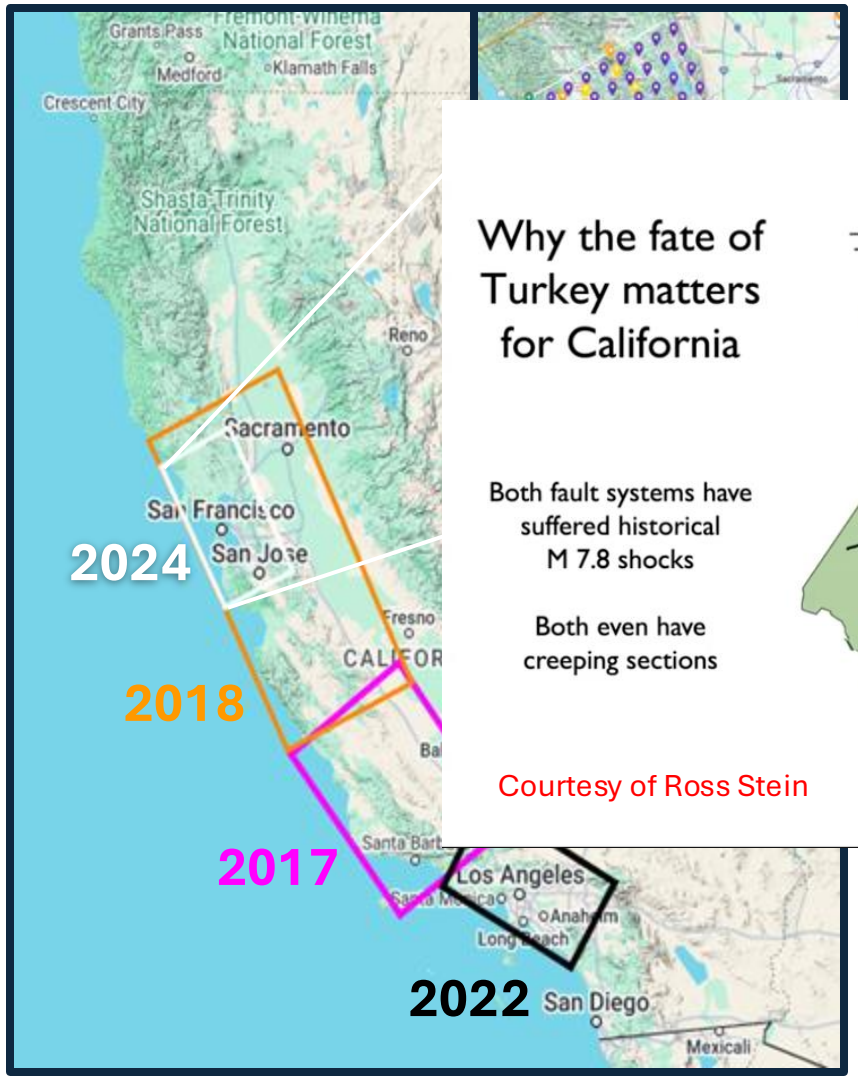

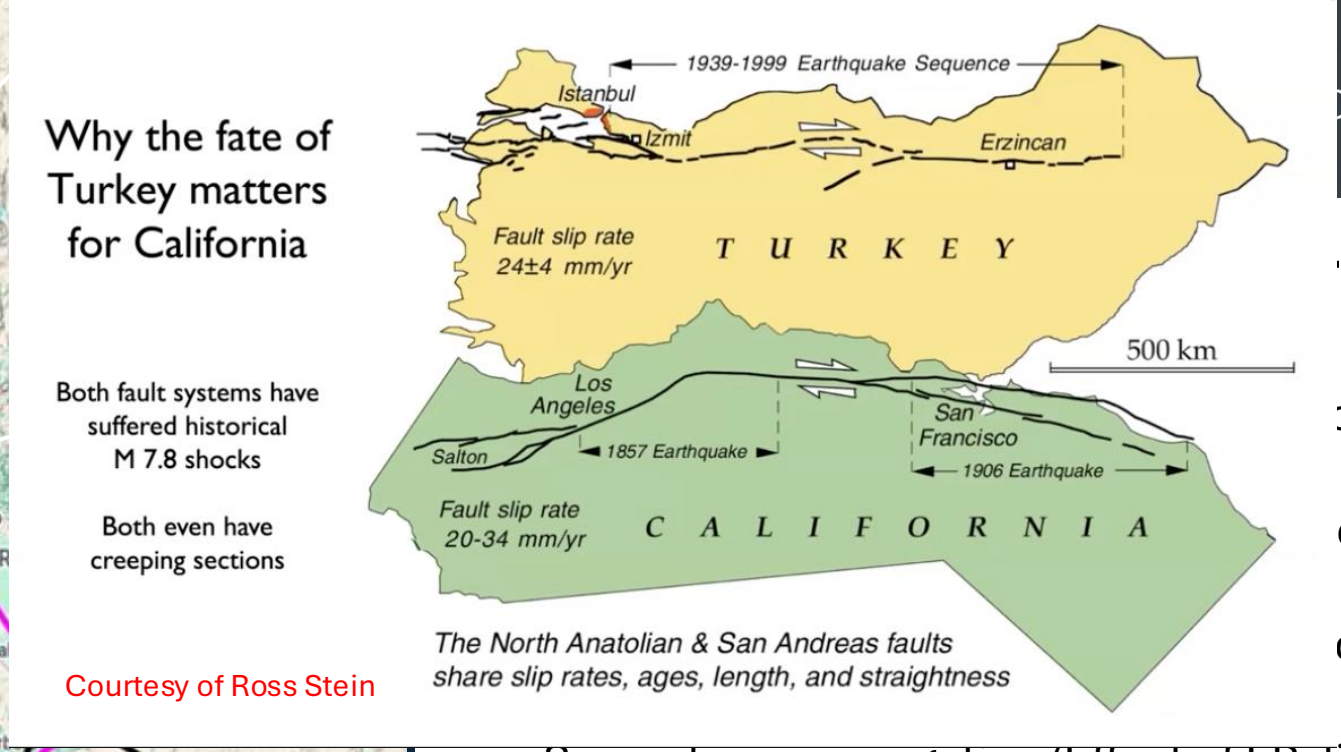

Ground Motion Simulation Validation (GMSV) Technical

(TAG)

equire our close

cs (a critical data gap)

on Systems

city models

- Supershear propagation (Effect of FP directivity)
- Vertical ground motion
- High-F and constraining multi-period spectrum in short periods
- Thresholds for triggering of secondary hazards.

Example : Resilience by Design (Physical science + Engineering + Social Science + Policy)

Source: Los Angeles Times

The 2008 USGS ShakeOut Scenario report (informed by SCEC CyberShake simulation) was the basis of the initial Great Southern California ShakeOut emergency response and preparedness exercise, inspired utility infrastructure improvements, and motivated LA Mayor Garcetti's ***Resilience by Design*** mandate for **smarter city planning** and retrofitting vulnerable buildings.

III. Embracing the AI Revolution!

It is ***REAL*** this time and it is not going away!

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AI + Physics is solving some long outstanding problems [e.g., polymer unfolding (Nobel Prize in Chemistry 24), and Vaccine design (Covid19)]

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Neural Operators are emerging as efficient surrogate models for forward and inverse problems in seismology: *what used to take days can now be solved in seconds*.

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Generative AI is opening new opportunities in data mining, language processing, multimodal data fusion.

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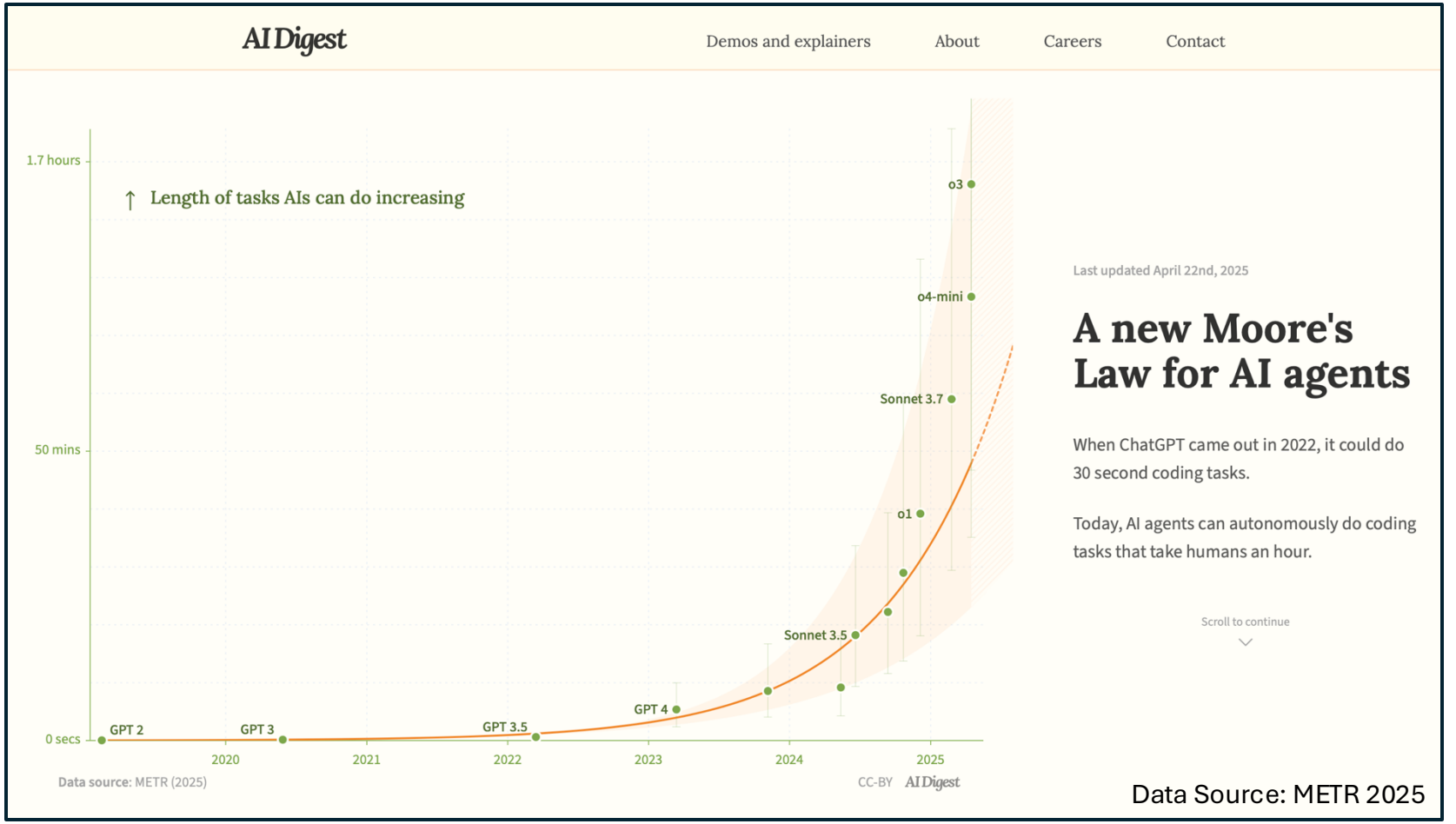
Data centers require high energy locally and could drive demand on *geothermal energy* and other *geo-energy sources* which also come with *seismicity risks* and require subsurface characterization

III. Embracing the AI Revolution!

Code generation, Code translation, and Software Sustainability



Data Source: METR 2025

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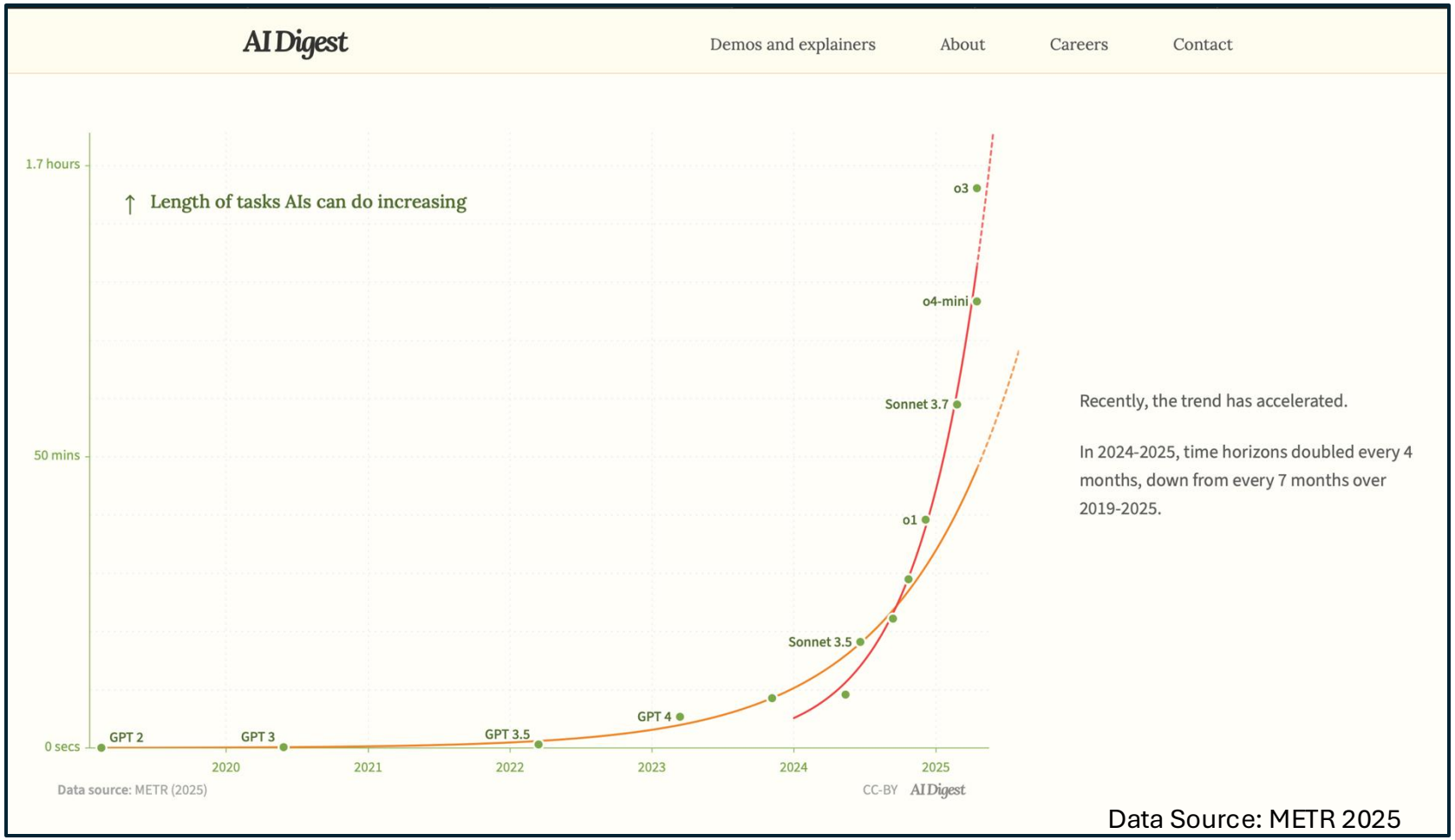

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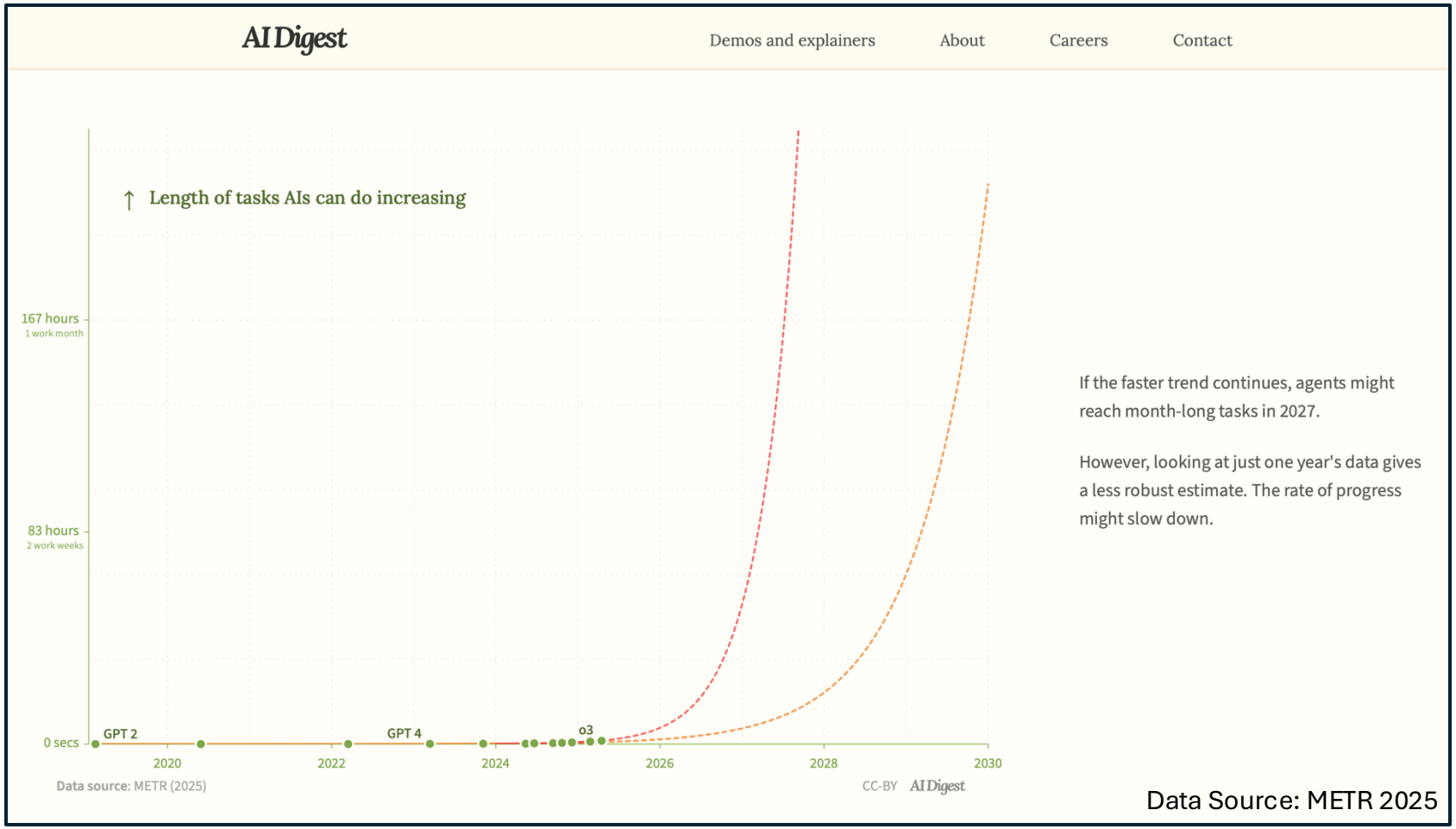

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IV. Re-imaging Earthquake Education and Workforce Development

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AI agents help with analysis of the literature, organization, content generation, and editing

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Multi-agent collaboration enables integration of text, image, math, and coding.

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AI + robots will extend the impact to the physical world (field assistants?)

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Multi-agent collaboration enables integration of text, image, math, and coding.

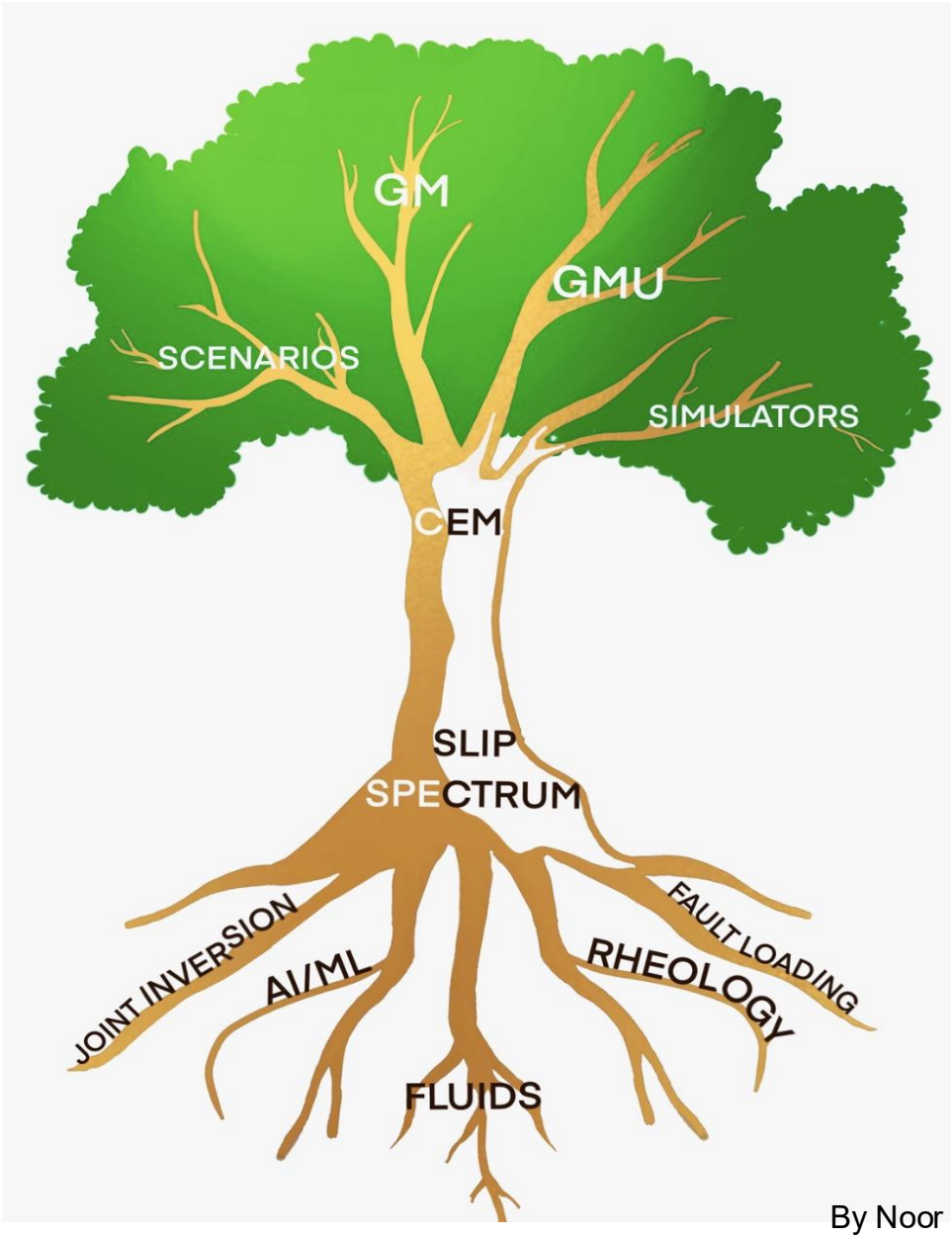
AI + robots will extend the impact to the physical world (field assistants)

Education and the future of work must adapt to this new paradigm: Personalization, Amplification of abilities, Interdisciplinarity. This is **inevitable**.

Putting it all together

Impact Cells

Discovery Units



By Noor

CEM: Community Earth Models

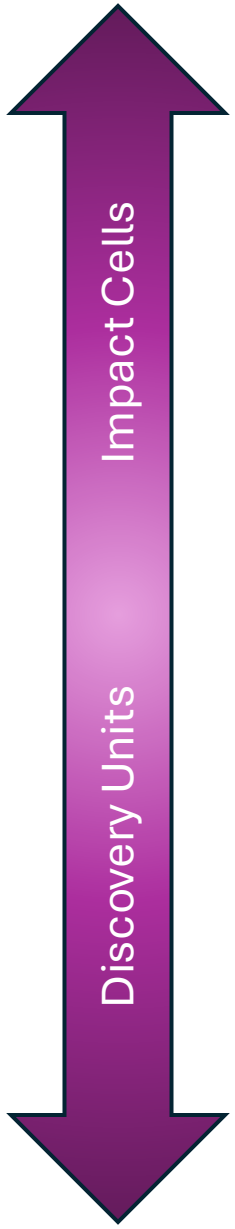
GM: Ground Motion Simulations

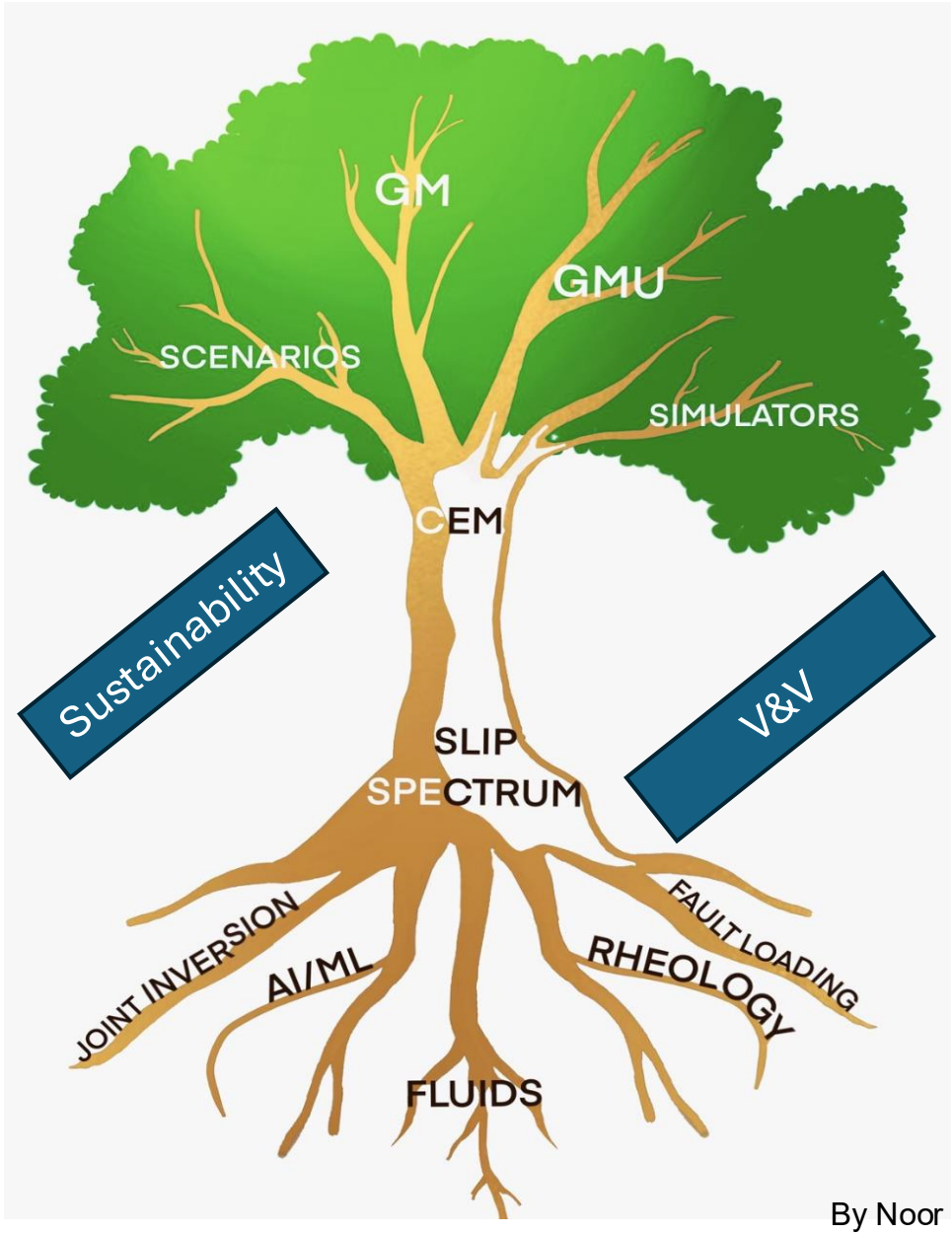
GMU: Ground Motion Utilization

Creating Aligned Opportunities for

Community Engagement
Public Preparedness
Workforce Development
Education and Outreach

Putting it all together





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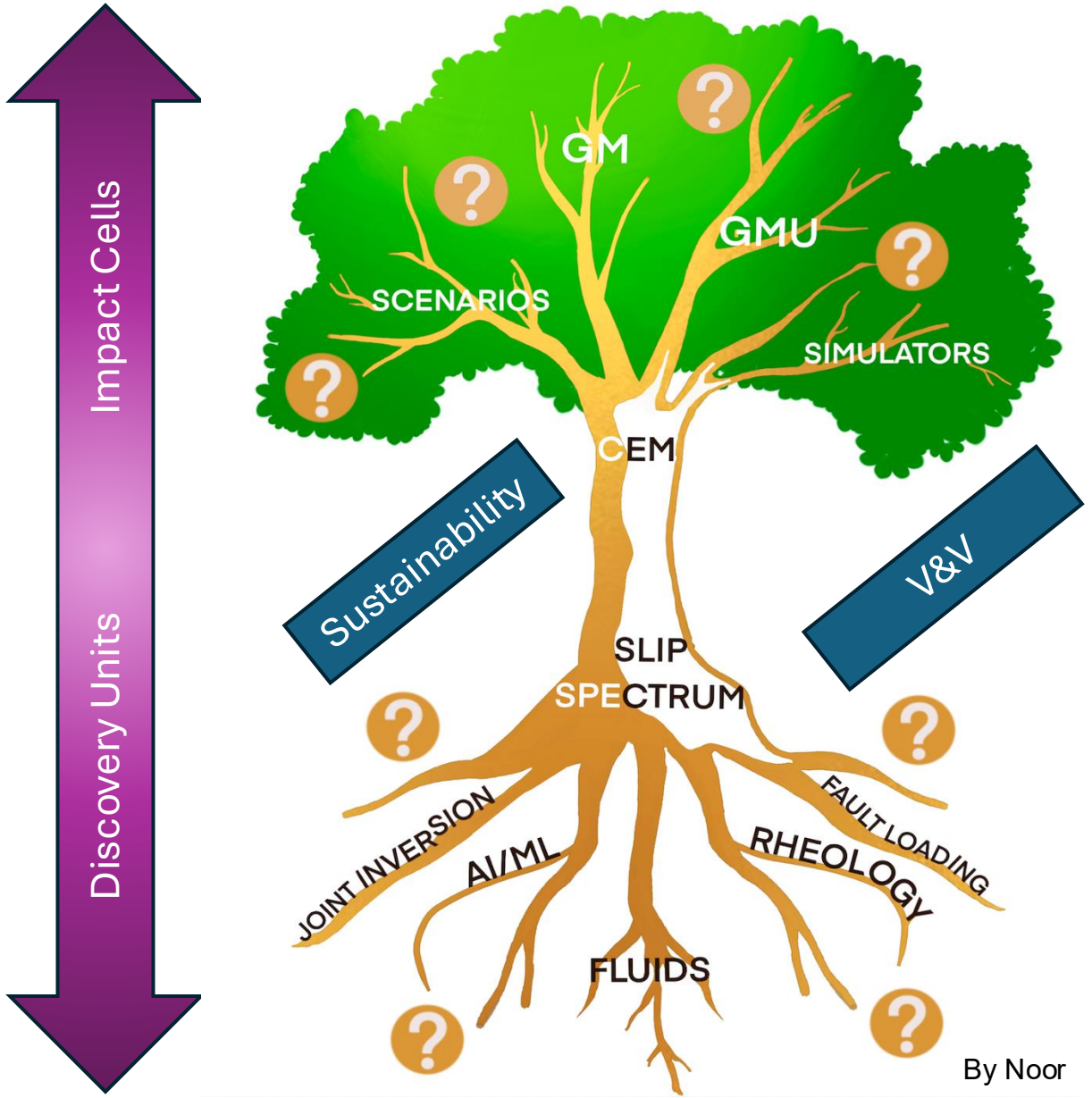

CEM: Community Earth Models

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Creating Aligned Opportunities for

Community Engagement
Public Preparedness
Workforce Development
Education and Outreach

Our Science will be done through

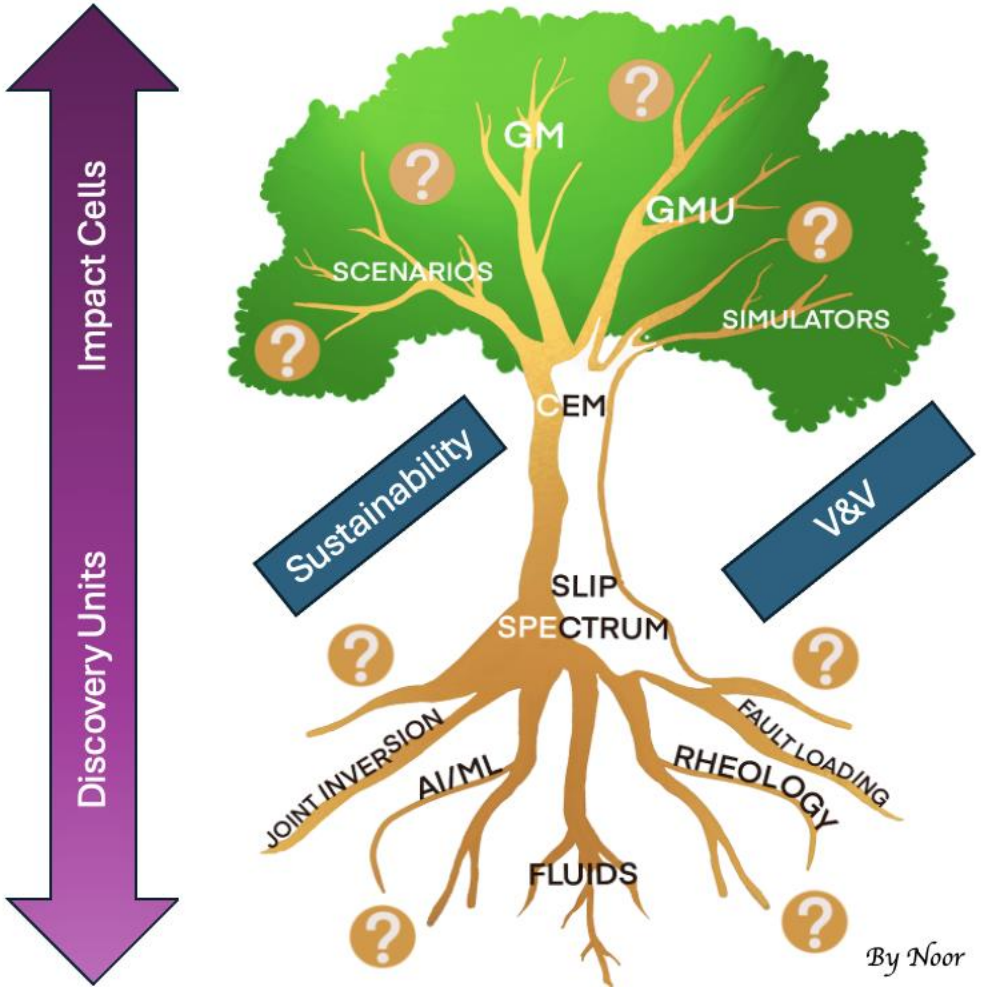
The Annual Meeting **(Yes! There will be an AM in 2026)**

Workshops

Supporting Early Career Scientists

Technical Activity (Working) Groups (Team Science)

Mentoring and workforce development



A Team Science Approach

An **RFP** to the community soliciting proposals along these topics from groups of SCEC members (**Team Science**)

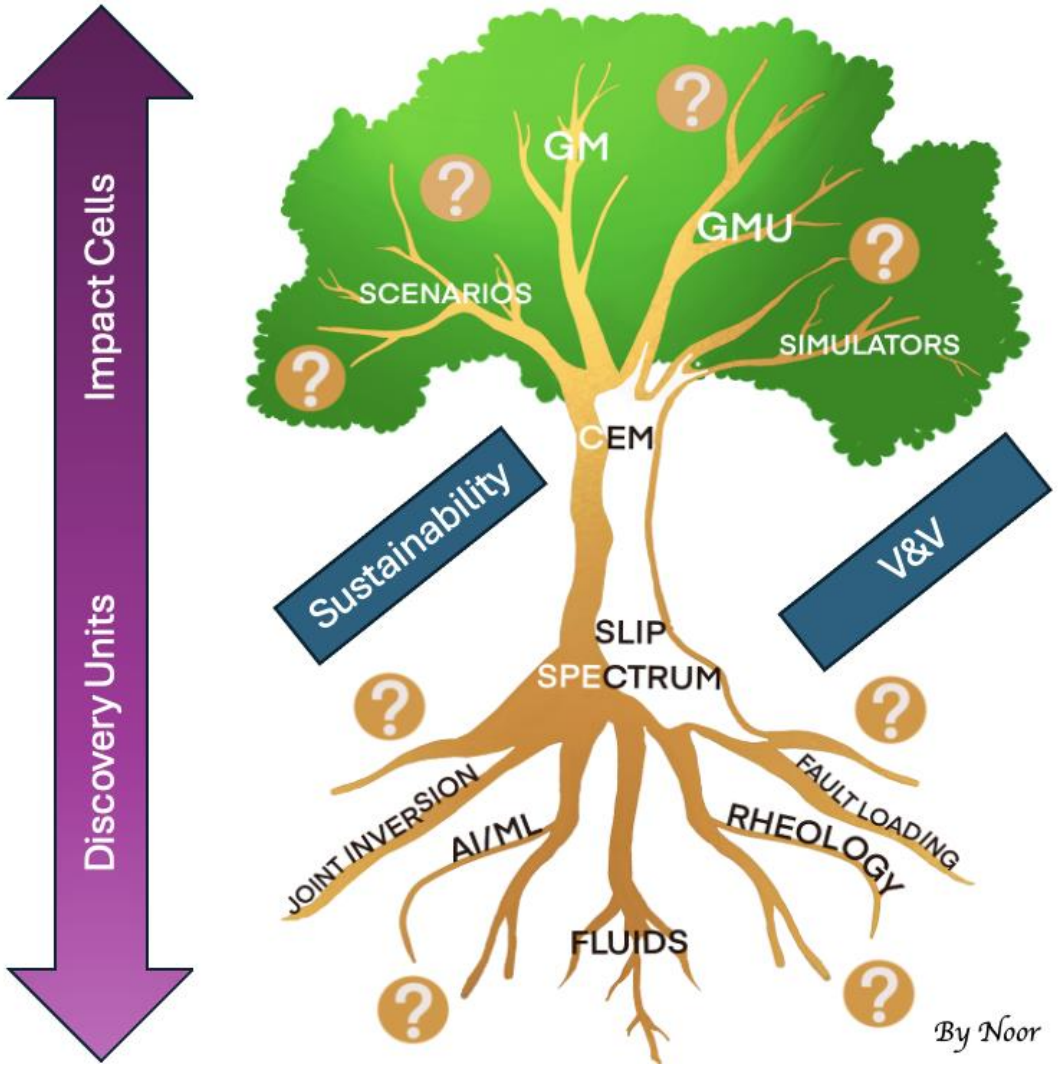
PRC reviews TAG proposals and select leading ones

Selected proposals lead the TAG activities and receive funds to support TAG activities (workshops and research – depending on source of funding)

TAG membership is open to all the community. Determine TAG priorities and workplan

RFP in subsequent years targeted at TAG activities. PRC reviews the proposals. Recipients may be the same or different as in previous years.

Proposals for additional TAGs are considered based on availability of funding



Maintaining Community Cohesion and Breadth

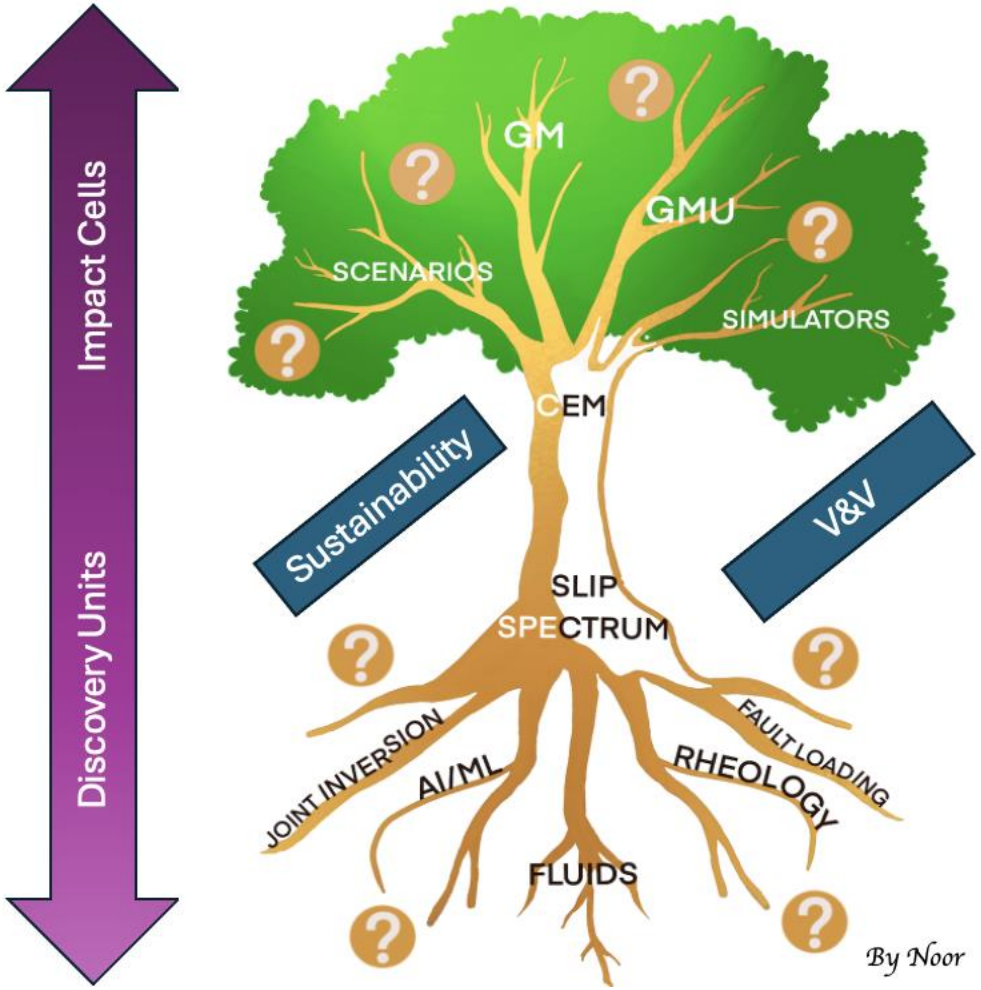
We anticipate 5-7 science workshops in 2026

These workshops are funded through NSF

The PRC will review the workshop proposals as well

The topics of the proposals are open to the community, but we encourage proposals around basic science and new initiatives to nucleate the Discovery Units

Additional workshops/meetings will be organized as part of TAG activities



Diversifying Funding Sources with YOUR HELP

Continued Partnership with Federal Agencies:

USGS: Translating science to societal impact
NSF: Opportunities in AI/ML, CSSI, Geo-informatics, and physics of solid Earth.
DOE: Energy security, subsurface imaging and modeling
NASA: remote sensing, data fusion, and digital twins.

Partnership with utilities

Partnership with the state (CalOES/SSC) and LA city

Forming an Industry Advisory Board:
Energy security/Enhanced Geothermal Energy, CO2 sequestration
Insurance and Re-insurance.
Infrastructure resilience

Media Campaign: Making the case for SCEC

Societal Resilience
Leadership in AI+Sceince
Energy Security and transition

Before I wrap up...

Thank you!

Yehuda Ben-Zion
USC, Director

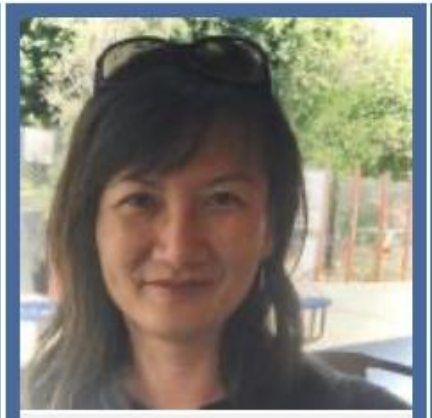
Greg Beroza
Stanford, Co-Director

Alice Gabriel
UCSD, SPC VC

Tim Dawson
CGS, Board Chair

Rachel Abercrombie
Boston U, Board VC

Phil Maechling
USC, Assoc Dir IT



Tran Huynh
USC, Assc Dir Sci Ops

Mark Benthien
USC, Assoc Dir CEO

Gabriela Noriega
USC, Dir of ELCA

Thank you for helping with the on-boarding and transition

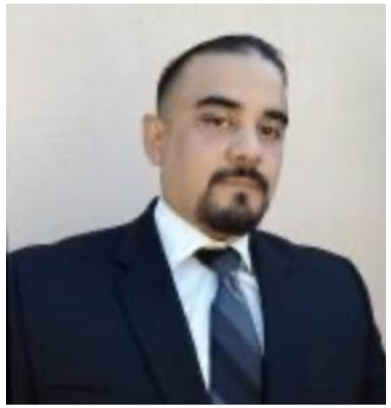
Thank you!

Mei-Hui Su

Fabio Silva

Scott Callaghan
USC

Edric Pauk
USC



Edward Salcido
USC

Akash Bhatthal
USC

Deborah Gormley
USC

Phoebe Long
USC

Xaul Starr
USC

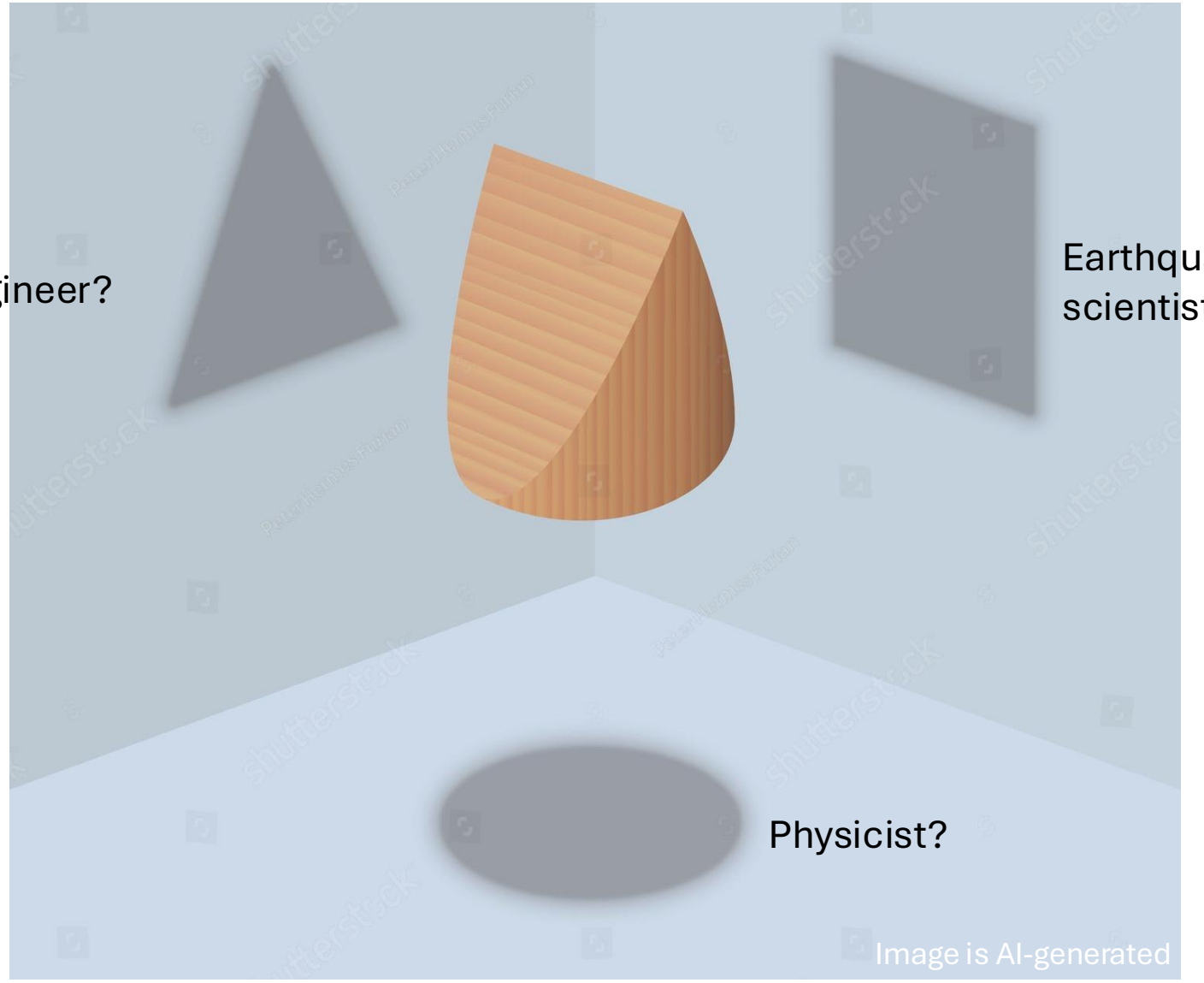
Te-Yang Yeh
USC

Xiaofeng Meng
USC

Camilo Ramos
USC

One more thing ...

Who is that guy?



My journey

Cairo University

Caltech

UCSB

UIUC

Mechanics of complex systems (friction, fracture, and waves)

Primary: Structural Engineering

Secondary: Geotechnical Engineering

Earthquakes and nonlinear dynamics.

Thesis: Dynamics of pulse-like ruptures on strong velocity-weakening frictional interfaces

Non-equilibrium physics of granular materials and polymers

Facts

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I am not a seismologist in the traditional sense

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But I will work with the best seismologists in the world at SCEC

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I am not a geodesist	But I will work with the best geodesists in the world at SCEC
I am an earthquake modeler and physicist	And I will work with as good or even better modelers at SCEC

The Magic of SCEC

Bringing the best in each of us and add synergy

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Our outcome is larger than the sum of our parts

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Our outcome is larger than the sum of our parts

We create large leverage for science and society!

Conclusions

There is light at the end of the tunnel!

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At SCEC we will work together to revitalize Earthquake System Science and deliver meaningful societal impact:

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There is light at the end of the tunnel!

At SCEC we will work together to revitalize Earthquake System Science and deliver meaningful societal impact:

1. **Digital Twins**: Advanced Computing, Ubiquitous Sensing, and Controlled Experimentation
2. **Transdisciplinary Collaboration**: Engineering and Technology, Team Science!
3. **AI-enabled**: Accelerating science, data analysis, and discovery
4. **Re-imagined education and workforce development:** Engaging, Personalized, and transdisciplinary.

Conclusions


Image is AI-generated

There is … end of the tunn…

At SCEC we will work toget… arthquake System Science and deliver meaningful societal imp…

I look forward to hearing from you!

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2. **Transdisciplinary Co**… …eering and Technology, Team Science!
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4. **Re-imagined education a**… …**force development:** Engaging, Personalized, and transdisciplinary.

Thank you

community

Mosaic generated using AI-assisted coding