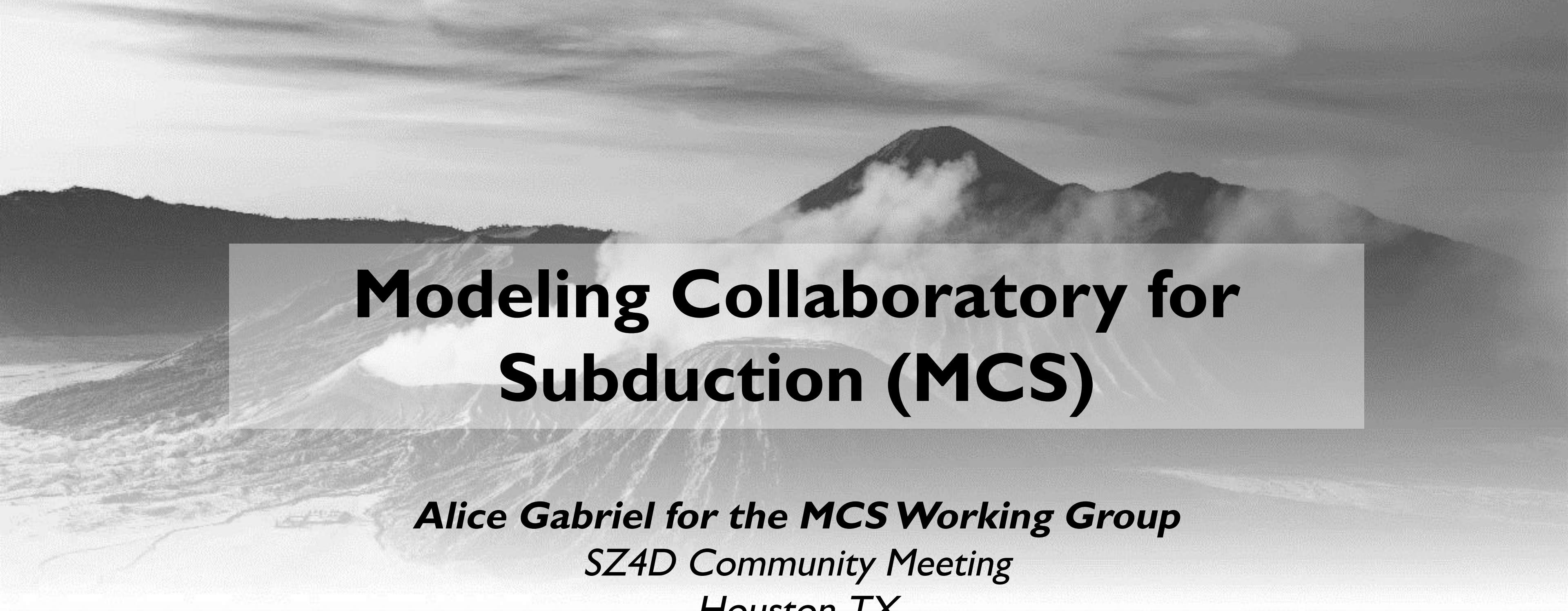


Modeling Collaboratory for Subduction (MCS)

Alice Gabriel for the MCS Working Group

SZ4D Community Meeting

Houston, TX

November 14, 2022

NSF

SZ4D

MCS RCN

Modeling Collaboratory for Subduction
RCN

sz4dmcs.org, Fall 2018 – Fall 2022

Major MCS RCN Activities

(engaging ~1000 scientists from >44 countries)

Fluid and Melt Transport Workshop (05/2019)

- Fluid migration & fracture formation in magma systems
- Lithosphere-scale magma transport
- Microscopic and short-time-scale processes

Megathrust Modeling Workshop (10/2019)

- Sequences of earthquakes & aseismic slip
- Dynamic rupture and tsunamis
- Geodynamics and surface processes

Volcano Modeling Workshops (Spring 2021)

- Location, timing, and magnitudes of volcanic eruptions on an arc scale
- How does the lithosphere influence magma transport?

- **Volcano modeling exercise** with CONVERSE, October 2021 and GRA support for website
- **MCS-SZ4D Landscapes and Seascapes integration and implementation workshop** October, 2021
- **Computational Solid Earth Science Initiative Coordination Meeting** (with CIG, CSDMS, VICTOR, ..) June, 2022

Modeling Collaboratory for Subduction Working Group

- Thorsten Becker
- Mark Behn
- Eric Dunham
- Alice Gabriel
- Sean Gallen
- David George
- Guil Gualda
- Matthew Herman
- Margarete Jadamec
- Leif Karlstrom
- Shuo Ma
- Tushar Mittal
- Marcos Moreno
- Joyce Sim
- Amanda Thomas
- Daniel Trugman
- Ikuko Wada
- Meng (Matt) Wei
- Penny Wieser

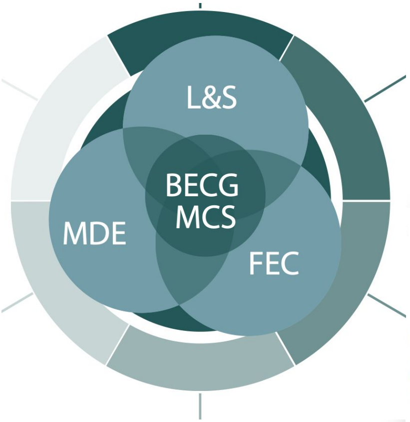
Since Fall 2022

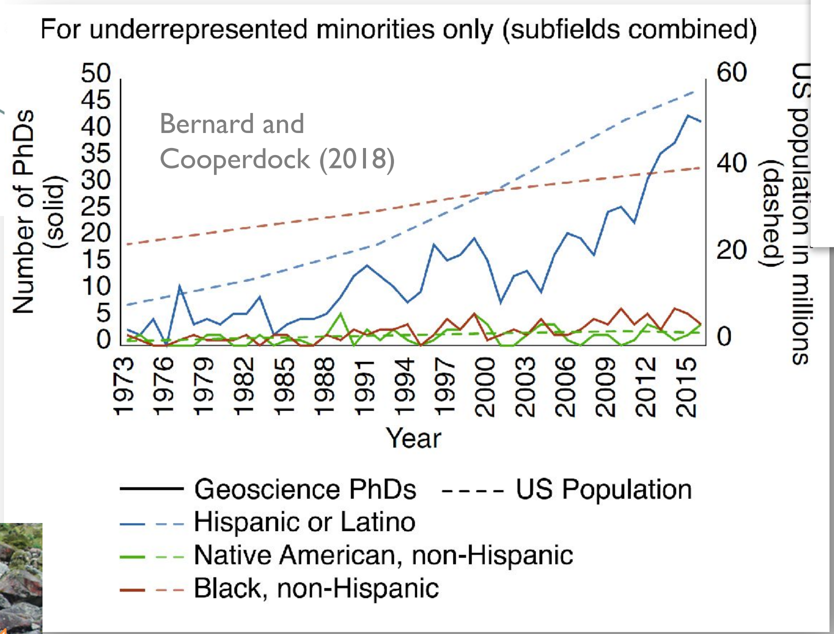
MCS Working Group Objectives

Physics-based models for subduction zone hazards to understand fundamental physical processes, guide instrumentation deployments, interpret observations, and assess predictability of hazards.

- Construct models that link subduction zone state and long-term margin evolution to the character and **predictability** of event occurrence
- Integrate observational constraints into models, while simultaneously using models to define **optimal observational strategies**
- Build **physics-based,** predictive models for volcano, earthquake, and geomorphic systems that are spatially and temporally coupled
- Build a **diverse and equitable** community of scholars who are well versed in modern modeling tools

Computational geoscience as a complementary pathway for enhancing diversity in the geosciences





No progress on diversity in 40 years

Rachel E. Bernard & Emily H. G. Cooperdock

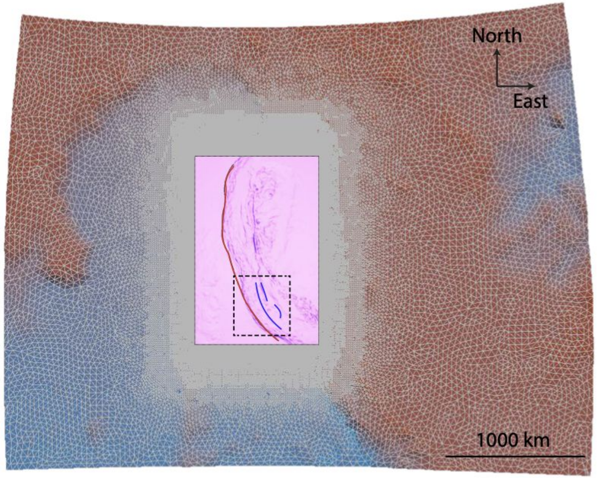
Nature Geoscience **11**, 292–295 (2018) | Cite this article

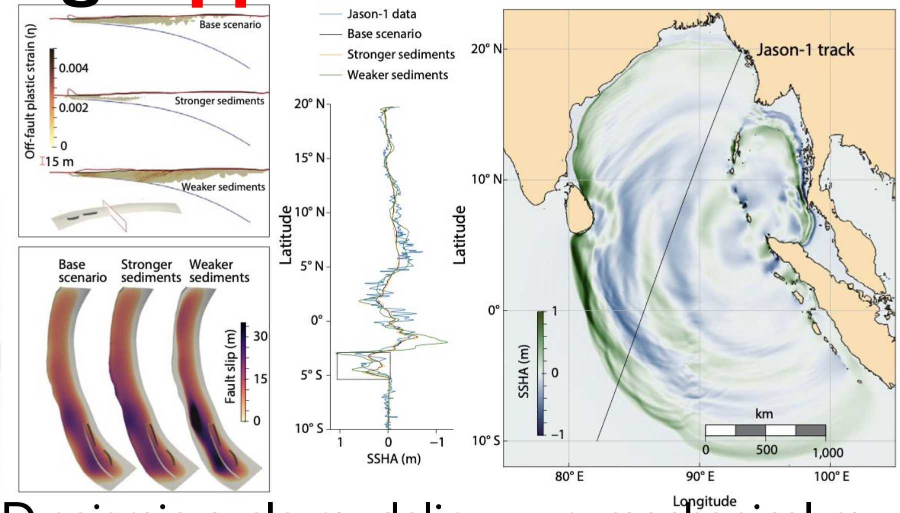
Ethnic and racial diversity are extremely low among United States citizens and permanent residents who earned doctorates in earth, atmospheric and ocean sciences. Worse, there has been little to no improvement over the past four decades.

AAPG Explorer

SCEC USEIt (2016), USC

SZ4D Modeling Opportunities - FEC





- needs for additional **physics** (e.g., 3D seismic cycle modeling, poromechanical modeling of subduction toe, fluid transport)

- **community codes** can build on partnership with CIG, EQ centers (e.g., SCEC, CRESCENT)

- enabling **cross-cutting science,** forecasting/prediction, cascading hazards, fluids, rheology/stress … e.g., rheology with laboratory / field geology!

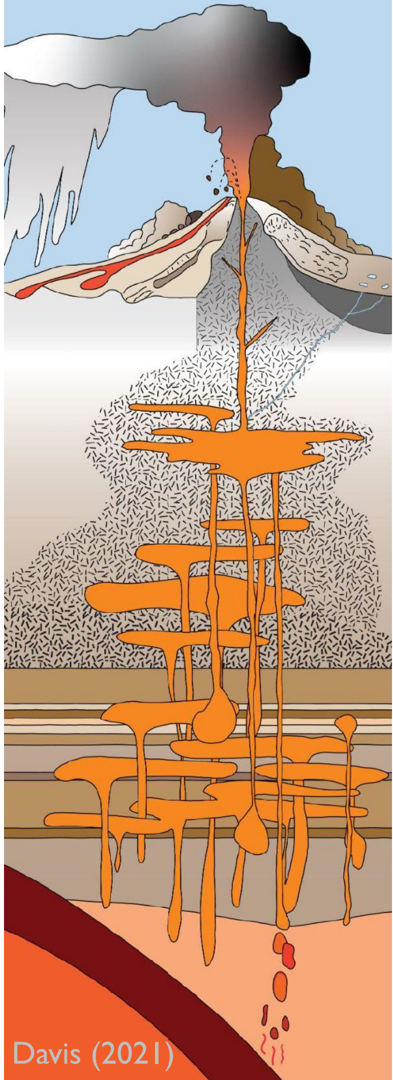
SZ4D Modeling Opportunities - MDE

- Opportunities for updating highly **used legacy codes**, e.g., magmatic phase equilibria, multiphase rheology, thermal and stress evolution

- Applications ranging from fundamental **hypothesis** testing, sensor **network** design to physics-based **forecasting** frameworks

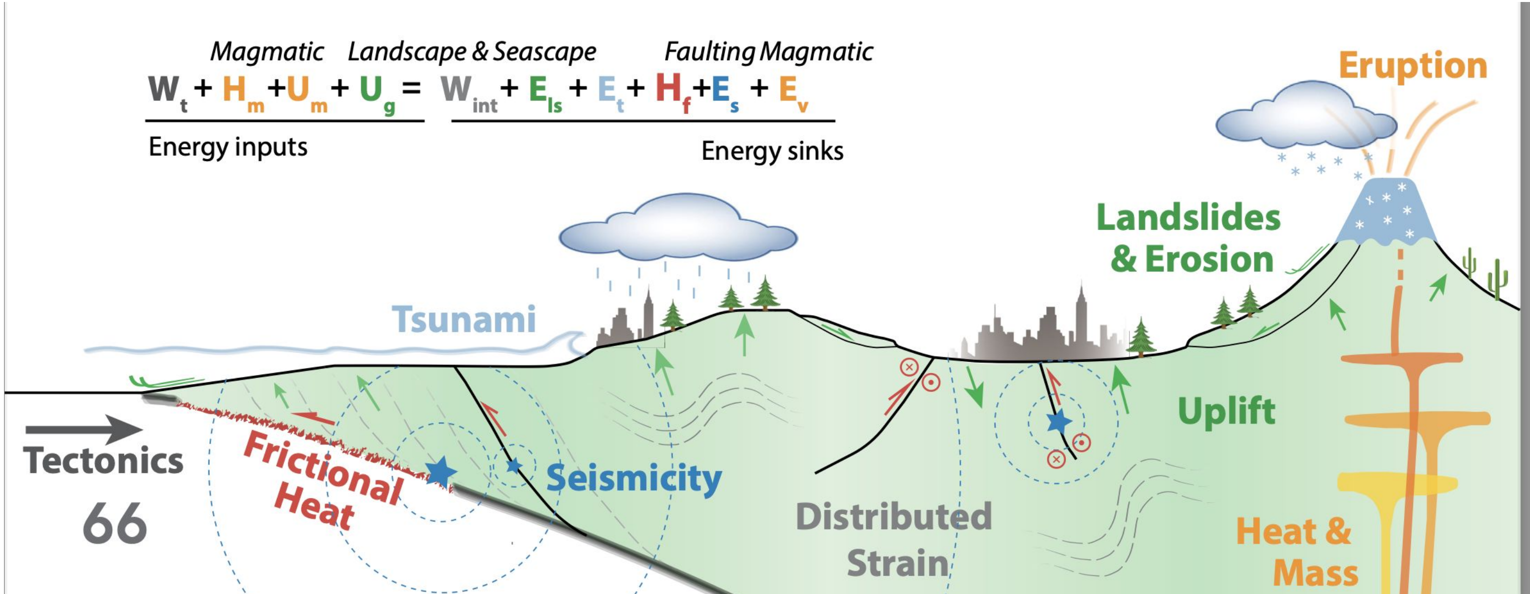
- **Community building,** e.g., benchmarks on volcano deformation modeling/inversion, and **working groups**

- **enabling cross-cutting science**, e.g., potential link of external eruption triggers from Glacial unloading to seismic waves



SZ4D Modeling Opportunities - L&S

- Priorities involve both **long** timescales (landscape evolution) and **short** timescales (events like landslides)
- **enabling cross-cutting science,** e.g., landslides triggered by seismic shaking/ruptures; cascading surface hazards associated with volcanic eruptions; landscape evolution and geodynamics, with conditions/state from long-term modeling



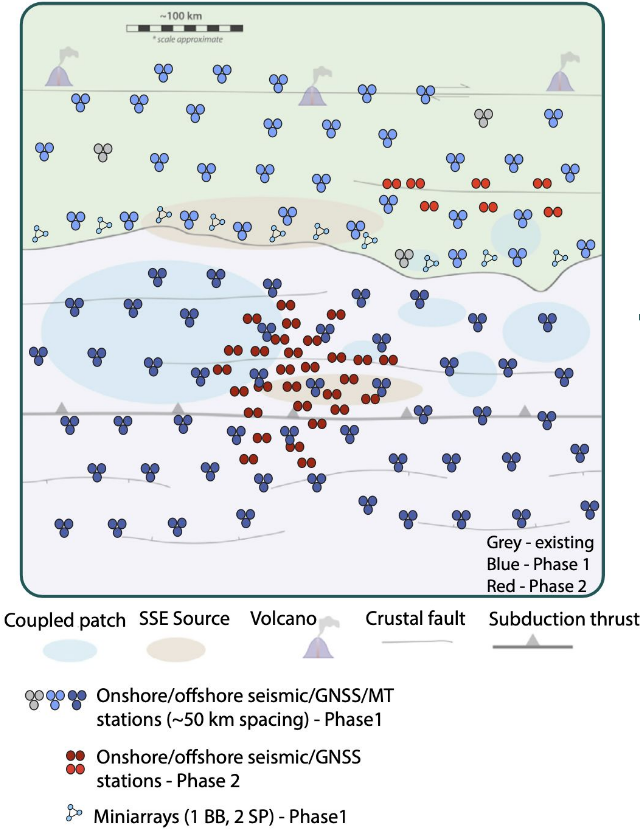
SZ4D Modeling Opportunities
data-rich *and* model-rich

- **ML data processing & denoising** to analyze real-time data collected from the on-and off-shore instrumentation (e.g., seismicity, magma plumbing systems using OBS, high-rate geodesy, volcanic gas emissions)

- rapid, physics-based data analysis of **real-time** multiparameter MegaArray, SurfArray, and VolcArray data (e.g., towards direct prediction of hazards such as shaking intensity and tsunami amplitudes)

- **hybrid ML & HPC** (e.g., to speed up forward for uncertainty quantification/ optimal experimental design)

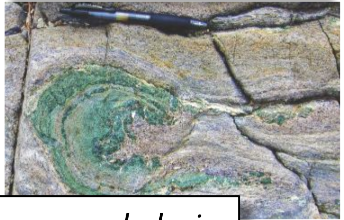
MegaArray



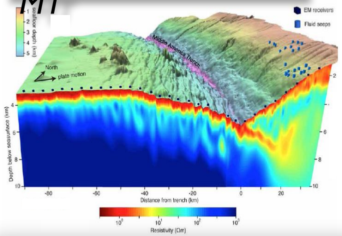
MCS **Implementation**

- physics-based forward models to study geologic hazards associated with subduction zones
- sustained exchange between computational, observational, and laboratory subduction zone scientists (regional & process-focused groups)
- centralized and PI-driven model development and benchmark exercises
- tutorials, cookbooks, and workflow examples
- storing and disseminating SZ4D data-derived products (e.g., community structural models) and inverse and forward modeling results

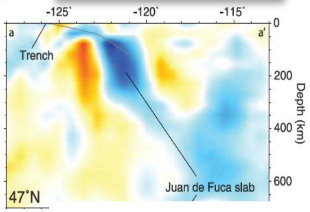
geological constraints



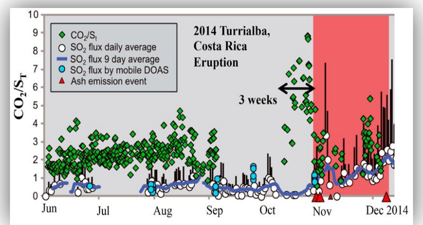
active source and MT

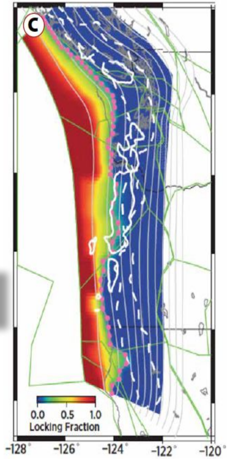


passive source

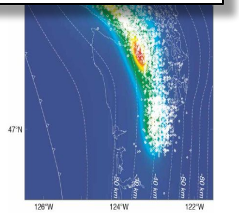


geomorphologic al constraints

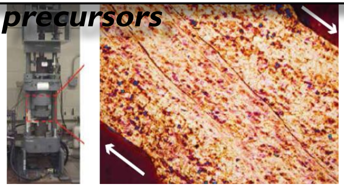




earthquake source seismology



Volcano and earthquake precursors



rock mechanics experiments

On- and off-shore geodesy

Gomberg et al. (2010); Naif et al. (2015); Chadwell et al. (2015); Schmalzle et al. (2014); Hawley et al. (2016); Tong & Lavier (2017); Proctor & Hirth (2015); W. Behr (pers. comm.), Kristen Cook

MCS Implementation

- **science** and **operations**

support access to computing resources, which will empower scientists with different backgrounds and institutional support, and broaden and democratize participation in HPC and cloud computing

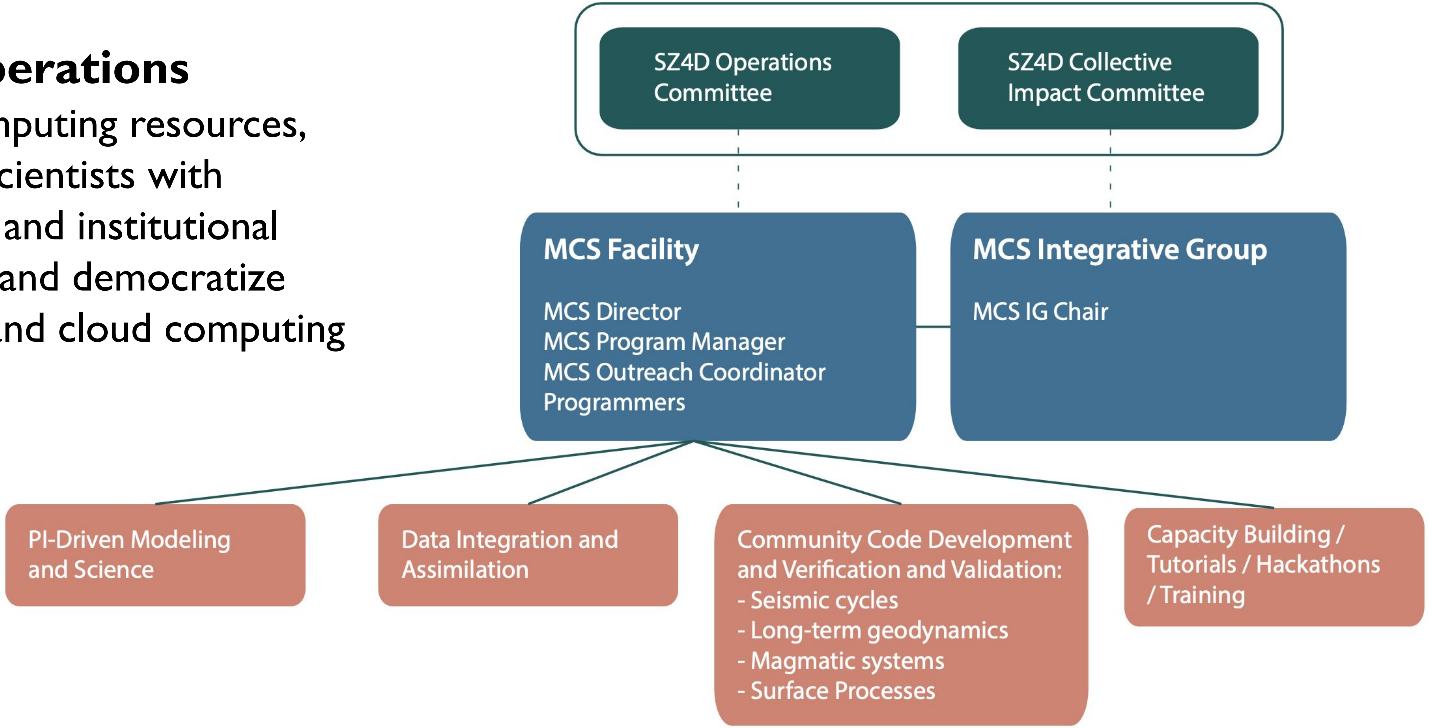


Figure MCS-2. *MCS organizational structure. Yellow boxes illustrate the two main components of the MCS: operations (MCS Facility) and science (MCS integrative group). The MCS integrative group, in coordination with the SZ4D Collective Impact Committee, will set priorities for code and model development efforts, workshops, training, and other activities performed by the MCS Facility. The orange boxes denote the activities that will be performed by the MCS Facility.*

MCS Implementation

- Providing validated, flexible, robust, well-documented, and efficient **open-source codes** with inherent consideration of multi-physics, cross-scale, adjoint approaches, and uncertainty quantification.
- Embracing the guiding principles of **open science and FAIR data practices**
- Empowering **the widest and most diverse representation** of the community

	Phase 1	Phase 2	Phase 3
Data-Stream Integration	- Use existing tools/methods to guide instrument deployment - Test/develop infrastructure to link models to incoming data streams - These tools have known limitations and approximations	- Integrate data streams into community structure models for use in simulations and hazard assessment	- Continued improvement of high volume data-stream integration with software - Continued refinement of community structure models for use in simulations and hazard assessment
		- Comparison of existing and newly developed codes to assess differences & improvements - Transition to new codes for data streams	- Well-tested community codes - Fully benchmarked - Scaled-up to full application - Ready to apply to multiple questions, regions, etc.. - Community-supported through documentation, hackathons, workshops, etc.
Geophysics/Hazard Process-Based Simulation	- Observation-motivated model development - Incorporation of new processes and/or physics - Identify/develop new numerical approaches & tools	- Expand problem applications (e.g., geometry, 3D vs. 2D, time, physics) - Fully benchmark new codes - Link or embed in more general codes - Begin documentation / training activities	