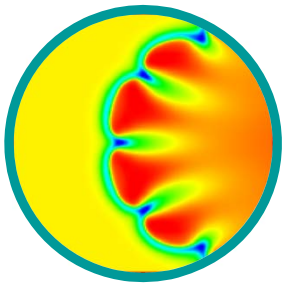
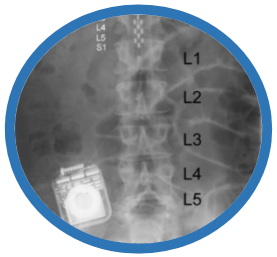
Mechanical and Civil Engineering

Create sustainable, autonomous, and resilient machines and infrastructure

- Address fundamental societal challenges
- Attract the best people and provide an inspiring atmosphere for research and education
- Increase and promote diversity

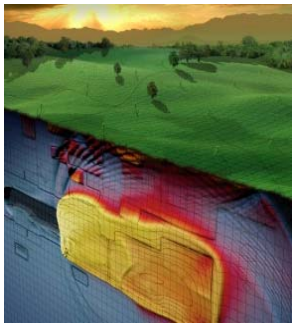


Energy



Medical devices

Novel materials



Resilience to hazards

Robots and mobility

Key research areas:

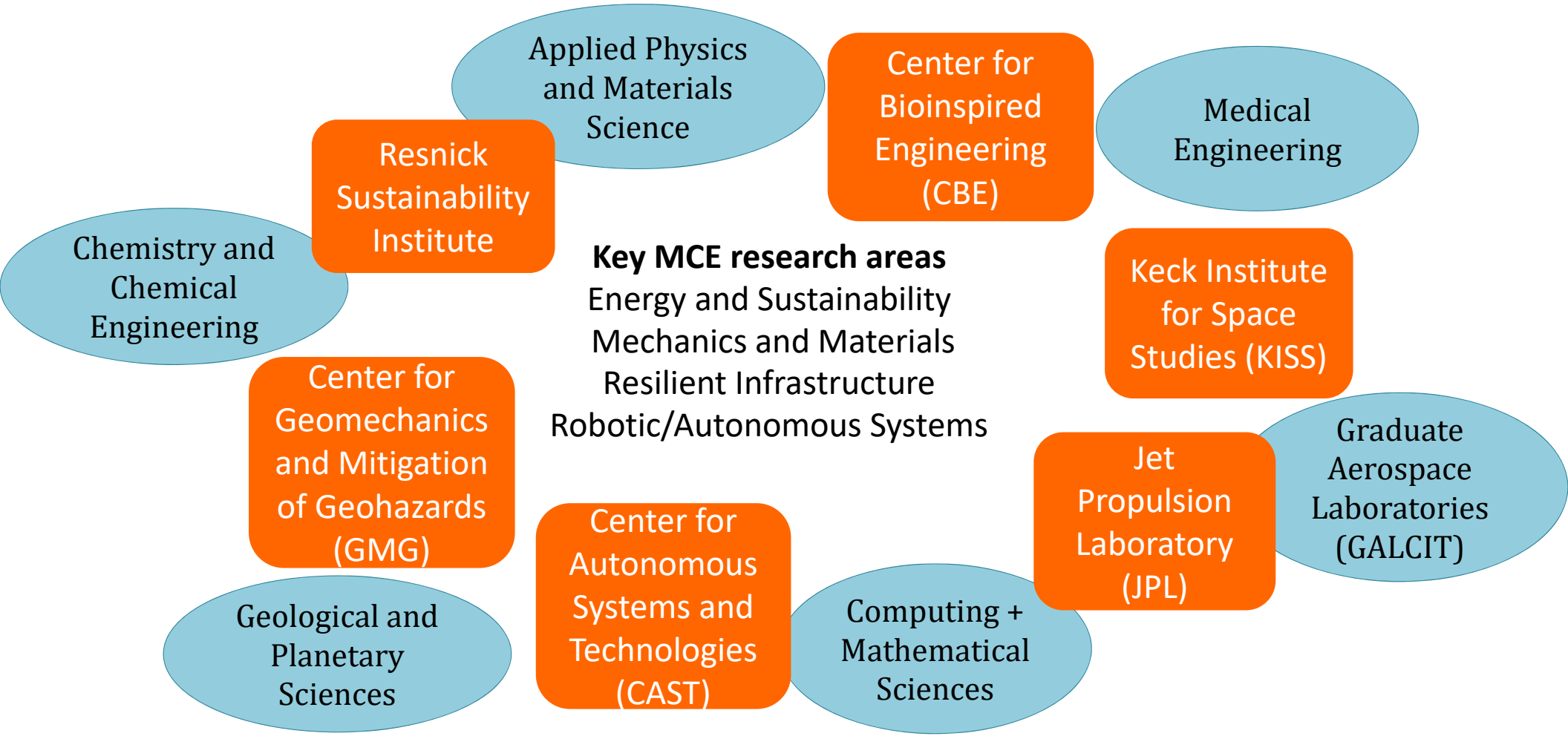
Energy and Sustainability

Mechanics and Materials

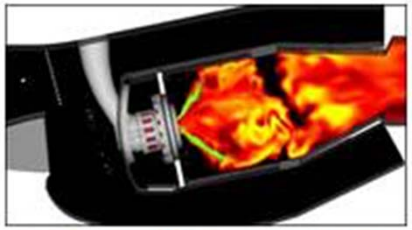
Resilient Infrastructure

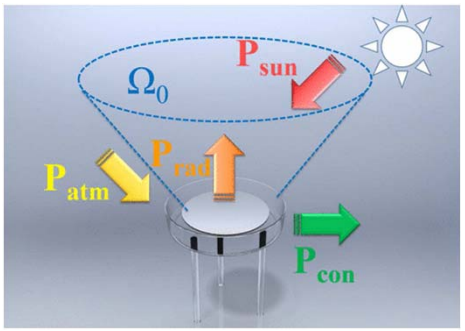
Robotic and Autonomous Systems

Interdisciplinary research and study



Energy and Sustainability





Flow-energy harvesting

Simulation, big data, and reduced-order modeling

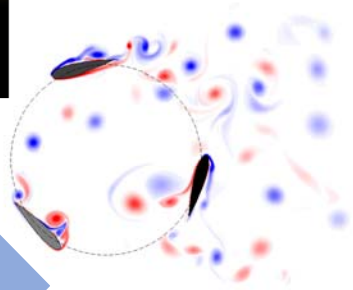
Quantum-limited sensing

Energy and Sustainability

Computation and materials discovery

Synthetic biology and biofuels

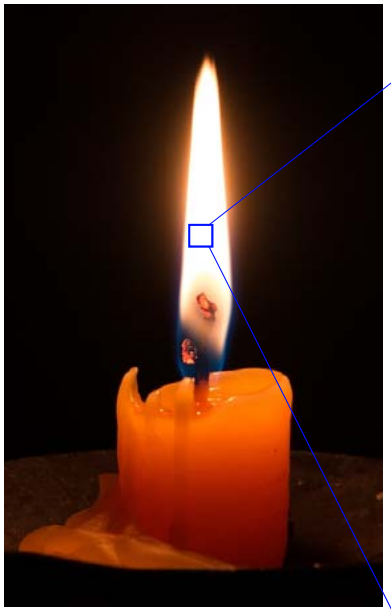
Modeling geomaterials with fluids

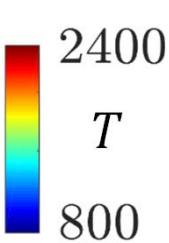


Applications:

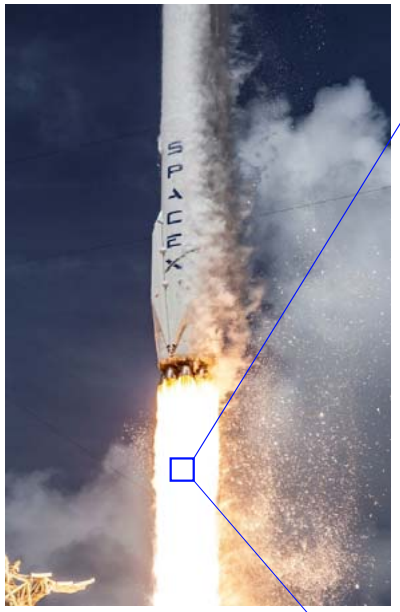
- **Energy generation**
- **Storage and management**
- **Detectors and sensors**
- **Space power generation**
- **Geothermal energy**
- **Stability and safety**

Turbulence-Flame Interactions

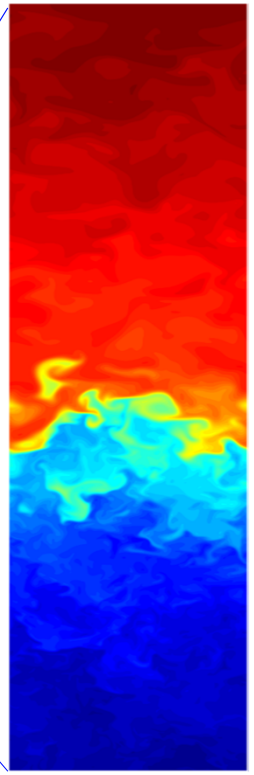


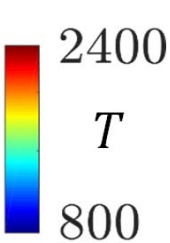


Laminar flame



SpaceX Falcon 9





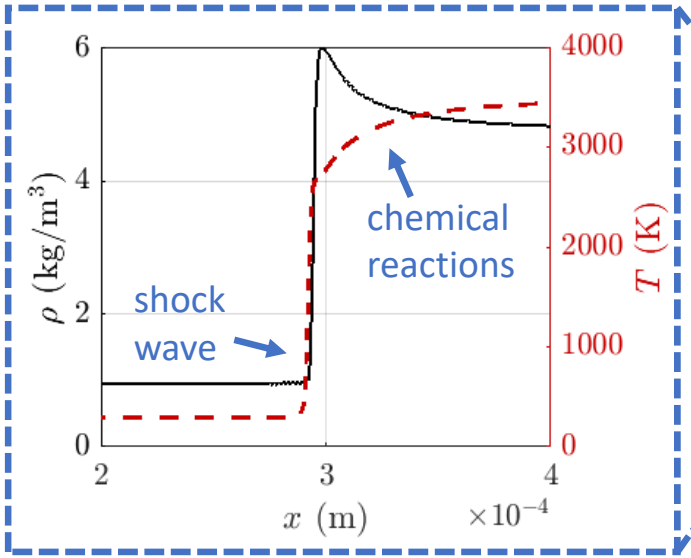
Turbulent flame

(*Beardsell & Blanquart, in prep., 2020*)

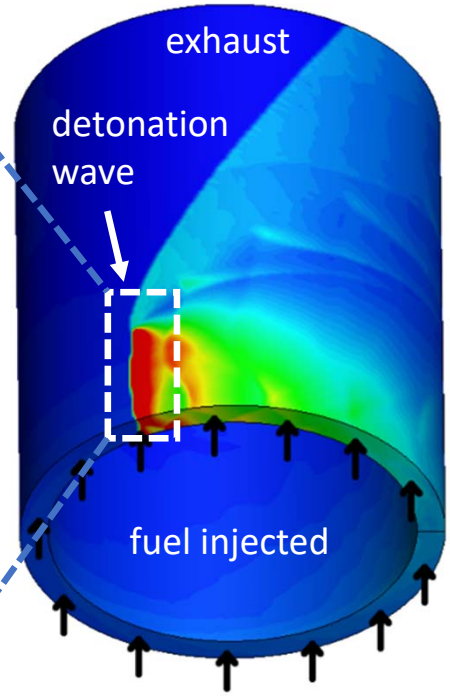
Turbulence → Increased mixing → Faster flame

Detonations

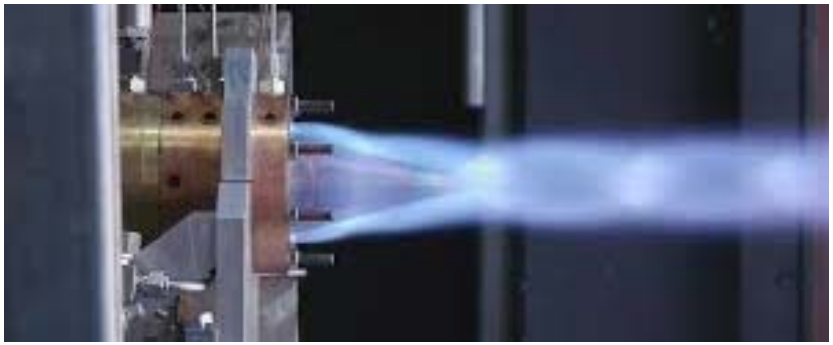
- Efficient energy production
  - Propulsion—lighter engines, higher thrust
- Need efficient detonation models that accurately capture the physics (fluid mechanics and combustion)

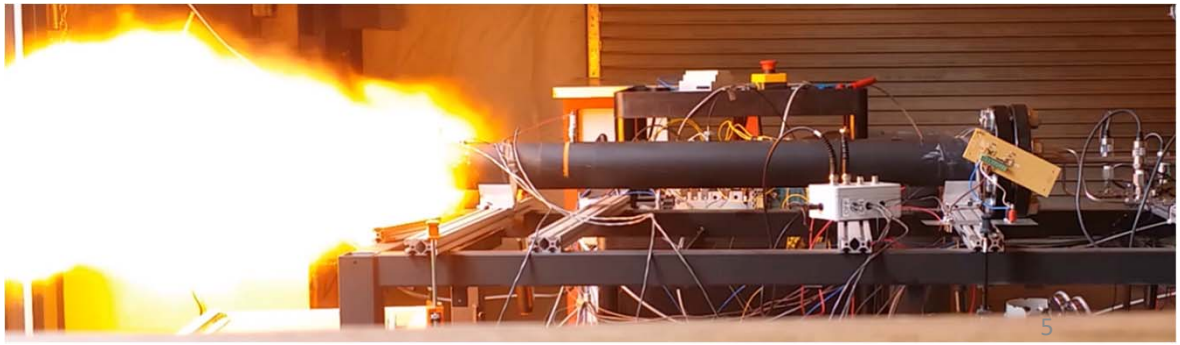


(Baumgart, Beardsell, and Blanquart, in prep)

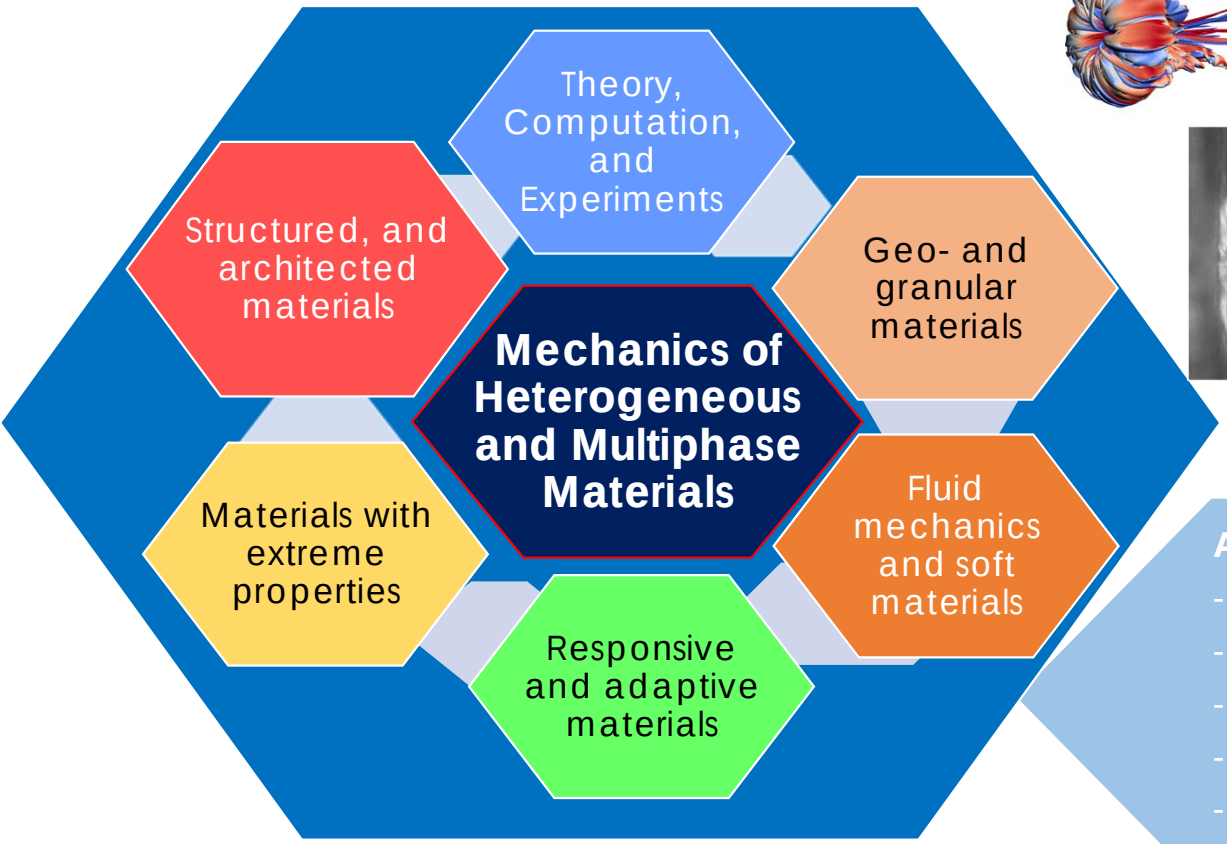


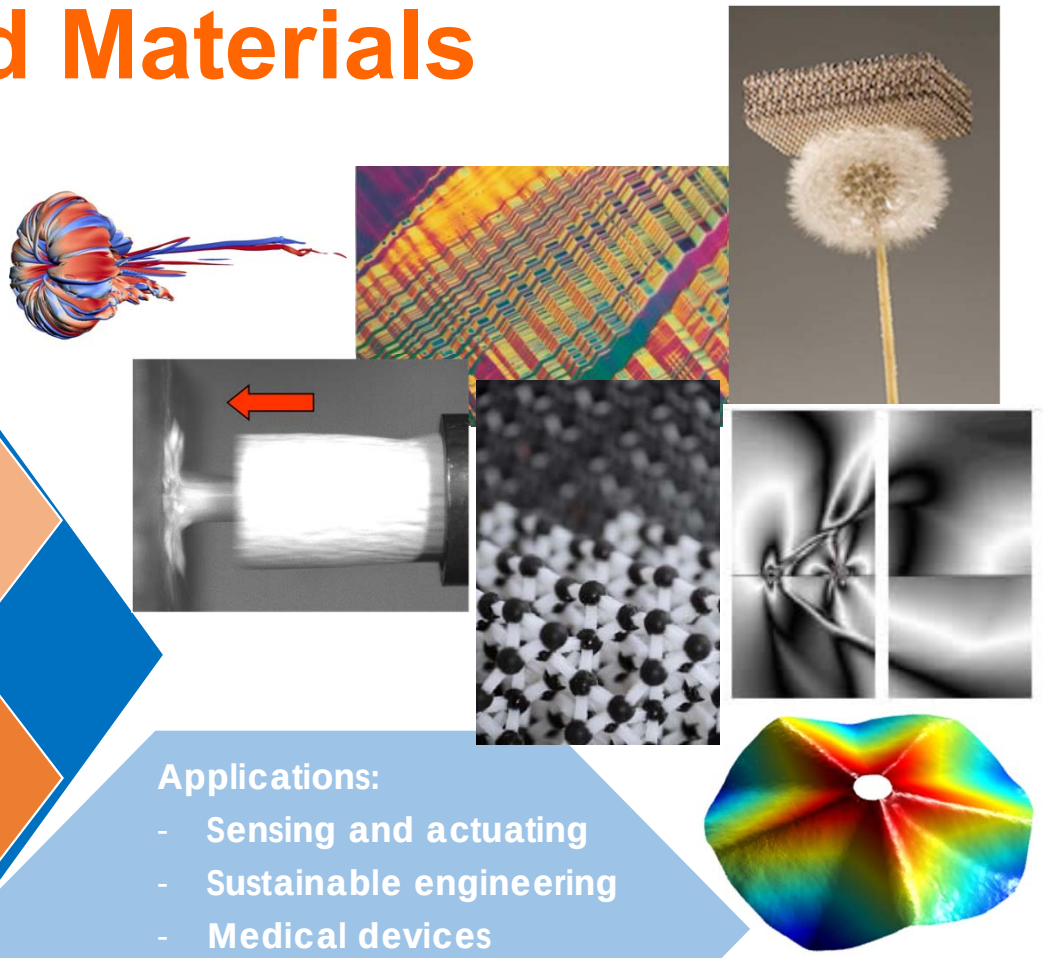
(Schwer and Kailasanath, 2010)





Mechanics and Materials

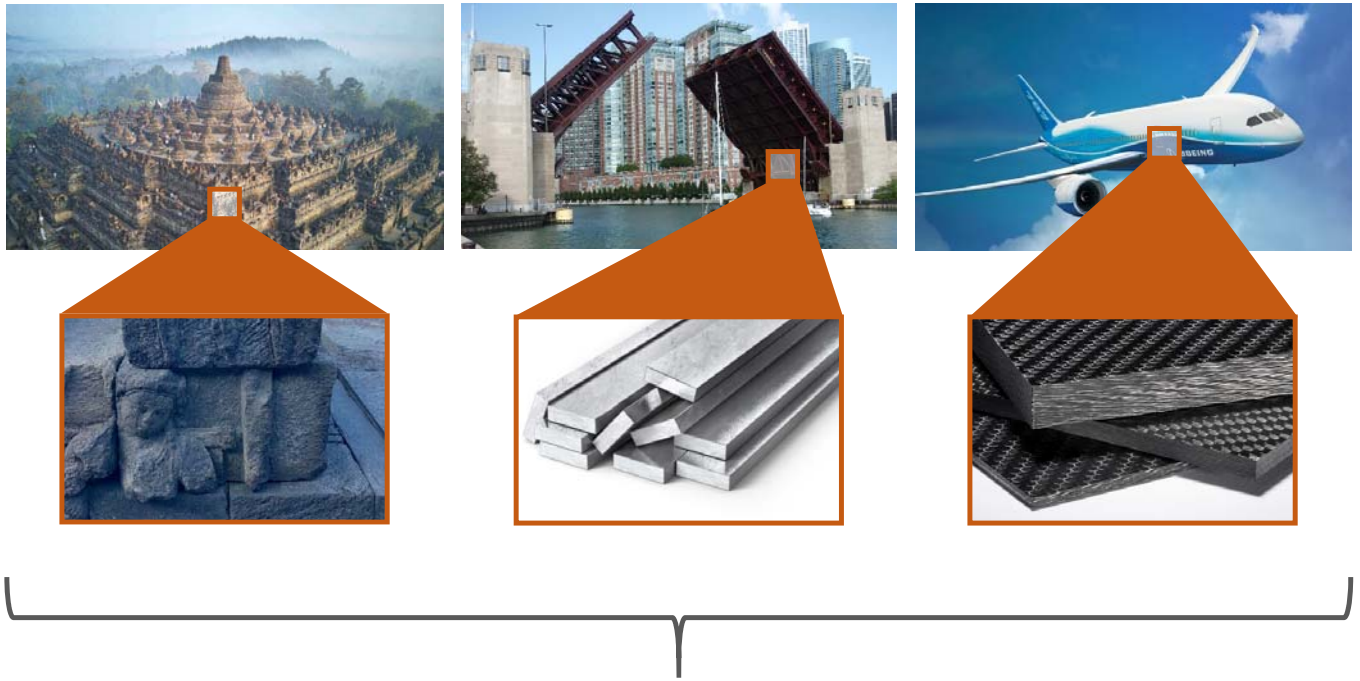




Applications:

- **Sensing and actuating**
- **Sustainable engineering**
- **Medical devices**
- **Space structures**
- **Energy generation and absorption**

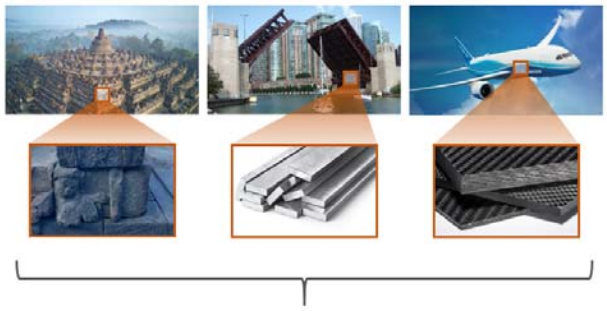
Towards Reconfigurable Materials with Extreme Properties



Passive – Properties generally cannot be altered after fabrication

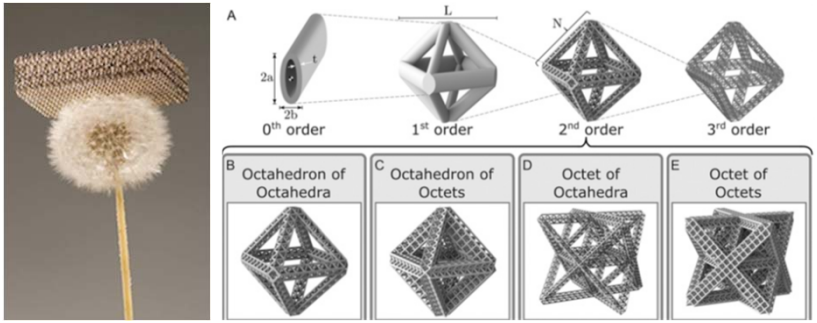
Limited Design Space – Properties are constrained to a specific range of density, strength, etc.

Towards Reconfigurable Materials with Extreme Properties



Passive – Properties generally cannot be altered after fabrication
Limited Design Space – Properties are constrained to a specific range of density, strength, etc.

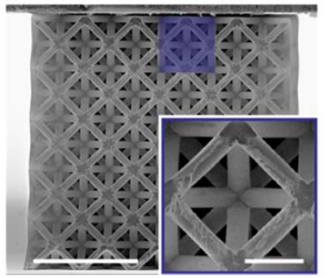
Ultra Lightweight & High Resilience



HRL Laboratories, LLC L. R. Meza, …, J. R. Greer (2015)

Structural elements that span across multiple length-scale

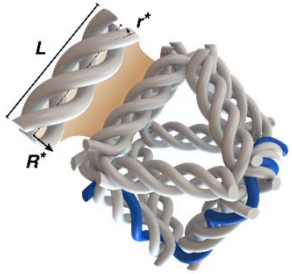
Ultralow Thermal Response

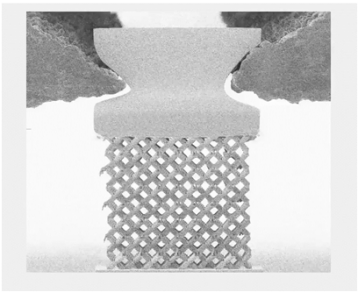


N. G. Dou, …, A. J. Minnich (2018)

Collaboration of experts

Extreme Deformability & Compliance

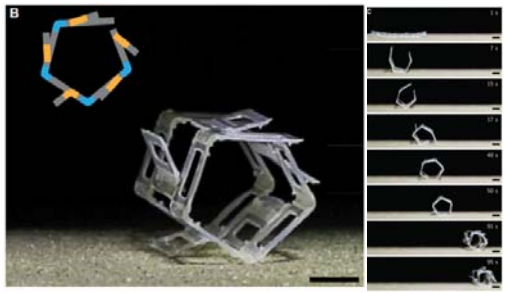




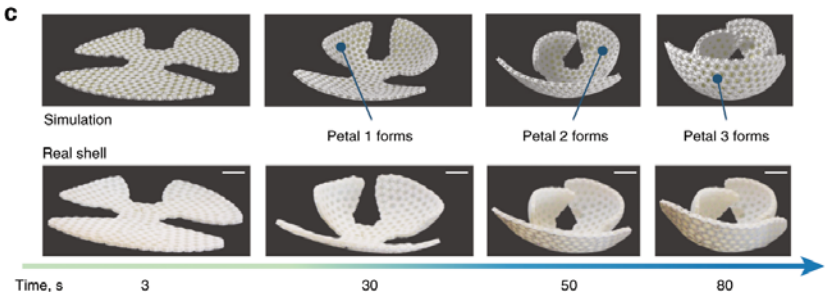
W. P. Moestopo, …, J. R. Greer, C. M. Portela (2020)

Made possible by advanced fabrication methods

Programmable Stimuli-Responsive Materials



A. Kotikian, C. McMahan, …, C. Daraio, … (2019)

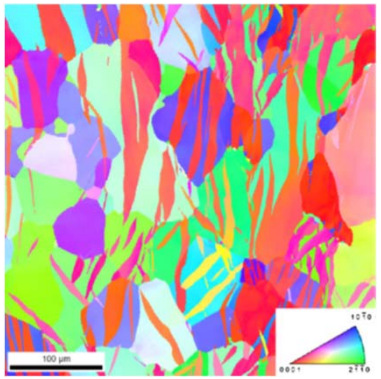


R. Guseinov, C. McMahan, …, C. Daraio, … (2020)

Controlling structural reconfiguration in space & time through engineered materials

Caltech mce

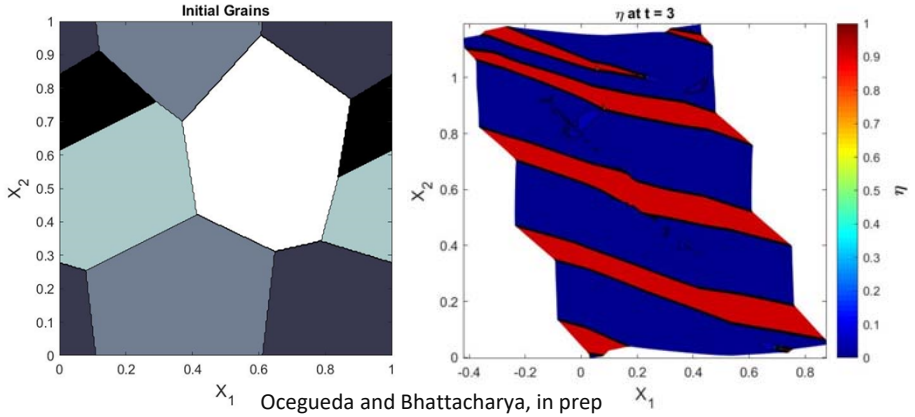
Multi-scale computational models to study the deformation of light-weight metals



Beyerlein, McCabe and Tome´, 2011

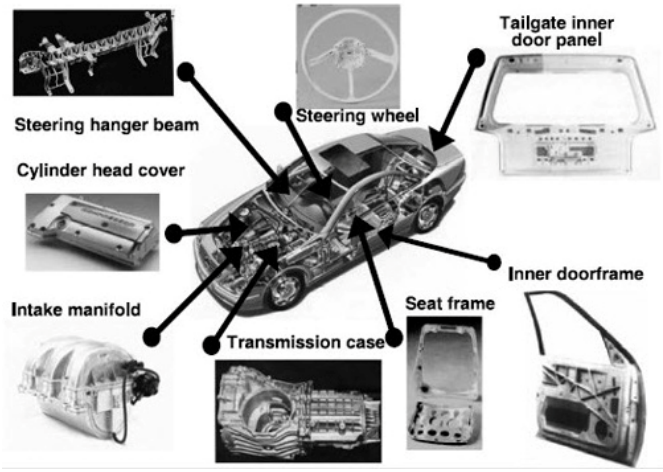
Experimental deformation twinning images

- Low-symmetry metals have high strength-to-weight ratio
- Comprehensive analysis requires nanoscale physics to describe complex deformation at the microscale
- Crucial to understanding failure of low-symmetry metals where microscale deformation interactions such as twinning lead to macroscopic failure

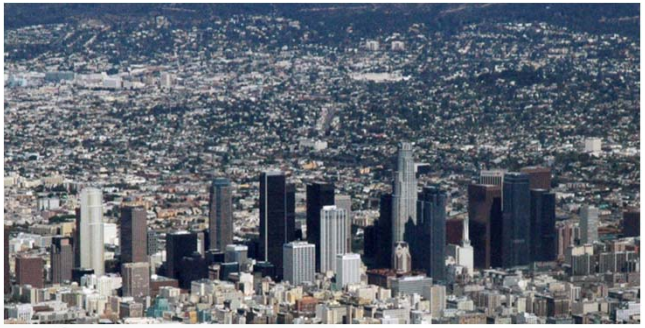


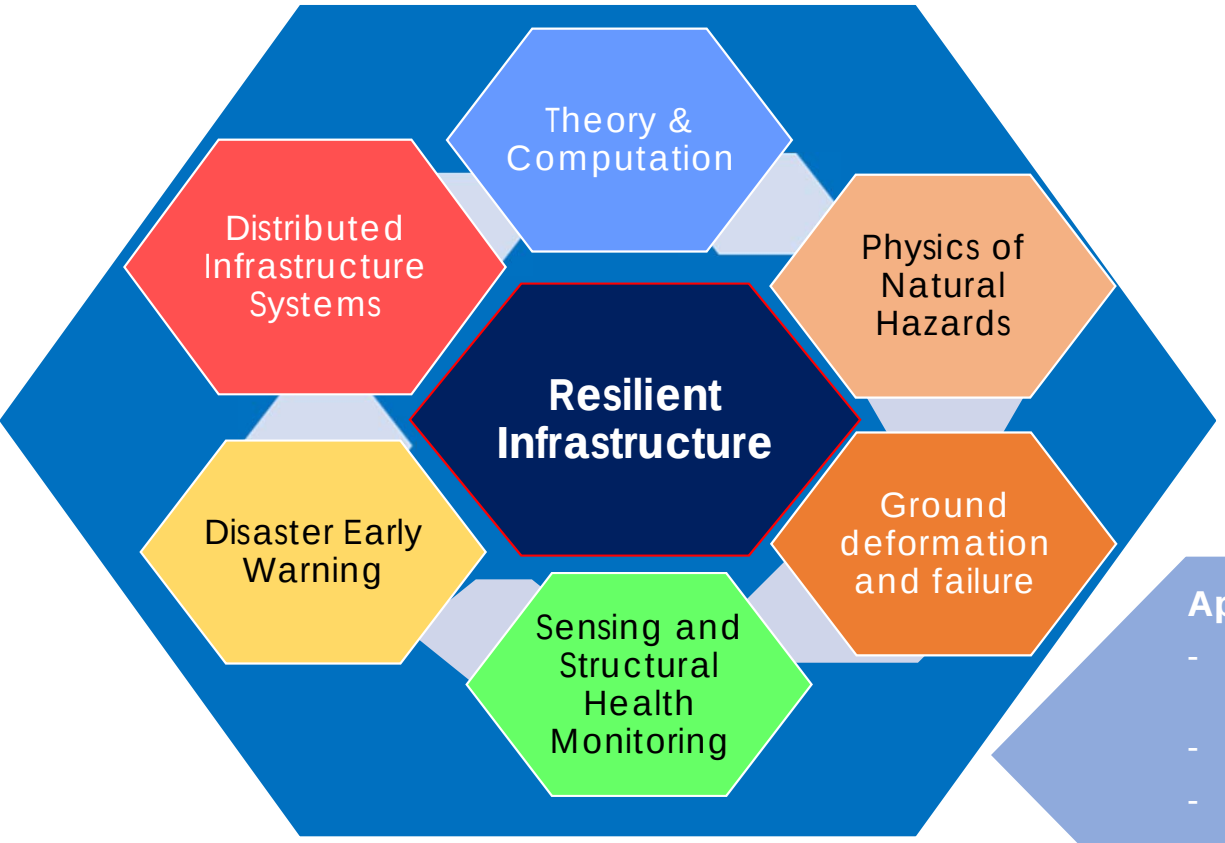
Ocegueda and Bhattacharya, in prep

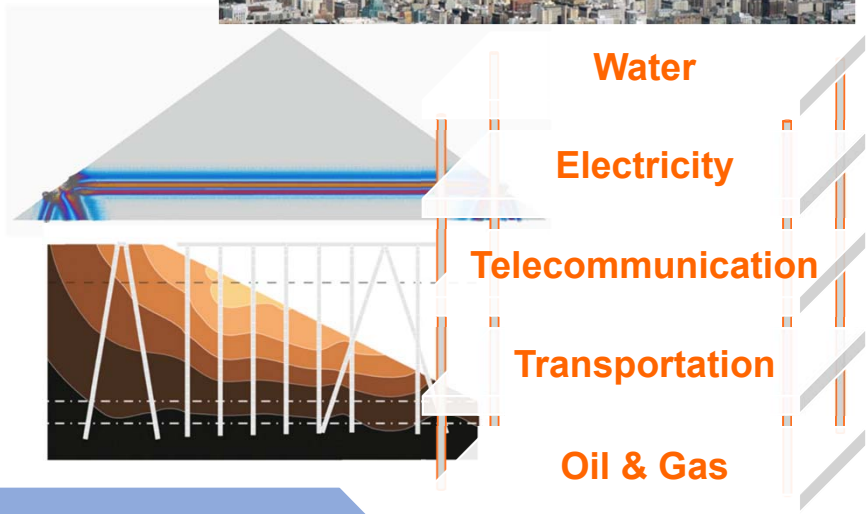
Computational twinning phase plots in polycrystalline



Resilient Infrastructure

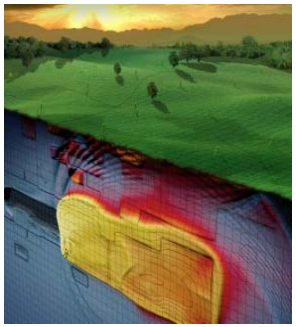




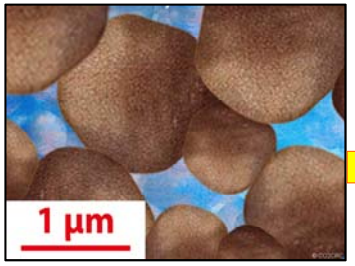


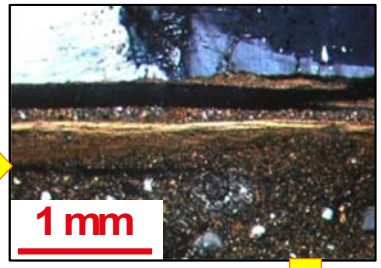
Applications:

- **Mitigation of earthquakes and other hazards**
- **Smart structures/systems**
- **Robust system design**
- **Energy-efficient systems**
- **Resilient Mega-Cities**

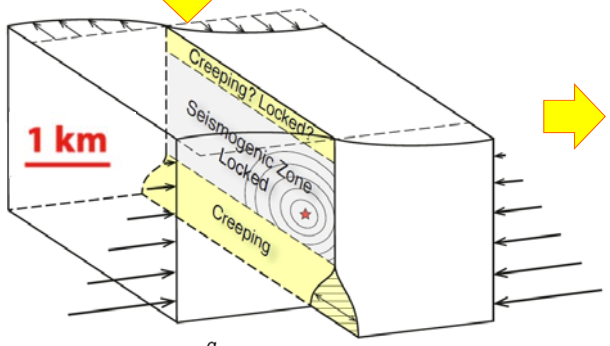


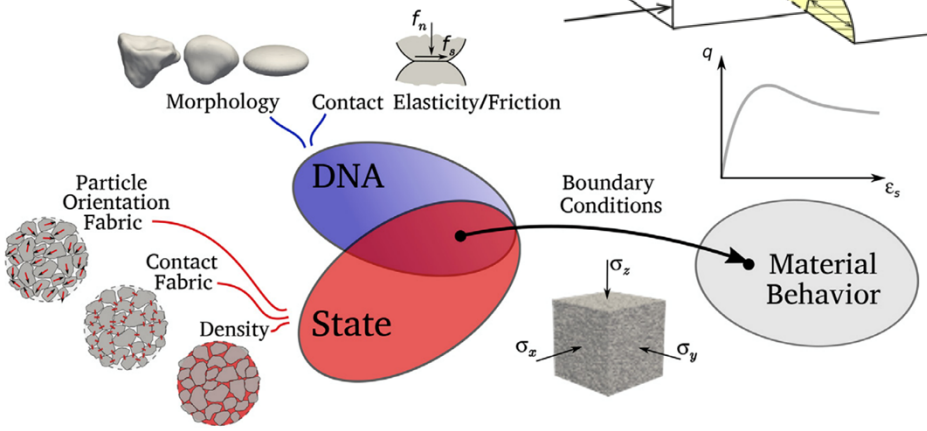
Modeling earthquake source: multi-scale, multi-physics, non-linear problem



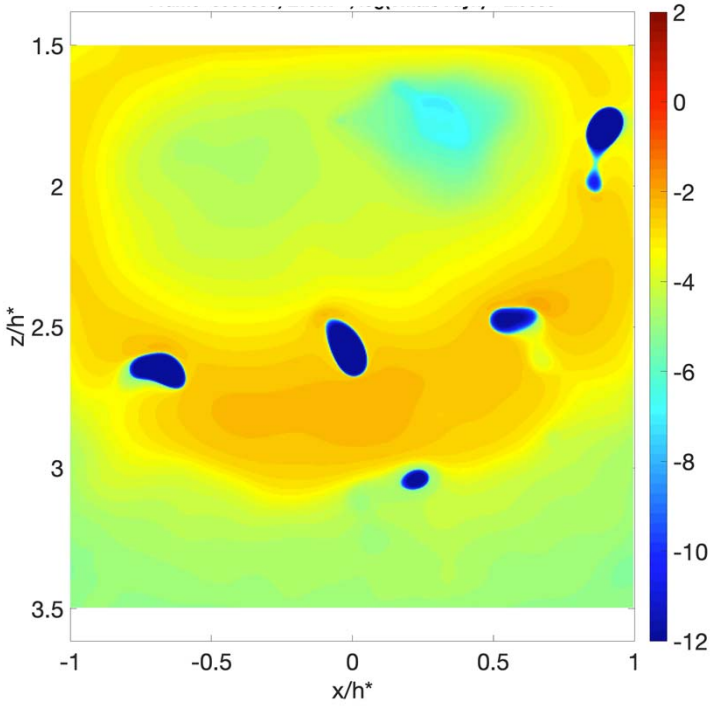


Mizoguchi et al. (2009)





(K. Karapiperis, J. Harmon, …. Andrade et al., 2020)

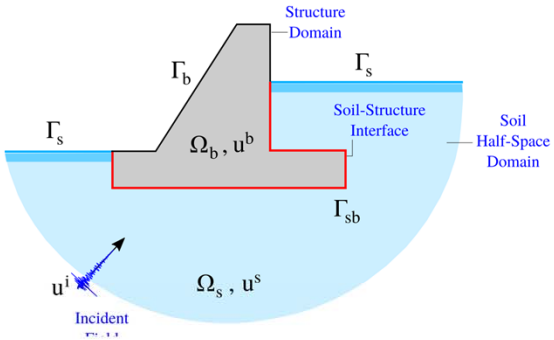


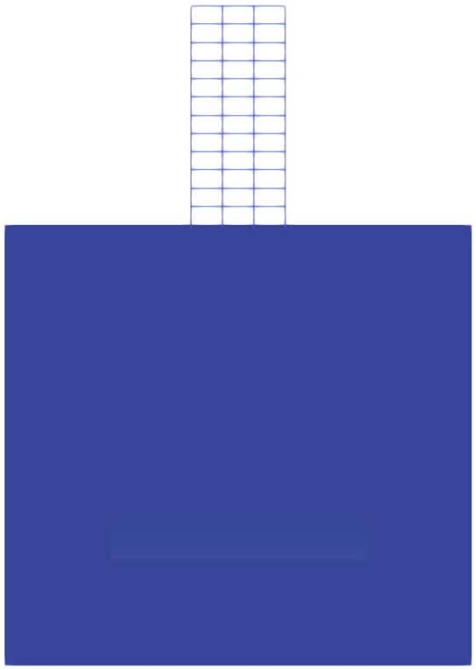
Slip rate $\log_{10}(V/V_{dyn})$

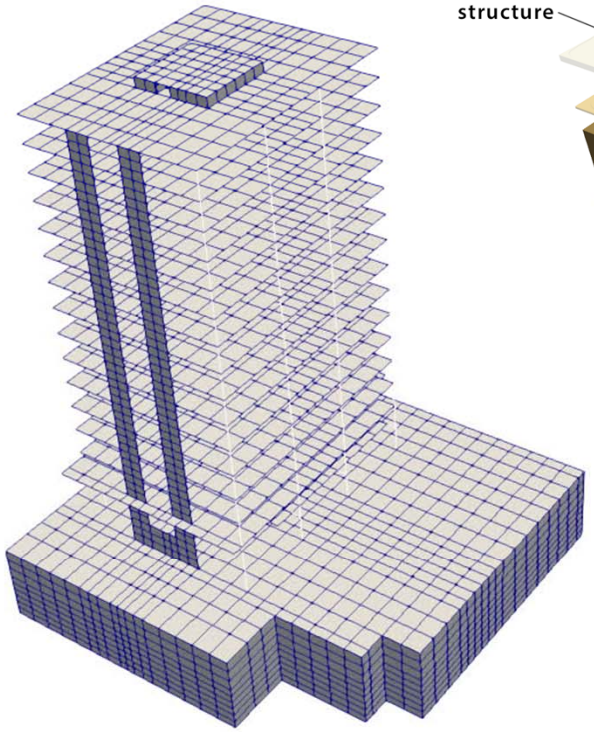
(Sudhir, K. and Lapusta N., in prep)

Granular scales → Tectonic scales

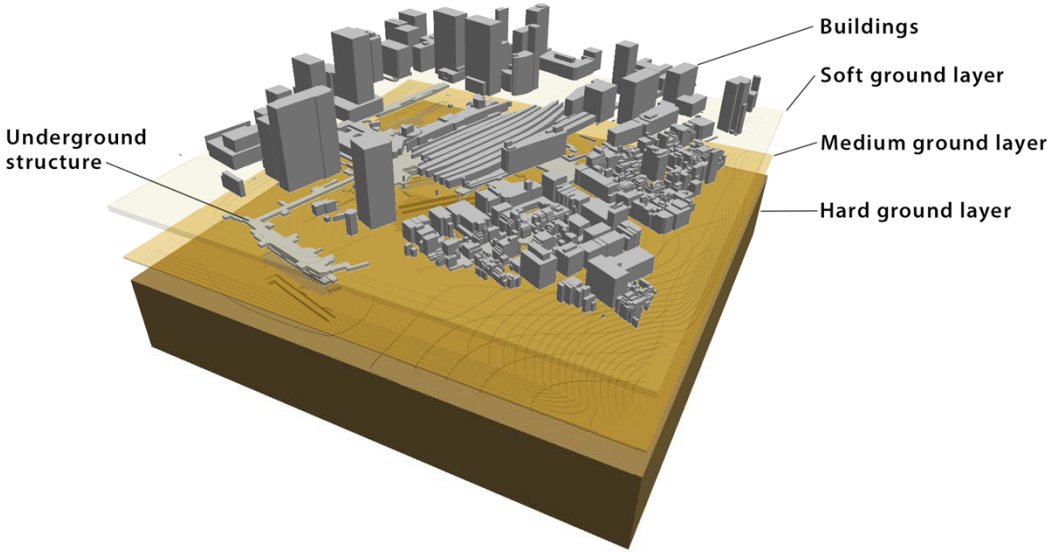
Translation of fundamental science to engineering applications

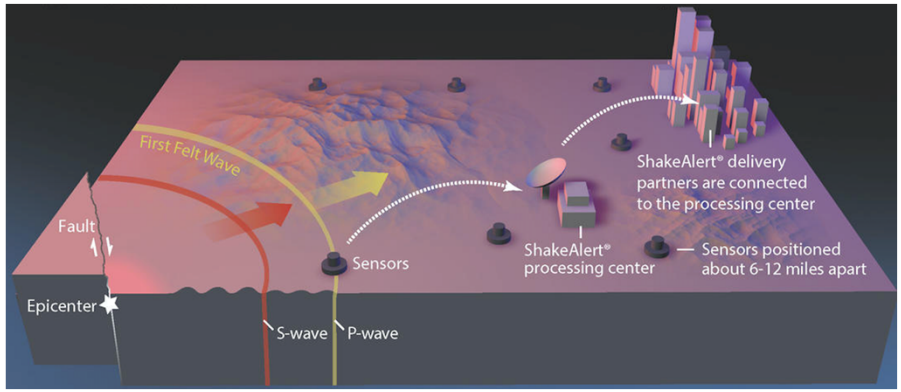






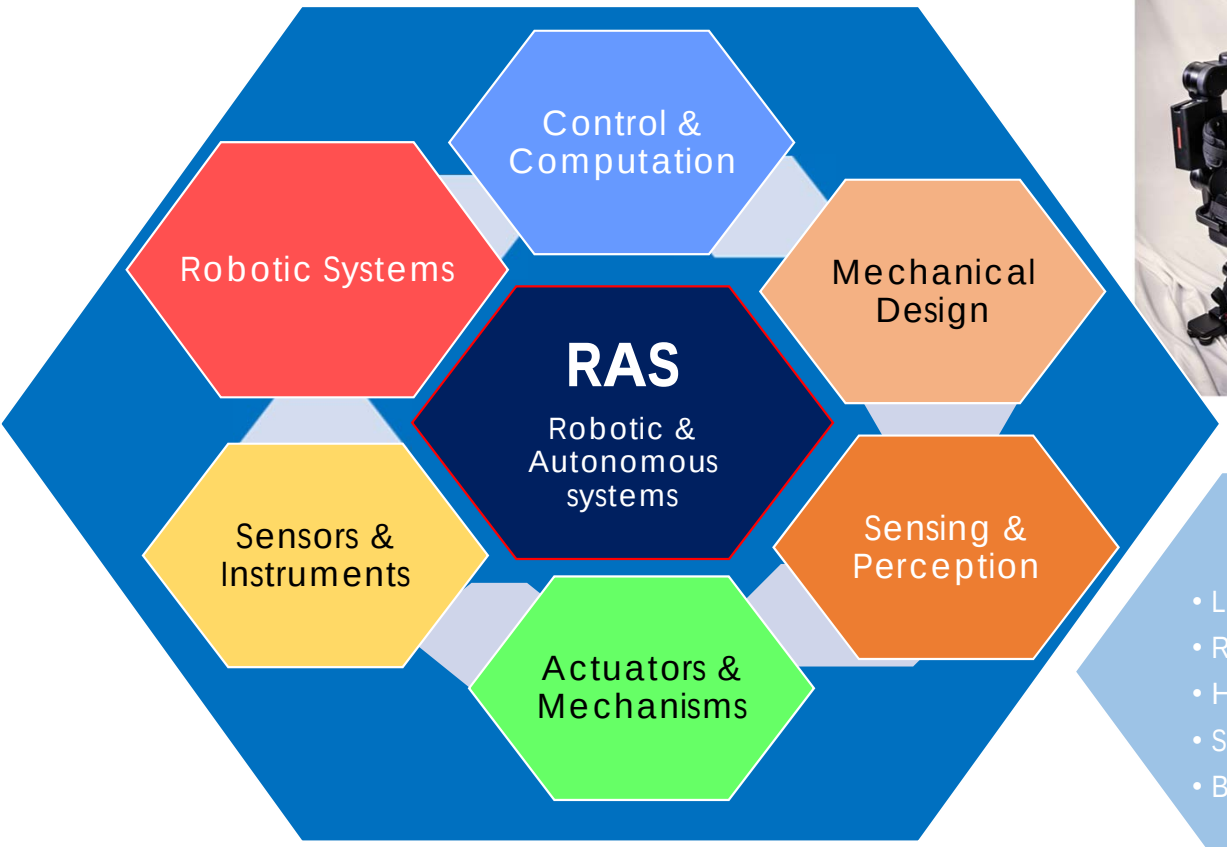
(Simulations with SeismoVLAB software, Kusanovic and Asimaki)

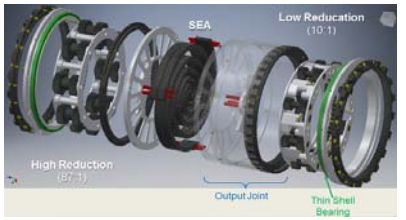




ShakeAlert® from USGS - Earthquake Early Warning System

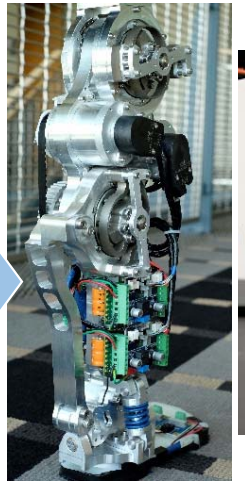
Robotic and Autonomous Systems

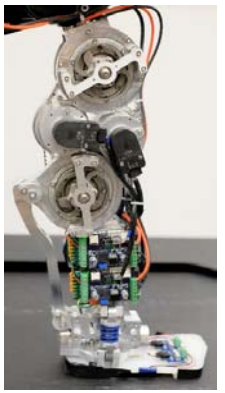




Applications:

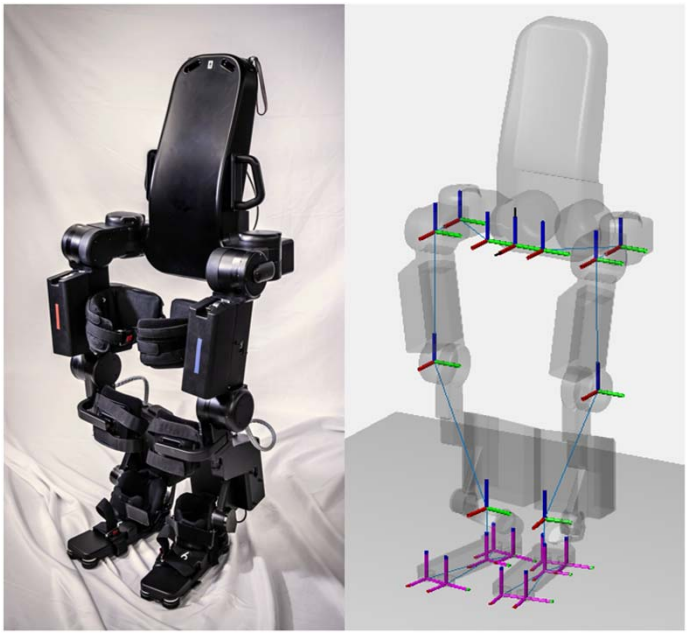
- Legged Locomotion
- Robotic Assistive Devices
- Human Robot Interaction
- Space Exploration
- Biomedical Devices





Dynamically Stable Crutch-less Exoskeleton Walking

- Translate theory from bipedal robotics to lower-body exoskeleton to realize crutch-less exoskeleton walking for people with paraplegia

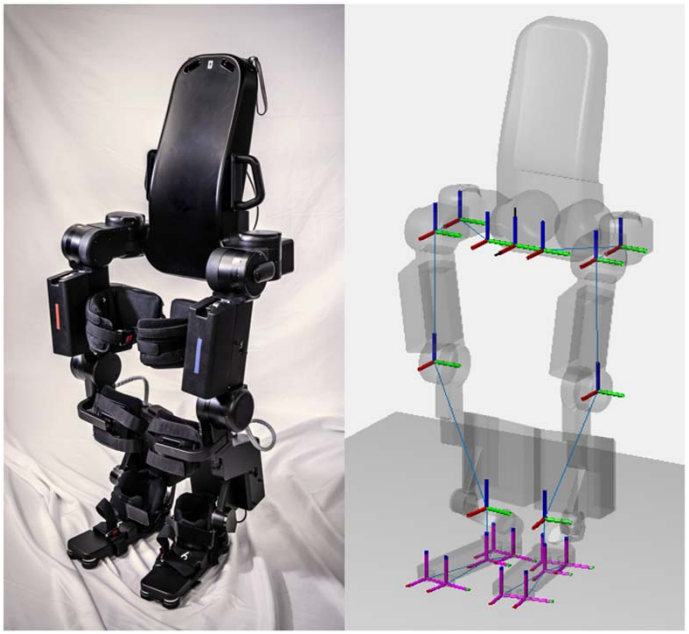


Atalante Exoskeleton designed by Wandercraft (12 actuated joints, 18 degree of freedom robot)

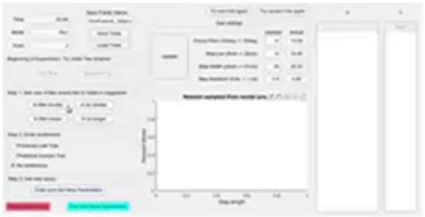
Multi-contact walking demonstrated on DURUS (Designed by SRI, 15 actuated joints, 23 degrees of freedom)

Subject with motor complete paraplegia using the Atalante Exoskeleton

Dynamically Stable Crutch-less Exoskeleton Walking



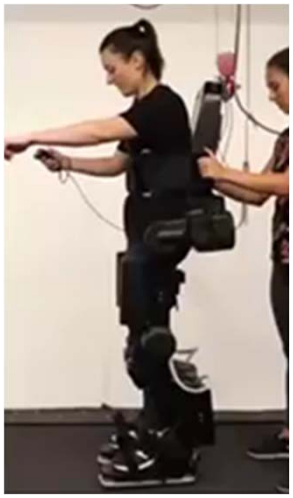
- Translate theory from bipedal robotics to lower-body exoskeleton to realize crutch-less exoskeleton walking for people with paraplegia
- Can optimize the exoskeleton walking for user comfort by learning from user preferences



Learning Algorithm

Exoskeleton gait

User feedback



Exoskeleton User

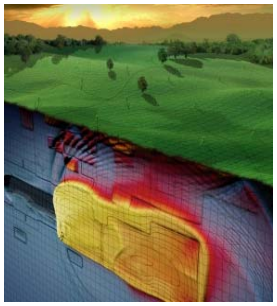
Human-in-the-loop optimization: As process repeats the algorithm learns the underlying user preferences and selects optimal gait parameters

(Tucker, Novoseller, Kann, Sui, Burdick, Yue, Ames 2020)
(Tucker, Cheng, Novoseller, Cheng, Burdick, Yue, Ames 2020)

Mechanical and Civil Engineering

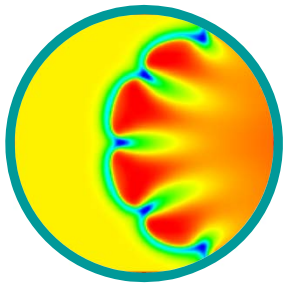
Create sustainable, autonomous, and resilient machines and infrastructure

Novel materials

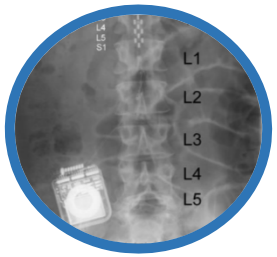


Resilience to hazards

Robots and mobility



Energy



Medical devices

QUESTIONS?

Contact:

Prof. Nadia Lapusta, MCE Option Representative, **lapusta@caltech.edu**
Holly Golcher, MCE Options Manager, **golcher@caltech.edu**

Commonly asked questions

- What made you decide to pursue a PhD in general and at Caltech specifically?
- What kind of career would you like to pursue after receiving your PhD?
- What was your favorite class you've taken?
- Do you offer only a Master's degree?
- How much does it cost to study at Caltech?
- How did you choose an advisor in your first year? Are there lab rotations, etc.?
- How specific were your research interests when you applied and/or started at Caltech?