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

Key research areas:
- Energy and Sustainability
- Mechanics and Materials
- Resilient Infrastructure
- Robotic and Autonomous Systems
Interdisciplinary research and study

Key MCE research areas
- Energy and Sustainability
- Mechanics and Materials
- Resilient Infrastructure
- Robotic/Autonomous Systems

Chemistry and Chemical Engineering
Resnick Sustainability Institute
Center for Geomechanics and Mitigation of Geohazards (GMG)
Geological and Planetary Sciences

Center for Bioinspired Engineering (CBE)
Center for Autonomous Systems and Technologies (CAST)
Computing + Mathematical Sciences

Medical Engineering
Keck Institute for Space Studies (KISS)
Jet Propulsion Laboratory (JPL)
Graduate Aerospace Laboratories (GALCIT)
Energy and Sustainability

Applications:
- Energy generation
- Storage and management
- Detectors and sensors
- Space power generation
- Geothermal energy
- Stability and safety
Turbulence-Flame Interactions

Turbulence → Increased mixing → Faster flame

Laminar flame

Turbulent flame

SpaceX Falcon 9

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

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

(Schwer and Kailasanath, 2010)
(Baumgart, Beardsell, and Blanquart, in prep)
Mechanics and Materials

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

Structured, and architected materials
Materials with extreme properties
Responsive and adaptive materials
Mechanics of Heterogeneous and Multiphase Materials
Theory, Computation, and Experiments
Geo- and granular materials
Fluid mechanics and soft materials
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

Ultra Lightweight & High Resilience
L. R. Meza, ..., J. R. Greer (2015)

Ultralow Thermal Response
N. G. Dou, ..., A. J. Minnich (2018)

Extreme Deformability & Compliance
HRL Laboratories, LLC
Structural elements that span across multiple length-scale

Programmable Stimuli-Responsive Materials
A. Kotikian, C. McMahan, ..., C. Daraio, ... (2019)
Controlling structural reconfiguration in space & time through engineered materials

W. P. Moestopo, ..., J. R. Greer, C. M. Portela (2020)
Made possible by advanced fabrication methods

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

- 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
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)

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

Granular scales $\rightarrow$ Tectonic scales

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

Slip rate $\log_{10}(V/V_{dy})$
Translation of fundamental science to engineering applications

(Simulations with SeismoVLAB software, Kusanovic and Asimaki)

ShakeAlert® from USGS - Earthquake Early Warning System
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

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)
Create sustainable, autonomous, and resilient machines and infrastructure

- Novel materials
- Resilience to hazards
- Energy
- Robots and mobility
- 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?