Researchers at the Paul M. Rady Department of Mechanical Engineering work in diverse and impactful areas to improve human health, enable security and promote sustainability. Please scroll through the slides in this document or click the links below to skip to a specific faculty member’s slide to learn about their areas of expertise and potential opportunities for collaboration.

**Research Areas**

- **Air Quality**
  - Peter Hamlington
  - Mike Hannigan
  - Daven Henze
  - Hope Michelsen
  - Jana Milford
  - Shelly Miller
  - Arthur Mizzi
  - Greg Rieker
  - Marina Vance
  - Christine Wiedinmyer

- **Biomedical**
  - Alaa Ahmed
  - Francois Barthelat
  - Mark Borden
  - Nick Bottenus
  - Carson布鲁斯
  - Sarah Calve
  - Xiaoyun Ding
  - Virginia Ferguson
  - Jean Hertzberg
  - Maureen Lynch
  - Debanjan Mukherjee
  - Todd Murray
  - Corey Neu
  - Mark Rentschler
  - Jacob Segil
  - Wei Tan
  - Franck Vernerey
  - Cara Gonzalez Welker

- **Materials**
  - Chunmei Ban
  - Francois Barthelat
  - Mark Borden
  - Carson布鲁斯
  - Sarah Calve
  - Longji Cui
  - Yifu Ding
  - Virginia Ferguson
  - Kaushik Jayaram
  - Se-Hee Lee
  - Baowen Li
  - Hope Michelsen
  - Todd Murray
  - John Pellegrino
  - Rishi Raj
  - Conrad Stoldt
  - Gregory Whiting
  - Xiaobo Yin

- **Mechanics of Materials**
  - Francois Barthelat
  - Mark Borden
  - Victor Bright
  - Carson布鲁斯
  - Sarah Calve
  - Yifu Ding
  - Longji Cui
  - Xiaoyun Ding
  - Kaushik Jayaram
  - Svenja Knapp
  - Baowen Li
  - Se-Hee Lee
  - Hope Michelsen
  - Marina Vance
  - Gregory Whiting
  - Jianliang Xiao
  - Xiaoobo Yin

- **Micro/Nanoscale**
  - Mark Borden
  - Nick Bottenus
  - Sean Humbert
  - Kaushik Jayaram
  - Robert MacCurdy
  - Mark Rentschler
  - Jacob Segil
  - Nicole X. Wu

- **Robotics and Systems Design**
  - Alaa Ahmed
  - Nick Bottenus
  - Sean Humbert
  - Kaushik Jayaram
  - Robert MacCurdy
  - Mark Rentschler
  - Jacob Segil
  - Nicole X. Wu

- **Thermo Fluid Sciences**
  - Mark Borden
  - Longji Cui
  - Xiaoyun Ding
  - Peter Hamlington
  - Jean Hertzberg
  - Nicole Labbe
  - Baowen Li
  - Hope Michelsen
  - Debanjan Mukherjee
  - John Pellegrino
  - Greg Rieker
  - Nathalie Vriend
  - Nicole X. Wu

*to open all faculty members in a research area when viewing online, hold ctrl or cmd while clicking each link to open multiple tabs*
The goal of my research is to understand how the brain controls movement from neurons to algorithms to behavior.

The effortless ease with which we move masks a profound complexity. While we can now build a car that can drive autonomously for thousands of miles and rival the performance of a human driver, we still cannot build a robot that can get into that car with the grace of even a 6-year old child.

Our lab is focused on understanding what makes movement so difficult and unraveling the computational processes the brain uses to solve these problems.

Areas of Expertise
- Biomechanics and motor control
- Neuromusculoskeletal modeling
- Bayesian decision making
- Computational models of learning

Tools
- Virtual reality environments
- Robotic interfaces
- Instrumented split-belt treadmill
- Electromyography
- Motion capture
- Eye-tracking

Current projects
- What are the roles of error, effort and reward in reinforcing how the brain learns new movements?
- How does uncertainty influence the learning, consolidation and generalization of new movements?
- Is there a link between the neural systems that drive our decisions and the systems that control our movements?
- How do effort and reward influence movement vigor in individuals with Multiple Sclerosis and Parkinson’s Disease?

Research at a Glance
The Neuromechanics Lab studies the movement biomechanics and control with the goal of reverse-engineering how the brain controls movement. We use a combination of theoretical and experimental approaches involving motion tracking, virtual reality and robotic interfaces. We employ a novel neuroeconomic approach, drawing on concepts and tools from mechanics, control theory, artificial intelligence, physiology, psychology, neuroscience and economics.
Chunmei Ban
Materials
www.colorado.edu/lab/ban/research
chunmei.ban@colorado.edu
scholar.google.com/citations?user=z1Hk5OAAAAJ&hl=en

Research at a Glance
Provide surface engineering that provides practical solutions to stabilize next-generation energy storage systems.

Our Research Expertise
- Focus areas
  - Surface stabilization
  - Multivalent electrochemical materials
  - Synthesis capability
- Surface and near-surface characterization
  - Ion diffusion
  - Mechanical failures
  - Electrode-electrolyte interaction
  - Surface instability
  - Reversibility of electrochemical reactions

Passion and Process in Battery Research: Harnessing Nature’s Bounty
The Surface Engineering Group at CU Boulder led by Prof. Chunmei Ban explores the use of surface modification to fully realize the material’s potential for renewable energy technologies.

Focus areas:
1. **Surface stabilization** for electrochemical materials to improve electrochemical reactivity and reversibility (as shown in the schematic figure on the left)
2. **Multivalent electrochemical materials** for low-cost and high-energy batteries

Expertise: Electrochemical analysis and characterization and surface modification systems customized for air-sensitive electrochemical materials, X-ray diffraction, transmission/scanning electron microscopy and x-ray photoelectron spectroscopy.
At the Laboratory for Advanced Materials and Bioinspiration, we discover and explore new concepts in materials design based on precise microarchitectures and programmable micro-mechanisms for the next generation of structural materials. Applications include transportation, biomedical and defense.

Materials, Biomedical Mechanics of Materials
www.colorado.edu/mechanical/francois-barthelat
francois.barthelat@colorado.edu
303-492-8322

Research at a Glance
We combine theoretical mechanics, numerical modeling, optimization, experimental mechanics, 3D printing and also a bit of biology (for inspiration) to create, explore and validate new classes of materials. Our favorite challenge is to create new material designs that combine properties which are traditionally difficult or impossible to achieve simultaneously in individual materials.

Research Approach 1: Material Architecture

Research Approach 2: Bioinspiration

Current Projects:

Morphing materials inspired from fish fins
Fish fins “probably represents the most elaborate and refined adoption of efficient interaction with water that has ever evolved” (Niederer 1993)

“Smart” granular materials
Design of grain geometry and mechanical stimuli for self-assembly, jamming, strength, healing and morphing

www.colorado.edu/mechanical/
Borden’s laboratory develops medical technology based on soft matter acoustic colloids to aid in the diagnosis and treatment of diseases, such as acute respiratory distress syndrome (ARDS), neurodegenerative diseases, heart disease and cancer.

My lab is looking to recruit self-starter graduate students interested making an impact on biomedicine by engineering novel imaging probes and drug delivery vehicles. Lab alumni have gone on to take faculty positions at Oxford, ETH Zurich and other universities, to startup new companies, and to take leadership positions in industry and government labs. In my lab, you will gain interdisciplinary knowledge in:

- intermolecular and surface forces in biology
- colloid and interface science
- biomedical ultrasound and acoustics
- biotransport and biointeractions
- human anatomy and physiology
- advanced medical imaging
- targeted drug, gene and oxygen delivery

We are also looking to partner with industry. My lab houses advanced particle characterization equipment, microscopy, ultrasound devices, imaging scanners and focused ultrasound systems. We have spun out three companies: Respirogen, TrulyOxygen, and Advanced Microbubbles Labs.

Acoustic Colloids (i.v. injection)

Focused Energy (e.g., ultrasound)

Composition ↔ Assembly

Physics & Acoustics

Bio-interactions ↔ Biotransport

Medical Performance

- colloid science
- soft matter
- emulsions & foams
- molecular imaging
- super-resolution imaging
- photo-acoustics
- targeted drug delivery
- gene therapy
- cancer therapy
- oxygen delivery
Our mission is to bring the value of ultrasound imaging to more patients in more situations with greater clarity and utility than ever before.

Areas of expertise:
- Ultrasound pulse sequencing
- Synthetic aperture and adaptive array beamforming
- Sources of acoustic clutter and image degradation
- Ultrasonic motion estimation
- Acoustic radiation force elasticity imaging

Our capabilities:
- Ultrafast ultrasound imaging up to 20 kHz
- Real-time acquisition of up to 256 channels of raw RF array data (Verasonics Vantage)
- 3-D acoustic field measurement in a water tank
- Linear and non-linear ultrasonic simulation

Research at a Glance
We design system-level solutions to clinical problems, working from scanner sequencing to signal and image processing. Our work focuses on improving ultrasound image quality in challenging imaging environments using advanced beamforming techniques.

Ongoing research:
Recovery of the complete data set from imaging sequences

Optically-tracked and motion estimate based swept synthetic aperture imaging
We integrate atomic, nano, and micro fabrication techniques and technologies, to develop nanoscale sensors and actuators that impact a diverse array of disciplines including physics, engineering, medicine, and biology.

Research at a Glance
Our multi-disciplinary group is committed to developing novel fabrication processes and devices that advance the field of micro- and nano-scale electromechanical systems (MEMS and NEMS). Current research directions are in applying atomic layer deposition (ALD) to create novel nanoscale sensors and developing novel tunable optics for applications such as microscopy and LIDAR using electrowetting lenses and prisms.

ALD Enabled NEMS

Electrowetting Optics
We leverage the emergent properties of nanomaterials to design technologies that solve problems in biomedical, energy, and manufacturing domains.

Research in the Emergent Nanomaterials Lab

Biomedical Tattoos

“Slide-Ring” Soft Materials

Self-Assembly + Machines

**Expertise / Capabilities:** Organic, Polymer, & Colloid Synthesis · Photolithography · Shear Rheology · Spectroscopy & Microscopy

---

Research at a Glance

Our interdisciplinary team combines chemistry, materials science, mechanical, electrical, & biomedical engineering to develop active materials with nanoscale features that enable them to respond to stimuli and use energy to manifest novel structures and functions.
The mission of the Musculoskeletal Extracellular Matrix Laboratory is to characterize the material properties of assembling tissues to establish design parameters for regenerative therapies.

Sarah Calve
Biomedical, Materials, Mechanics of Materials
www.sarahcalve.com
sarah.calve@colorado.edu
303-492-7640

Research at a Glance
The Musculoskeletal Extracellular Matrix Laboratory is actively developing tools to quantify how the composition, turnover, organization and mechanical properties of the musculoskeletal system change during tissue assembly. The goal is to use these tools to elucidate how different extracellular matrix components integrate to form functional tissues during development, regeneration and scar-free repair.

Dynamics of extracellular matrix (ECM) synthesis
Mass spectrometry + bio-orthogonal labeling of newly synthesized proteins in vivo

Spatial organization of ECM components
Clearing and decellularization to visualize cell + tissue architecture in 3D

Influence of organization on ECM mechanics
Experimental and computational modeling of ECM fibril and network mechanics at the mesoscale

Prospective graduate students and postdoctoral associates motivated to integrate engineering principles with the fundamentals of biology are encouraged to email Prof. Calve: sarah.calve@colorado.edu
Our mission is to provide nanoengineering and nanoscience based tools and solutions to address the pressing grand challenges in the 21st century including cheap and clean renewable energy, next-generation microelectronics, and high-performance nanomaterials.

- Ultra-high Resolution Thermal Sensing and Imaging
- Atomic, Molecular, and Quantum Electronics
- High-efficiency Nano-thermoelectrics
- Nano-gap Thermophotovoltaics and Plasmonic Applications

Research at a Glance
Our group focuses on developing nanostructures and nanoengineering tools capable of resolving energy transfer, conversion, and dissipation down to the scale of single atoms and molecules. Our research provides fundamental understandings to address the limitations existing in the performance and energy efficiency of nanotechnology-enabled thermal, electrical, and optical applications.
We create novel Lab-on-a-Chip, Microfluidic technologies, and other Biomedical Microdevices to tackle challenges in life science and health care through cell/bioparticle manipulation, precise intracellular drug delivery, cell physics, and cellular mechanical biomarkers.

In general, we develop novel Lab-on-a-Chip and biomedical microsystem and technologies for cell based applications for fast and accurate diagnosis and therapy.

Research at a Glance
Our group centers on interdisciplinary research at the frontiers of Micro/Nano Engineering, Biology, Medicine, and Physics. We focus on creating cutting-edge micro/nano systems and technologies for various cell based biomedical applications in life science, healthcare, and medicine. Our recent focus includes cell mechanics for biomarkers, cell membrane disruption and recovery and its application for precise intracellular drug delivery in immunotherapy and gene editing, bioparticle manipulation and sensing for fast diagnosis.
Our lab engineers better materials and membranes for water treatment, bioseparation, gas separation and nanomanufacturing.

The Ding research group specializes in developing new techniques to spatially modify structures and surfaces of polymer films and porous membranes. Our current projects include:

- Developing surface-patterned antifouling membranes for bioseparation and desalination.
- Improving mechanical and permselective properties of dense membranes using precisely patterned mechanical heterogeneity.
- Developing elastomers with low gas permeability and low friction coefficient.
- Engineering supertough hydrogels for membrane applications.
- Understanding bonding mechanism between polymer and porous membranes for membrane device manufacturing.

We closely collaborate with industry through our Membrane Science, Engineering and Technology (MAST) center, an NSF industry university collaborative research center (IUCRC). Our lab is well-equipped with tools for

- polymer processing, fabrication, and characterization;
- membrane fabrication, characterization and process evaluation;
The Turbulence and Energy Systems Laboratory (TESLa) focuses on numerical simulations of turbulence for fundamental flow analyses, model development, design optimization, and performance analysis.

There are three core areas of research in the Turbulence and Energy Systems Lab (TESLa):
1. Turbulence modeling (e.g. machine learning, parameter estimation, optimization)
2. Geophysical turbulence (e.g. upper ocean dynamics, biogeochemistry)
3. Reacting flows and combustion (e.g., fire dynamics, auto-ignition at high speeds)

In TESLa, applied research topics are examined at the intersections of core areas:
1. Propulsion and transportation (e.g. rotating detonation engines)
2. Wildland fire (e.g., fire prediction and mitigation)
3. Wind and ocean renewable energy (e.g. ocean and wind current turbines)
4. Ocean carbon cycle and contaminant transport (e.g. chemical species, plankton)

A range of advanced tools are used in TESLa:
High-performance computing, computational fluid dynamics, adaptive mesh refinement, machine learning, massively parallel simulations

Simulations from TESLa: 1) Pool fire, 2) helium plume, 3) compressible turbulence, 4) supersonic nozzle, 5) Rayleigh-Taylor instability, 6) rotating detonation engine, 7) axisymmetric bump, 8) premixed flame
With the end goal of improving human health, we explore the links between human activities and the environment through the development and use of novel, low cost measurement systems.

The Hannigan Group is at the forefront of the use of sensors systems to assess air quality as well as household energy systems. They are also known for figuring out the origins of air quality problems.

Current research areas include:

- Developing low-cost point based systems to monitor for leaks in hydrocarbon heavy industries
- Collaborating with communities impacted by multiple air pollutant sources in LA to develop strategies to minimize harmful exposures
- Improving our understanding of particle emissions, transport and fate from wildfires
- Assessing the impact of cooking and open burning on air quality in the global south.

Current teaching activities include:

- Project-Based Learning in Rural Schools
- Statics
Using ambient observations, satellite remote sensing, and computer simulations of the atmosphere to identify the role of human activities on the environment, air pollution, human health and climate.

Daven Henze
Air Quality
https://spot.colorado.edu/~henzed
daven.henze@colorado.edu
cuboulder.zoom.us/my/davenhenze

Research at a Glance
Our research focuses on the sources and fate of atmospheric constituents (aerosols, NOx, ozone, and long-lived greenhouse gases) and their roles on air quality, long-range pollution transport, and climate change. A large part of this research stems from chemical data assimilation, the process by which both models and observations are combined to produce estimates of the atmospheric state that are often more complete than those provided by either approach alone. This encompasses more specific interests in remote sensing, sensitivity analysis, inverse problems, and source apportionment.

Subset of Current Research Projects
- Top-down estimates of PM2.5 precursor emissions: SO2, NH3, NOx (NASA)
- Using remote-sensing observations to support health impact assessments and air quality policy (NASA, Wellcome Foundation)
- Emission strength and impacts of wildfires on air quality (NOAA, NASA)
- Machine-learning for AQ modeling (NASA)
- Chemical mechanism reduction using machine learning (EPA)

Consulting Activities
- Regional to global air quality model simulations (GEOS-Chem, CMAQ, WRF-Chem)
- Evaluation air quality sources and trends using satellite observations of trace-gases and aerosols
- Health impact assessment tools, i.e. estimating premature deaths owing to exposure to air pollution from a specific policy or technology scenario
Flow visualization lets us see the physics of the gases and liquids that are all around and inside us. Fluids can be beautiful or icky, useful or insignificant, but always, endlessly, fascinating.

Jean R. Hertzberg
Fluid Dynamics, Biomedical and Engineering Education Research
https://www.jeanbizhertzberg.com
hertzberg@colorado.edu
303-492-5092

Research at a Glance
I love flow visualization for both its beauty and utility. My fluids research is generally human-scale experimental fluid physics ranging from combustion to cardiac hemodynamics. I’m also interested in how the aesthetics of engineering can be used to promote transformative experiences in engineering education.

Top left: flow in a human heart. 4DMRI is an MRI imaging technique that shows blood flow velocity. Here, white pencils represent velocity, flowing from the right cardiac atrium in to the ventricle, and the colored arrows represent vorticity. These data are useful in measuring pulmonary hypertension and the damage from diabetes.

Top right: Musical instruments (brass, woodwinds) and singers emit more potentially infectious aerosols than quiet humans. This laser sheet visualization shows that masks on instruments reduce high speed flow with a minimal impact on sound.

Left: Students in a course on Flow Visualization produced this laser sheet visualization of flow from a suddenly started planar jet. Student in this course and in Aesthetics of Design report improved attitudes towards engineering.
The Bio-Inspired Perception and Robotics Laboratory (BPRL) seeks to distill the fundamental sensing, processing and feedback principles that govern robust behavior in organisms to enable new classes of robotic systems with improved agility, locomotion and autonomy.

Areas of expertise
- Reduction principles in biology
- Sensor and actuator-rich feedback principles
- Novel sensorimotor feedback architectures
- Dynamics and control of highly flexible synthetic systems
- Bio-inspired sensors and sensory processing
- Rotary wing, fixed wing and flapping wing flight mechanics, stability and control
- Autonomous navigation and collision avoidance

Research at a Glance
Main research focus is perception, reduction and feedback principles in biology. Our laboratory works with biologists to apply control- and information-theoretic tools to formalize these principles in small animals such as insects, providing insight into the biology and resulting in novel, robust and computationally efficient solutions for engineered systems.
Our research aims to develop a rich ecosystem of robotic devices that, in the not-so-distant future, will have the potential to benefit human lives in the areas of search and rescue, inspection and maintenance, personal assistance, and environmental monitoring.

Research Expertise:
- Bioinspired Robotics
- Biomechanics
- Locomotion Robustness
- Origami-based Design and Fabrication
- Distributed Sensing

Current Projects:
- Autonomous insect scale robots
- Spider locomotion biomechanics
- Collective communication and coordination
- Millimeter scale actuators, sensors

Research at a Glance
Our group’s research combines biology and robotics to, uncover the principles of robustness that make animals successful at locomotion in natural environments, and, in turn, inspire the design of next generation of novel robots for effective real-world operation.
Combining microfabrication approaches with atomic spectroscopy, we engineer novel sensor and system technologies with direct impact in biomedical, industrial, and defense applications.

### Atomic Quantum Sensors

**Our projects**
- Optically-pumped magnetometers for conformal non-invasive brain imaging
- Unshielded non-invasive brain-machine interfaces
- Magnetographic camera for magnetic nanoparticle imaging
- Vector magnetometry from CubeSats and small unmanned vehicles
- Advanced chip-scale atomic clocks

**Our expertise**
- Advancement of microfabricated atomic vapor-cell technology
- Novel atomic quantum sensor development
- System engineering of compact quantum sensor systems
- Working with diverse user groups on developing new applications for atomic quantum sensors

### Entrepreneurship

In 2017, Svenja Knappe founded FieldLine Inc. with Orang Alem and Jeramy Hughes with the aim to translate the quantum magnetometer technology into industry. FieldLine are currently offering magnetic imaging systems for non-invasive brain imaging, industrial, and defense applications. More information can be found at: [www.fieldlineinc.com](http://www.fieldlineinc.com)
Designing new fuels that burn greener, cleaner, and more efficiently from the atom up.

Nicole Labbe  
Thermo Fluid Sciences  
www.thelabbelab.com  
nicole.labbe@colorado.edu  
303-735-4821

Research at a Glance  
The Labbe Lab uses a combined experimental and theoretical approach to understand the complicated chemistry of combustion systems. With this knowledge, we are able to determine why fuels behave the way they do in engines, determine how to reduce the negative effects of combustion such as pollution, and design new fuels to make our engines run cleaner and more efficiently, often using renewable resources.

Our Expertise:  
- Gas phase reaction kinetic modeling for combustion, atmospheric, and interstellar systems  
- Rational fuel design for emerging transportation engine technologies  
- Experimental design for molecular detection of combustion and pyrolysis intermediates  
- Biofuel blendstocks for targeted combustion behavior

Some Current Projects:  
- Photoionization mass spectrometry detection of biofuel pyrolysis

Our Capabilities:  
- Photoionization mass spectrometry and IR Spectroscopy detection for reacting flows  
- Computational chemistry expertise for reaction dynamics  
- Detailed kinetic model development for gas phase reacting systems  
- Hybrid manufacturing techniques for high temperature ceramics

For more information, visit: www.thelabbelab.com
Our research covers new materials design and development, chemical synthesis, materials characterization, property measurements, fabrication of prototype devices and their evaluation, and a fundamental understanding of structure-property-performance relationships of materials. Nanostructured materials including metal oxides and metal chalcogenides are being investigated.

Solid State Li Metal Batteries

Interface Engineering for Li-ion batteries. ALD, MLD, and other vacuum depositions are being utilized.

RTIL for Advanced Li Batteries

Research at a Glance
The Electrochemical Energy Laboratory is set up to design and develop high performance materials for sustainable energy applications (mainly electrochemical systems such as batteries, supercapacitors, fuel cells, electrochromic windows, and photoelectrochemical devices).
We aim to advance the fundamental knowledge on the nonlinear mechanics of soft materials and flexible structures, and to address key engineering problems involving soft materials including large deformation, fracture, fatigue, damage, contact, adhesion, and friction.

Research at a Glance
My research interest is in the broad area of nonlinear mechanics of soft materials and flexible structures, especially problems that involve fracture, contact, adhesion, friction and multi-physics coupling. We combine experimental testing with theoretical/computational modeling, aiming towards advancing our knowledge in the complex nonlinear behaviors of soft materials and flexible structures. We are also exploring new applications of novel polymer material systems in composite manufacturing and soft robotics.
Our long-term goals are to identify novel, mechanically-sensitive therapeutic targets for treating and preventing bone metastases as well as cancer-associated reductions in bone strength.

**Mechanical Regulation of Bone Metastatic Cancer**

**Research at a Glance**
My research focuses on the role of the skeletal mechanical environment in regulating breast cancer bone metastasis. The skeleton remodels itself in response to local mechanical forces, which arise due to physical activity. We take multi-pronged approach - in vitro, in vivo, in silico - to study the impact of mechanical stimuli on: i) tumor cells directly, and ii) their signaling with resident bone cells.

**Expertise / Capabilities:** Bone biomechanics & mechanobiology; development of in vivo/in vitro/in silico mechanical loading models

---

**Breast cancer bone metastasis is highly bone-destructive**

**Increased mechanical loading may be anti-tumorigenic**

**Research Approaches**
- **In vitro** multi-modal loading bioreactor
  - Compression
- **In vivo** tibial compression
- **In silico** modeling

**Expertise / Capabilities:** Bone biomechanics & mechanobiology; development of in vivo/in vitro/in silico mechanical loading models
The Matter Assembly Computation Lab (MACLab) develops new algorithms, materials, and print methods to enable design and print on-demand of functional artefacts, from personalized surgical planning models to soft robots customized for a specific user’s needs.

The MACLab merges computational design and fabrication, with a focus on automation and fabrication scaling.

Our unique capabilities include:
- Two high-throughput, multimaterial inkjet 3D printers: Stratasys J750 (7 channels), DCS ElectroUV 3D (8 channels)
- Custom 4-channel direct-write/extrusion 3D printer capable of materials from water to ABS
- Custom volumetric (voxel) design software
- Dual-band laser cutter
- Laser scanning confocal microscope and optical stereo microscope
- Dedicated 128 node compute cluster
- Various electromechanical testbench and commercial simulation tools

Prof. MacCurdy is an expert in optimization-driven multimaterial design automation. He holds a BS in Physics, a BS in Electrical Engineering, and MS and PhD degrees in Mechanical Engineering. While much of our work involves writing design automation software, MACLab members also fabricate and test micro-fluidic devices, design and build new 3D printers, and formulate novel 3D-printable materials.
Soot is responsible for millions of deaths annually, severe degradation of air quality, and enhanced global warming, but it also has significant industrial importance. Despite its ubiquity, the chemical mechanisms by which it is formed are not understood. We focus on experimental and computational investigations to develop a fundamental understanding of soot and other carbonaceous-particle formation under a wide range of conditions.

Our work involves

- Experimental studies of the chemical composition of particles formed during combustion and pyrolysis
- Development of X-ray and laser-based diagnostics for *in situ* observations of particles in flames
- Computational studies of the chemistry of particle formation at high temperatures
- Development of laser-based diagnostics for atmospheric measurements
- Lab-based studies of heterogeneous chemistry and aging of soot
- Field measurements of atmospheric carbonaceous particles

Our work aims to develop an understanding of soot and other carbonaceous-particle formation in order to reduce their emissions, mitigate their impacts on air quality, human health, and climate change, and control their characteristics for commercial applications.
We develop and apply ensemble-based, computational modeling systems to better understand and predict the chemical composition of the earth’s atmosphere. We make extensive use of ground, aircraft, and satellite observations to improve and validate those forecasts.

Dr. Mizzi’s group uses the Weather Research and Forecasting atmospheric model with online chemistry coupled with the ensemble Kalman filter (EnKF) data assimilation system known as the Data Assimilation Research Testbed (WRF-Chem/DART). WRF-Chem/DART is used by AQ research/forecast institutions and universities through North America, Asia, and Western Europe. Their results show:

- Assimilation of surface observations with emissions adjustment improves AQ forecast skill and predictability.
- Assimilation of surface and satellite observations with emission adjustment improves nitrogen dioxide (NO$_2$) forecasts near the earth’s surface.
- Assimilation of satellite-based NO$_2$ and formaldehyde (HCHO) observations improves ozone (O$_3$) forecasts near the earth’s surface.

Improving the health and wellbeing of communities by deepening our understanding of the major sources of air pollution and reducing exposure to these pollutants through our actions, strategies, and technology.

- **Urban Air Pollution and Health Effects**
  - NEW: Disruptive events such as road construction are disproportionately impactful environmental justice communities (NSF)
  - NEW: Wildfire smoke exposure impacts healthy aging
  - Urban industrial odors negatively affect wellbeing and sources of these odors can be identified with mobile apps
  - Traffic-related air pollution increase adverse respiratory symptoms

- **Building Environmental Quality**
  - NEW: Low-cost energy efficient air sensing and cleaning for Navajo communities
  - Households with higher infiltration rates have better lung function
  - Cooking emissions quickly degrade home indoor air quality without local exhaust

- **Air Pollution Control**
  - NEW: germicidal ultraviolet light - Indoor chemistry and efficacy for disrupting disease transmission
  - Mitigating airborne infections in public buildings
  - Air cleaners reduce indoor concentrations of wildfire smoke and can mitigate bioaerosols
Flow physics, living systems, organized behavior - these themes define our mission of impacting human health using interdisciplinary tools and technologies; and educating future engineers from diverse backgrounds to tackle grand challenges in human health.

Debanjan Mukherjee
Biomedical, Thermo Fluid Sciences
www.flowphysicslab.com/
debanjan@colorado.edu
303-735-8368

Research at a Glance
As FLOWLab at CU Boulder, we engage in interdisciplinary investigations on complex flow physics and transport phenomena. We seek to unravel how flow physics influences phenomena involving living systems. Within this theme, we study flow and mechanics of physiological processes in health and disease; efficacy of treatment approaches; medical device and drug delivery; and infection transmission and control. We are also interested in fundamental advancements in computational mechanics approaches for flow physics, particulate media, and particle-laden flows.

Medical Image-based Modeling

Stroke & Cerebrovascular Flows
Thrombosis and Blood Clot Mechanics
Stroke and Cerebrovascular Flows
Vascular Flow & Transport in Large Vessels
Infectious Disease Transmission & Control
Vascular Drug Delivery
AND THE NEXT NEW PROJECT … !!

FLOWLab CURRENT RESEARCH PROGRAM

Current Research Projects

Core Skills & Expertise

Interested in working with us?
Visit our website, or email debanjan@colorado.edu
We would love to hear from you!

www.colorado.edu/mechanical/
Sustainable and economically attractive processes and devices rely on membranes.

Expertise
- membrane characterization
- transport processes for gas and liquid species
- speculative material & process synthesis

Commercial activities

Illustrative current projects
- scale-up and testing of membranes containing regular surface patterns produced with nanoscale dimensions;
- engineering research studies on the crystallization processes inherent in water recovery and reuse associated with zero-liquid-discharge;
- and creating alkaline fuel cells using glucose to power prosthetic devices.

Our lab engages with industrial partners through:
- NSF/IUCRC Membrane Science, Engineering and Technology (MAST) Center;
- Joint proposals to NSF, DOE, US Bureau of Reclamation, and DoD including GOALi, SBIR, and STTR;
- Direct contracts and Service agreements.

Research at a Glance
My research revolves around fundamental membrane development, characterization, and applications. We study how the properties of the membrane, the streams, and the choice of operating conditions control the separations and productivity results. We explore new concepts and the materials that may make them viable. Our lab improves membranes and creates new processes or devices for applications in water and the environment, energy storage and production, bioprocessing, food, and biomedical.

Unique capabilities & facilities
- gas-liquid porometry
- roll-off angle metrology
- roll-to-roll embossing and stamping
- high pressure, membrane transport metrology

Ideas
- Powering biomedical devices with the body’s glucose
Through our research in the Advanced Medical Technologies Laboratory we strive to improve the quality of life for people by reducing surgical and medical procedure invasiveness, improving physician’s capabilities, and reducing overall medical costs.

**Research at a Glance**
In striving to improve the quality of life for patients, our research focuses on fundamental understanding of key questions to enable intelligent medical devices and surgical robotics which are, in turn, setting a foundation for patient-specific medical care and ultimately leading toward an operating room of the future. These efforts include design of novel surgical tools, devices, and robotics; characterization and modeling of how these tools, devices, and robots interact with the patient; and optimization based on these models.

**Consulting**
Mark Rentschler is a professor, entrepreneur, inventor, program director, design engineer, roboticist, expert witness, and seasoned engineering consultant. He has over 15 years of leadership in mechanical and biomedical engineering consulting and intellectual property development. He is a published subject matter expert focused on medical devices, surgical robotics, mechanical design and mechatronic design and control. He has served as an expert witness in numerous patent litigation and personal injury cases.

**Entrepreneurship**
In 2018, Mark Rentschler and Steven Edmundowicz (Professor of Medicine at CU Anschutz Medical Campus) founded a CU technology spin-out, Aspero Medical, with the goal of translating their research from benchtop to bedside to complete GI endoscopy procedures the first time. As CEO of Aspero, Dr. Rentschler is leading a dynamic team through FDA approval and initial sales launch. More details at asperomedical.com.
Greg Rieker
Thermo Fluid Sciences, Air Quality
www.colorado.edu/lab/rieker
greg.rieker@colorado.edu
303-492-6802

Research at a Glance
Research in Greg Rieker’s Precision Laser Diagnostics Laboratory aims to understand and improve real-world systems through laser-based sensing. The laboratory places strong emphasis on entrepreneurship in academic pursuits, from challenging the traditional ways that research has been carried out in a particular field, to actively commercializing technologies that can have a positive impact on our future.

Activities of the Precision Laser Diagnostics Laboratory:

- Hypersonic Propulsion
- Quantum Sensor Networks
- Wildfire Dynamics
- Atmospheric Sensing
- Exotic Environment Spectroscopy
Our goal is to enable new and improved design, characterization and inspection procedures for mechanical, transportation and biological systems by studying their dynamic behavior under different environmental conditions.

Research at a Glance
Our research group specializes in structural dynamics and wave propagation. We experimentally and theoretically investigate smart solutions and materials for wave guiding and manipulation, acoustic absorption, transducer design, vibration isolation and noise reduction. Examples include aircraft components, magnetostrictive materials and periodic metastructures. We also apply dynamic methods for the inspection and characterization of mechanical systems and biological tissues such as bonded composite joints and the human skull.

Massimo Ruzzene
Mechanics of Materials
www.colorado.edu/faculty/ruzzene
massimo.ru zzene@colorado.edu
303-735-0424

Aero-Adaptive wings

Guided waves in the human skull

Composite and magnetostrictive materials

Physics of non-Hermitian active media

Dynamics of quasi-periodic media

Vibro-Tactile communication in collaborative micro-bots
I create artificial limbs that blur the lines between human and machine by plugging into the nervous system.

Research at a Glance
My research mission is to enable the embodiment of artificial devices by providing physiologically appropriate somatosensory feedback. Using neural interfaces, biomechatronic devices, and machine learning, I plan to blur the lines between human and machine by eliciting perceptions of our natural body using the artificial devices.

Current Research
- Investigation of Embodiment of Prosthetic Hands (VA RR&D, 5 years)
- Semi-Autonomous Control of Prosthetic hands (NIH STTR, 1 year)
- Development of Surgical Tooling for Hip Arthroscopy (CO OEDIT, 1 year)

Entrepreneurial Ventures
- 8 patents and applications all licensed to partnering startup companies
- Founder and CTO, MITA LLC acquired by Stryker in 2017 (link here)
- Founder, Point Designs LLC, a provider ratcheting prosthetic fingers
We develop biomaterials, in particular micro/nano-biomaterials, and leverage the biomaterials technologies to innovate medical devices and 3D biomanufacturing processes, with an ultimate goal to transform cardiovascular treatment.
We employ engineering tools perform experimental research on aerosol physical properties in the laboratory and in the field to minimize human and environmental exposure.

Our Expertise:
- Studies on the formation, transport, and fate of aerosols, ranging from single-nanometer to tens of micrometers in size.
- Evaluation and use of low-cost sensors for air pollution measurements indoors and outdoors.
- Assessment and minimization of people's exposure to environmental contaminants.
- Ambient and source aerosol sampling and characterization.
- Understanding the release of nanomaterials or aerosols from consumer products.

Our capabilities:
- Experimental measurements of aerosols in controlled chambers, in real indoor environments, and outdoors using real-time and offline instrumentation.
- 38 m² aerosol test room chamber for emissions testing.
- Expertise in modeling of indoors aerosol emissions and inhalation exposure.

For more information, visit: www.colorado.edu/lab/vance
Our aim is to fundamentally understand the link between molecular interactions and the mechanical behavior of biological and bioinspired materials, including deformation, flow, fracture, self-healing, growth, and morphing.

We are an interdisciplinary team working across the fields of mechanics, physics, biology, and materials science to elucidate the complex behavior of soft materials. We develop arrays of multiscale theoretical and computational approaches to link the structure-property relationship of bio and bio-inspired polymers, with applications in bioengineering, cell mechanics and active solids. Our current work ranges from fundamental to applied research with focus on:

1. Mechanics, adhesion, and fracture of polymers with dynamic bonds.
Nathalie Vriend
Thermo-Fluids, Mechanics of Materials
https://www.colorado.edu/mechanical/nathalie-m-vriend
nathalie.vriend@colorado.edu
720-431-1662

Research at a Glance
Our research involves detailed laboratory experiments and targeted field work involving particulate flows such as sand and snow, complemented with numerical simulations and theoretical modelling.

I have active projects in granular rheology and avalanching, and dune structure and migration. In the past, I worked on the dynamics of real snow avalanches, singing sand dunes, silo honking and seismic wave propagation.

Our aim is measure, characterize and model granular flows to mitigate natural hazards of geophysical mass flows and reduce economic losses in industrial processes.

1. Photoelastic avalanches: rheology of granular flows

In my laboratory, we obtained high-quality dynamic measurements of both velocity and stress fields in fast avalanches using photoelasticity. This approach is original and novel: we are the first in the world to experimentally probe the stress state in fast, dynamic processes. This was feasible due to two novel developments: (a) we fabricate bespoke, superior-quality birefringent photoelastic particles and (b) we conduct experiments at a high frame-rate (up to 10,000 fps) and analyse the data with a non-equilibrium force algorithm.

2. Sand dunes in a 1D annulus: dune interaction & migration

Our experiment is the first of its kind and generates enticing novel empirical data, allowing mathematical analysis at the cutting-edge of our field. Our approach is novel: by using a recirculating geometry we avoid sand supply problems encountered in linear flumes and we can perform experiments for long periods.
Our mission is to advance understanding of the human sensorimotor control system and human-device interaction in order to effectively develop devices that assist those with movement impairments or augment everyday movement to reduce fatigue or injury.

Expertise:
- Biomechanics
- Haptic device design
- Biomimetic device control and biofeedback
- Human subject experiments
- Musculoskeletal modeling

Projects:
- A novel haptic device to provide feedback from a robotic prosthesis
- Enabling volitional control of assistive devices to gain insight into the human cost function during walking
- Optimizing control parameters for robotic prostheses
- Characterizing human perception during different types of motion
Using additive manufacturing techniques, we can engineer unconventional electronic systems able to address a wide range of important issues in areas including agriculture, energy generation, robotics, assistive technologies, and off-planet manufacturing.
We develop tools to predict the emissions of air pollutants and to examine their impacts on air quality, climate and health so that we can develop the best mitigation strategies to improve air quality, understand climate change processes, and benefit public health.

Our Activities Include:

- Development of air pollutant emissions inventories for input to air quality and climate models.
  - Global open waste burning emissions: [http://bai.acom.ucar.edu/Data/fire/](http://bai.acom.ucar.edu/Data/fire/)
  - DICE-AFRICA

- Estimating air pollutant emissions from open burning, at local, regional and global scales.
  - FINN

- Examine air quality impacts from wildfires

- Assess the impacts of open burning for residential heating and cooking
  - REACTING
Flexible wearable devices can help solve some of the biggest healthcare problems, including self-health monitoring and preventive medicine, and thus can greatly improve patient care and experience. The self-healing and recycling capabilities ensure long-term reliability and minimal environmental impact.

- Superior flexibility and stretchability for wide applicability
- Multifunctional and integrated devices
- Self-healing, recycling and reconfiguration
- Design and mechanical optimization

Research at a Glance
Our research focuses on bridging hard and soft materials, to foster new devices, systems and technologies. Specifically, we are interested in:

- Design and fabrication of stretchable/flexible electronics and optoelectronics; Integration of hard and soft materials to create smart soft machines; Bio-integrated and bio-inspired devices; Mechanics of thin films on compliant substrates; Mechanics of nanomaterials.
Our mission is to develop and deploy bioinspired aquatic robots to monitor the ocean and track climate change. By combining features from both natural and engineered designs, we aim to create more energy-efficient, maneuverable, and robust robots to aid in environmental stewardship.

Areas of Expertise
- Bioinspired and biohybrid swimming robots and underwater vehicles
- Experimental fluid dynamics
- Theoretical and physical modeling
- Field work in coastal and ocean environments

Research at a Glance
The Xu Lab is an interdisciplinary research group at the intersection of robotics, fluid dynamics, and biology. Our goal is to design and implement swimming robots in real-world environments for applications such as ocean conservation and observing natural phenomena. To do this, we apply principles from nature, which have been honed over millions of years of evolutionary pressure, onto engineered systems to create bioinspired aquatic robots and underwater vehicles.

Research Projects
- **Expanding tools to explore different areas of the ocean**
  Biohybrid robotic jellyfish for ocean monitoring
- **Improving persistence and maneuverability in underwater vehicles using bioinspired features**
  Shark-inspired surfaces for turbulent drag reduction
  Robotic fish fins for thrust production in near-shore applications