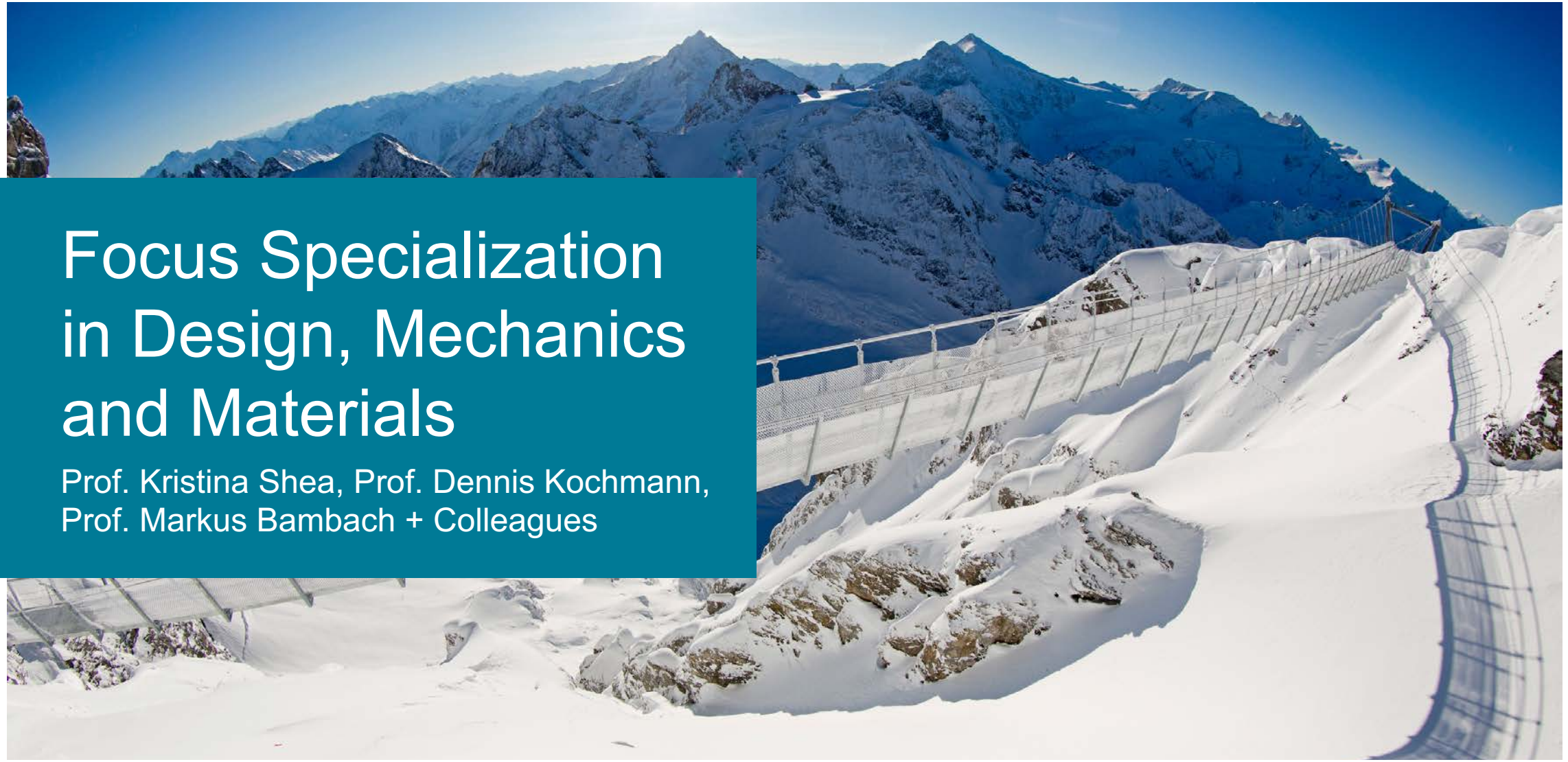
ETH zürich

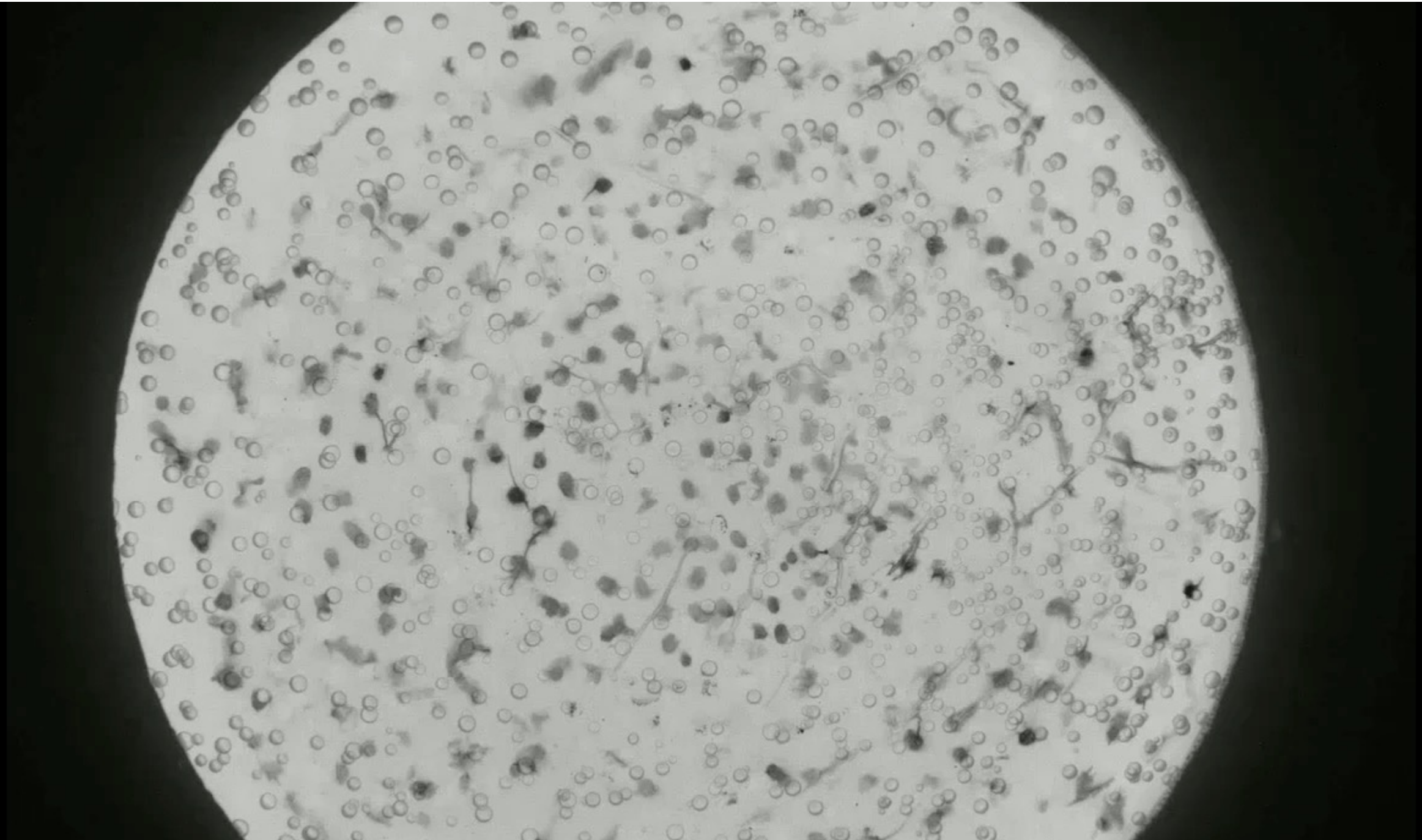


Focus Specialization in Design, Mechanics and Materials

Prof. Kristina Shea, Prof. Dennis Kochmann,
Prof. Markus Bambach + Colleagues

Outline

- **Introduction and Motivation**
- Lectures
- Bachelor Theses and Research
- Beyond Your Bachelor Degree



Diverse Industry Domains: Beyond the Traditional!

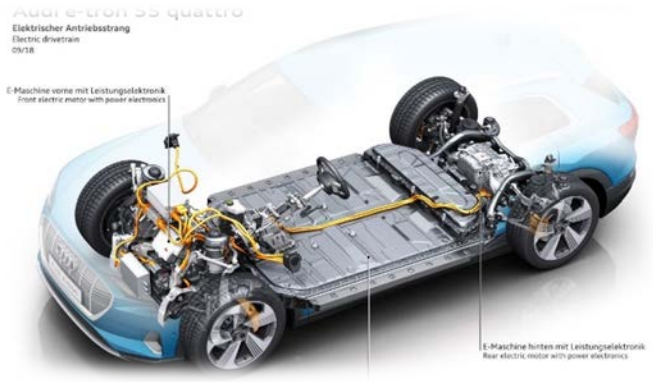


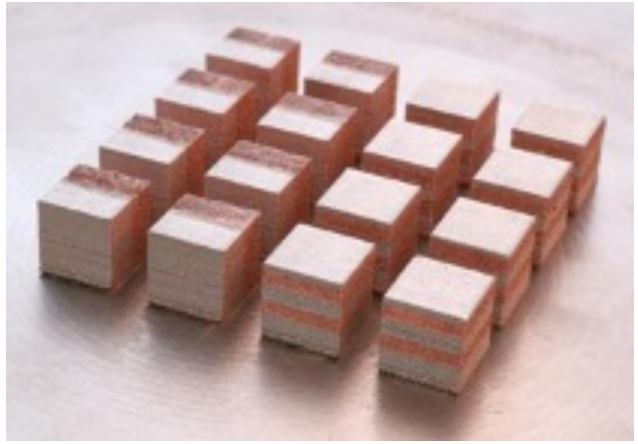
Image credit: Audi

Image credit: robotics & automation news

Renewable Energies

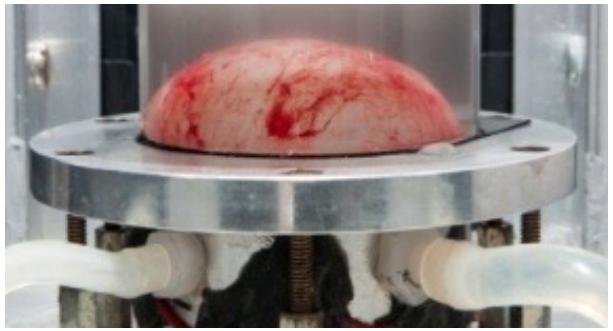
Robotics

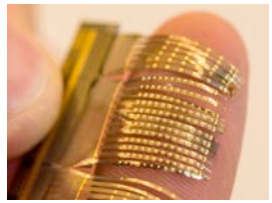
Healthcare



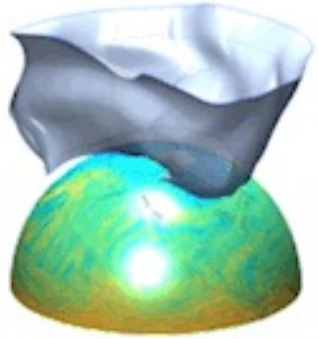
Advanced Manufacturing

Interdisciplinary + Addresses Grand Challenges





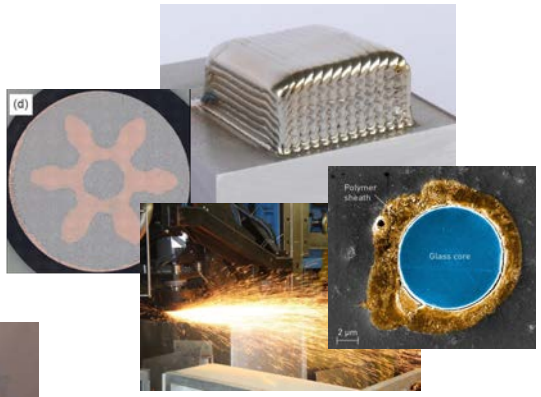
Ensuring healthy lives



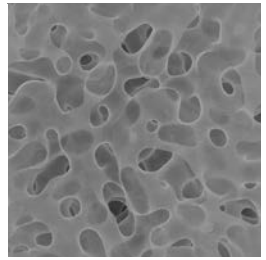
Understanding global transport processes

Addressing sustainable development

Environmental sensing for the future



Reinventing manufacturing



Developing sustainable materials

Mechanical Systems are Highly Interdisciplinary

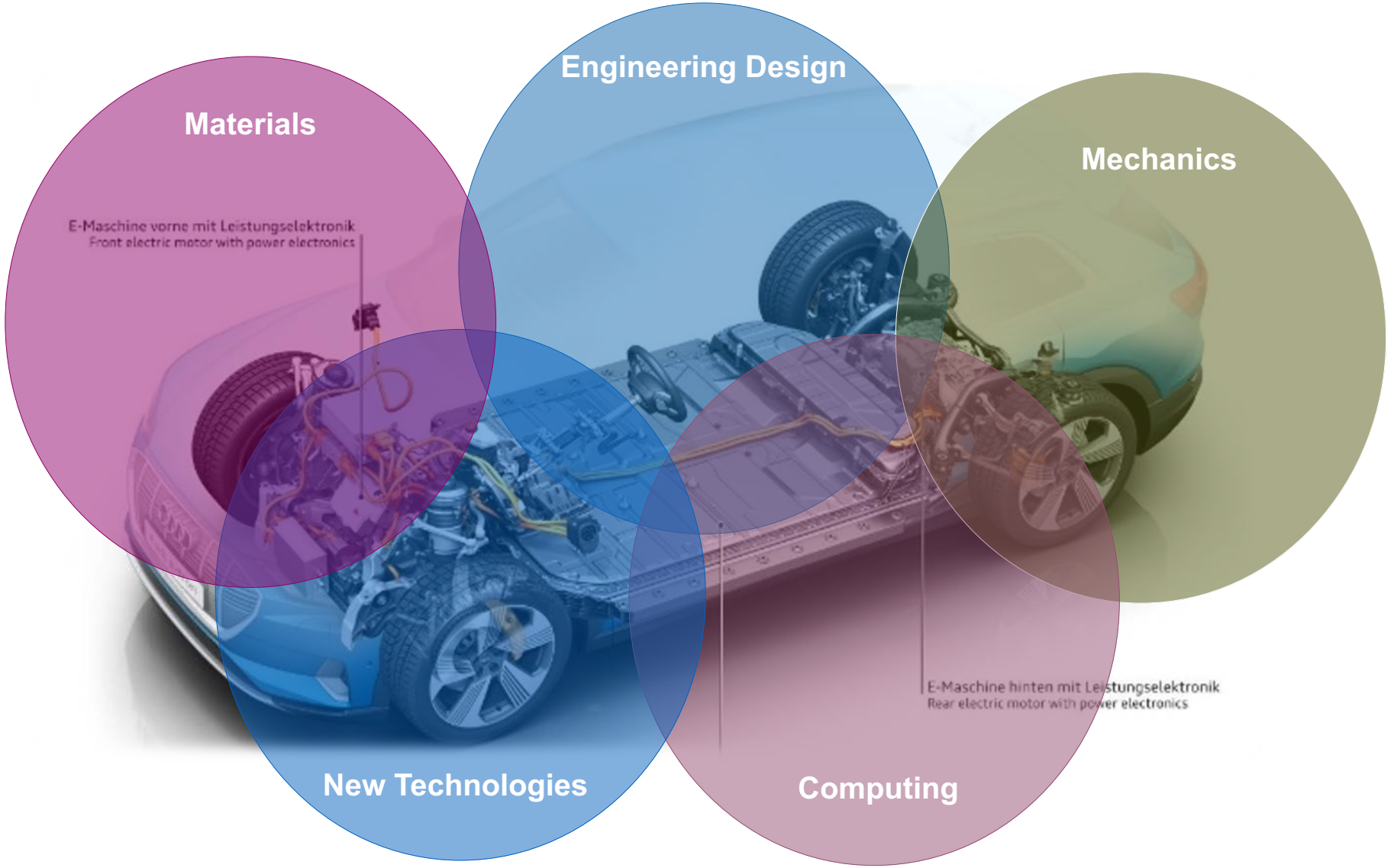


Image credit: Audi

Mechanical Systems: Design, Mechanics and Materials

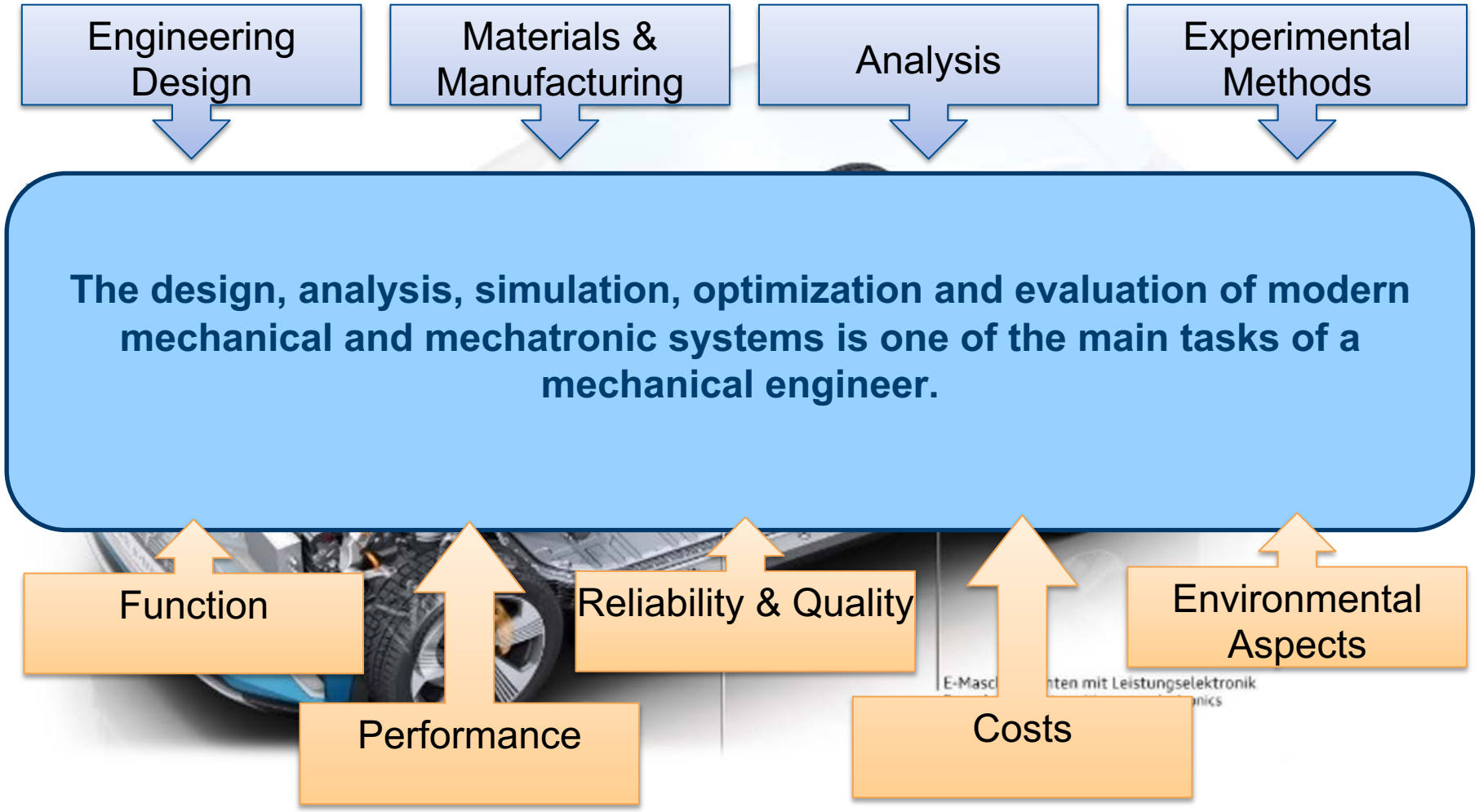


Image credit: Audi

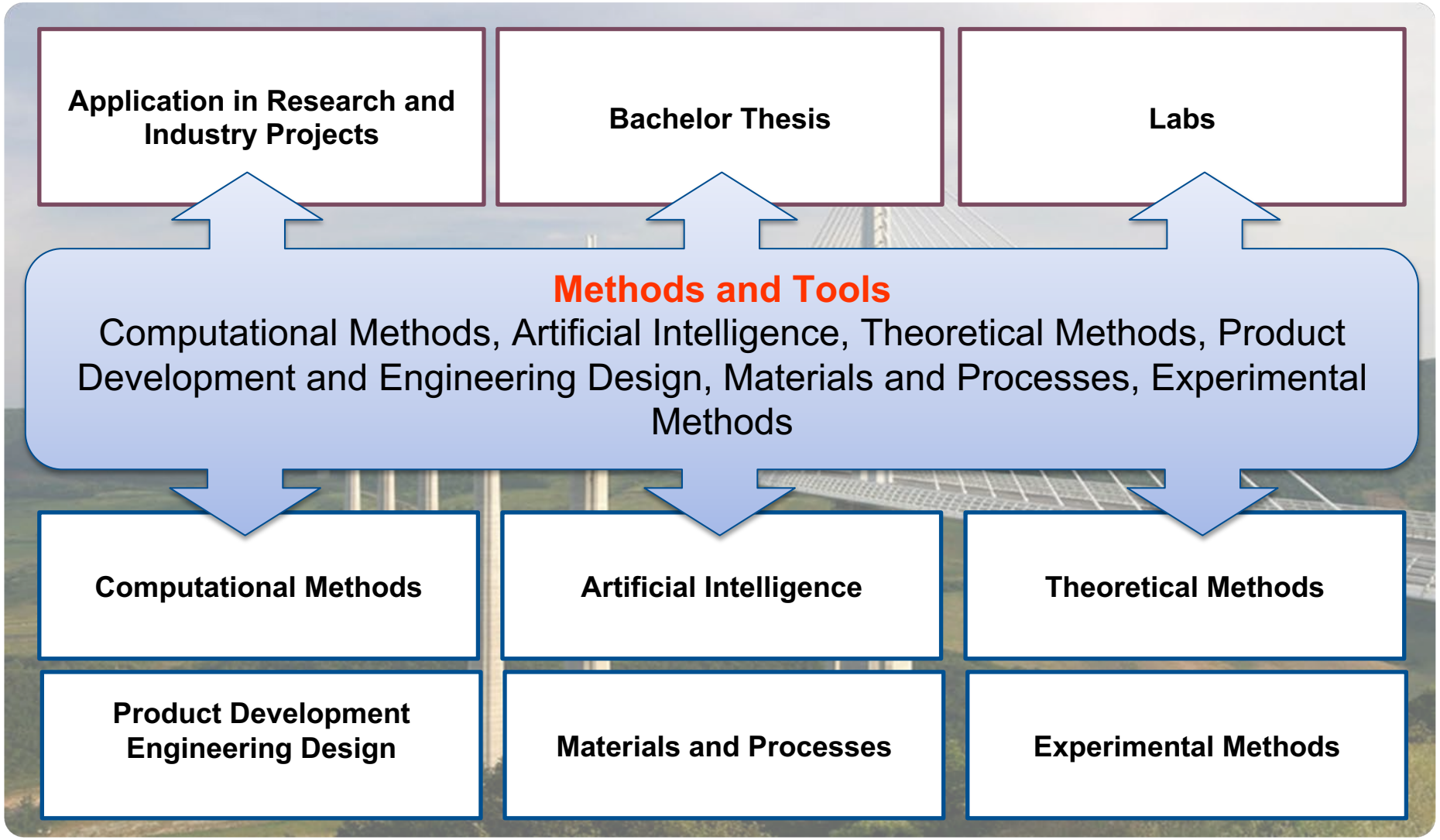
The Team

- K. Shea (Design), D. Kochmann (Mechanics), M. Bambach (Materials), D. Ahmed, P. Ermanni, A. Kunz, L. De Lorenzis, E. Mazza, M. Meboldt, D. Mohr, E. Tilley, P. Tiso

Outline

- Introduction and Motivation
- **Lectures**
- Bachelor Theses and Research
- Beyond Your Bachelor Degree

Bachelor Focus



Lecture Overview: You select five lectures freely (plus optionally one “wildcard” lecture) Courses in Fall Semester

Number	Title	Type	ECTS	Lecturers
	Engineering Design			
151-3209-00L	Engineering Design Optimization	W	4	K. Shea, T. Stankovic
151-3213-00L	Integrative Ski Building Workshop	W	4	K. Shea
151-3204-00L	Coaching Innovation Projects	W	2	I. Goller
	Mechanics			
151-0364-00L	Lightweight Structures Laboratory	W	4	M. Zogg, P. Ermanni
151-3207-00L	Lightweight	W	4	P. Ermanni
151-0509-00L	Acoustics in Fluid Media: From Robotics to Additive Manufacturing	W	4	D. Ahmed
151-0524-00L	Continuum Mechanics I	W	4	A. E. Ehret
151-0544-00L	Metal Additive Manufacturing - Mechanical Integrity and Numerical Analysis	W	4	E. Hosseini
151-0833-00L	Applied Finite Element Analysis	W	4	B. Berisha
	Materials			
327-1204-00L	Materials at Work I	W	4	R. Spolenak, R. Koopmans
151-0741-00L	Sustainable Materials	W	4	L. Deillon

Lecture Overview: You select five lectures freely (plus optionally one “wildcard” lecture)
Courses in Spring Semester

Number	Title	Type	ECTS	Lecturers
	Engineering Design			
151-3202-00L	Product Development and Engineering Design	W	4	K. Shea, T. Stankovic, E. Tilley
151-0306-00L	Visualization, Simulation and Interaction - Virtual Reality I	W	4	A. Kunz
151-0332-00L	Interdisciplinary Product Development: Definition, Realisation and Validation of Product Concepts	W	4	M. Schütz
151-0522-00L	Case Studies in Computer Aided Engineering - Applied FEM	W	4	D. Valtorta
151-0840-00L	Optimization and Machine Learning	W	4	B. Berisha, D. Mohr
	Mechanics			
151-0515-00L	Continuum Mechanics 2	W	4	E. Mazza, R. Hopf
151-0518-00L	Introduction to Finite Element Analysis	W	4	D. Kochmann
151-0540-00L	Experimental Mechanics	W	4	P. Carrara
151-0552-00L	Fracture Mechanics	W	4	L. De Lorenzis
151-0534-00L	Advanced Dynamics	W	4	P. Tiso
	Materials			
151-0324-00L	Engineering Design with Polymers and Polymer Composites	W	4	G. P. Terrasi
327-3002-00L	Materials for Mechanical Engineers	W	4	R. Spolenak, A. R. Studart, R. Style
151-0740-00L	Metal Additive Manufacturing – Fundamentals and Process Technology	W	4	M. Bambach, L. Deillon, M. R. Tucker

Outline

- Introduction and Motivation
- Lectures
- **Bachelor Theses and Research**
- Beyond Your Bachelor Degree

Please see the websites of each professor for current available student projects and theses!

- **Design:** Prof. Kristina Shea, Engineering Design and Computing Laboratory https://edac.ethz.ch/
- **Mechanics:** Prof. Dennis Kochmann, Mechanics and Materials Laboratory https://mm.ethz.ch/
- **Materials:** Prof. Markus Bambach, Advanced Manufacturing Lab https://www-advanced-anufacturing.ethz.ch
- Prof. Paolo Ermanni, Laboratory of Composite Materials and Adaptive Structures https://structures.ethz.ch/
- Prof. Andreas Kunz, Innovation Center Virtual Reality, https://www.icvr.ethz.ch/index_EN
- Prof. Laura De Lorenzis, Computational Mechanics Group https://compmech.ethz.ch/
- Prof. Eduoardo Mazza, Experimental Continuum Mechanics https://ecm.ethz.ch/
- Prof. Mirko Meboldt, pd|z Product Development Group Zurich https://pdz.ethz.ch/
- Prof. Dirk Mohr, Computational Modelling of Materials in Manufacturing https://mohr.ethz.ch/
- Prof. Elizabeth Tilley, Global Health Engineering https://ghe.ethz.ch
- Dr. Paolo Tiso, Nonlinear Dynamical Systems Group http://www.georgehaller.com/
- Prof. Daniel Ahmed, Acoustic Robotics Systems Lab https://arsl.ethz.ch/

Engineering Design

For the Product Development and Engineering Design course of the 2022 spring semester, students were asked to design, develop, and prototype an accessible latrine pump for a low- resource setting.

Integrative Ski Design and Fabrication Workshop

Design – CAD – Mechanics – Sustainable Materials – Testing

Prof. Elizabeth Tilley

Global Health Engineering: *understanding the social, economic, and technical reasons for poor environmental and human health*

We work with small businesses, NGOs, government and openly available data to test, design and optimize technologies and systems related to:

Human Excreta

Air Quality

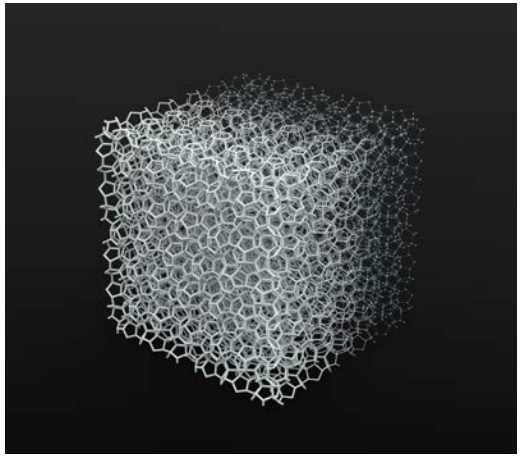
Solid Waste

Organic Waste

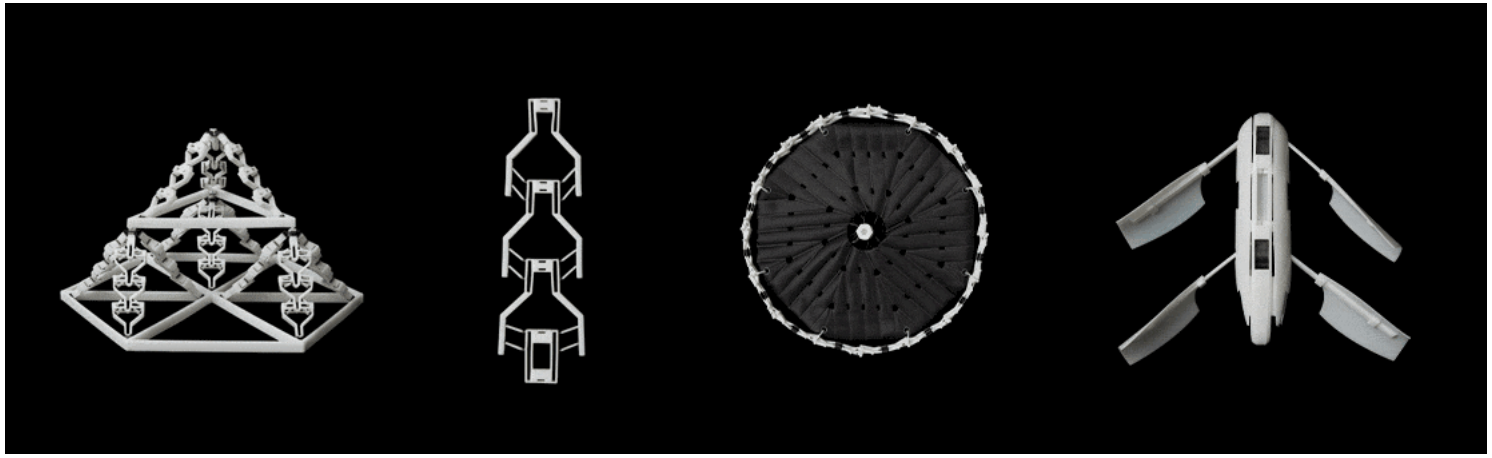
Prof. Kristina Shea, Engineering Design and Computing Laboratory

We combine engineering design, computation and fabrication to design and prototype creative engineering systems with new functionalities that help to achieve sustainable development goals. We are both curiosity and impact driven.

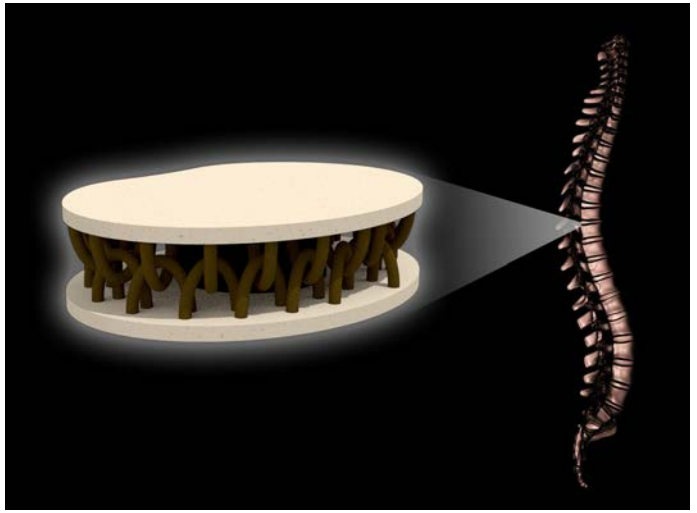
Computational Design of Structures and Metamaterials



Designing Novel Machines with 4D Printing

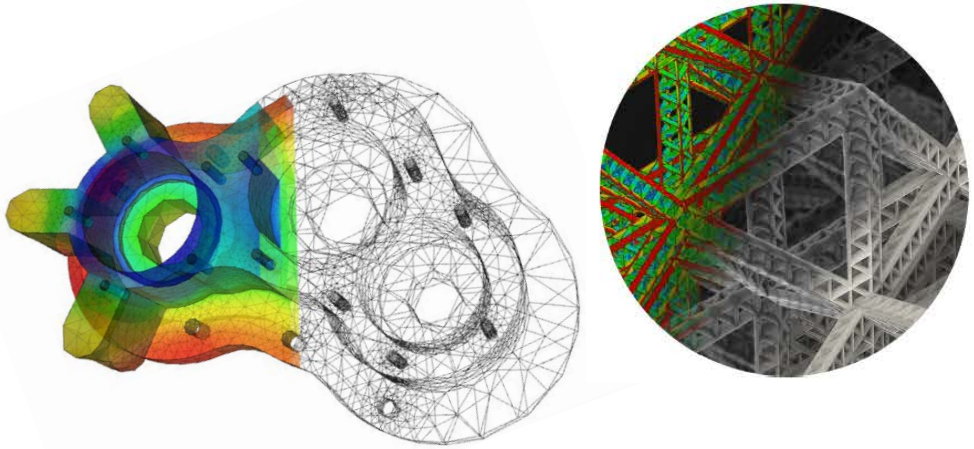


Design for Additive Manufacture and 3D Printed Material Characterization

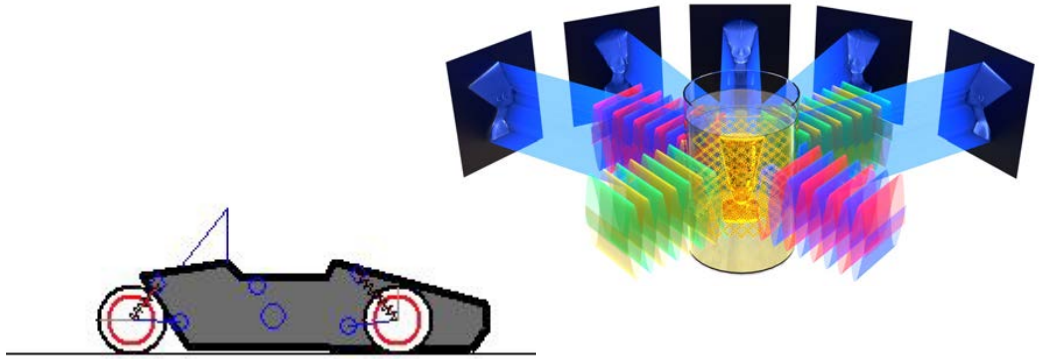


Development Engineering: Low-Cost Ventilator

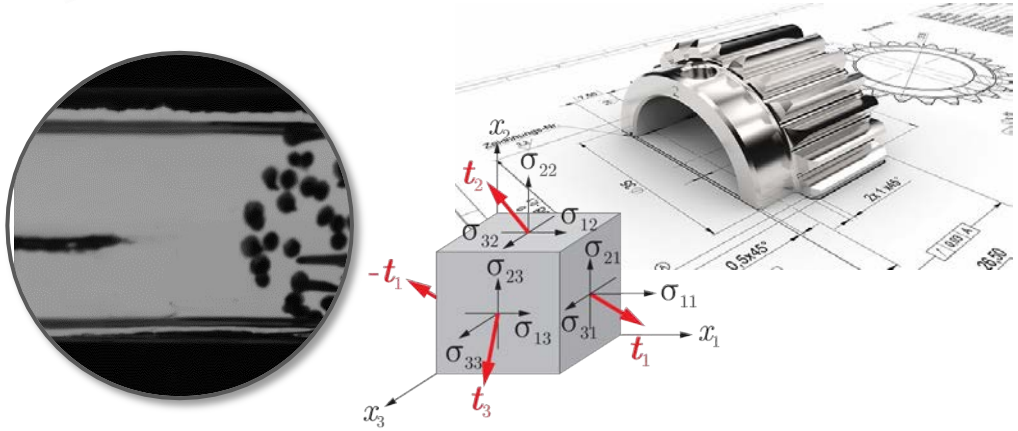
Mechanics



Computational Modelling



Dynamical Systems & Acoustics

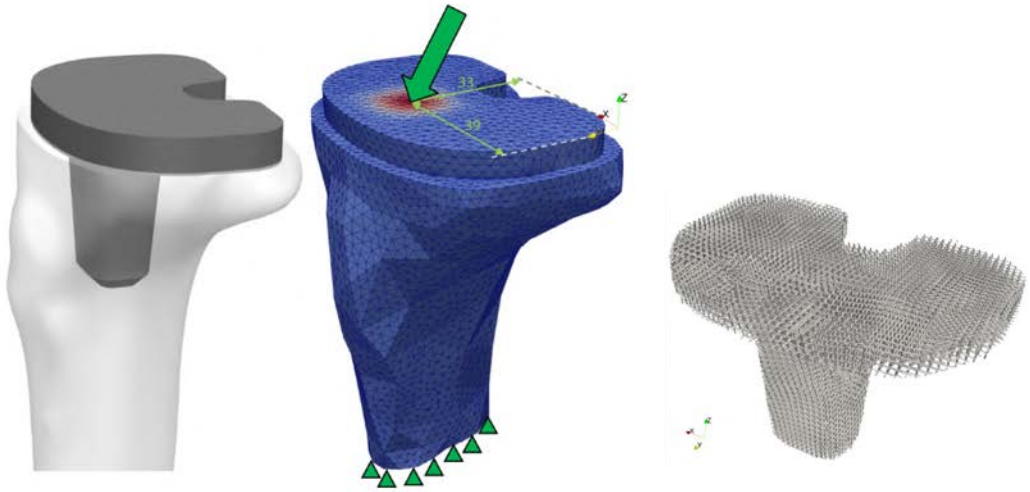


Theory, Material Modelling & Dimensioning

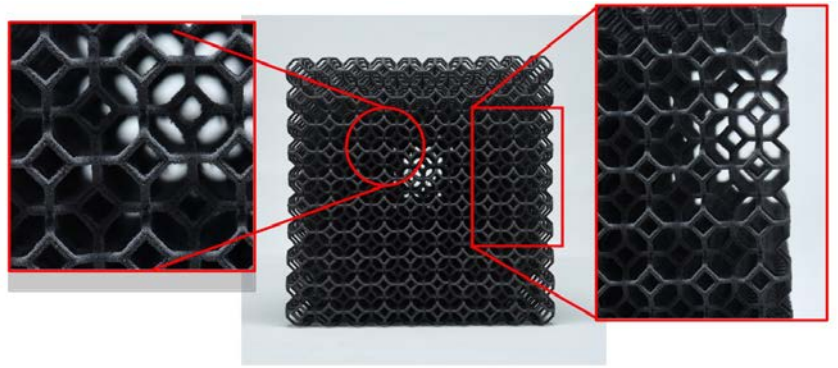
Experimental Techniques

Prof. Dennis Kochmann
Mechanics & Materials Laboratory

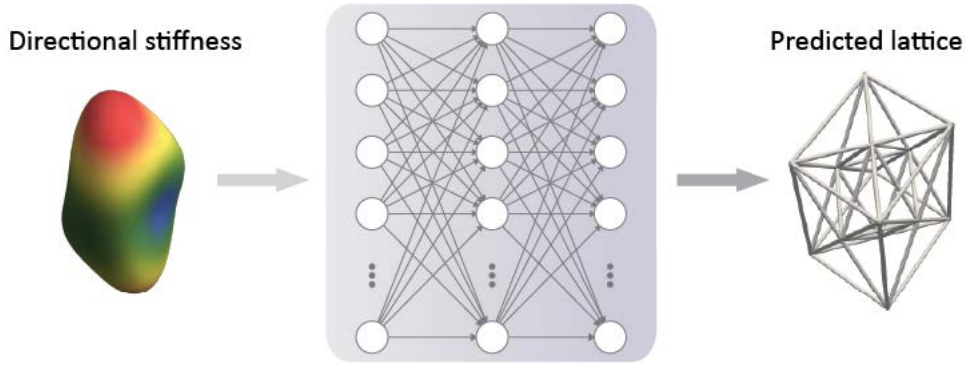
Mechanics & Materials Laboratory
www.mm.ethz.ch



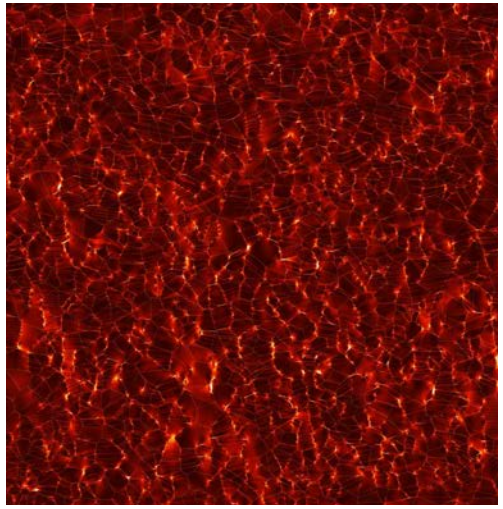
Architected materials for bionic implants



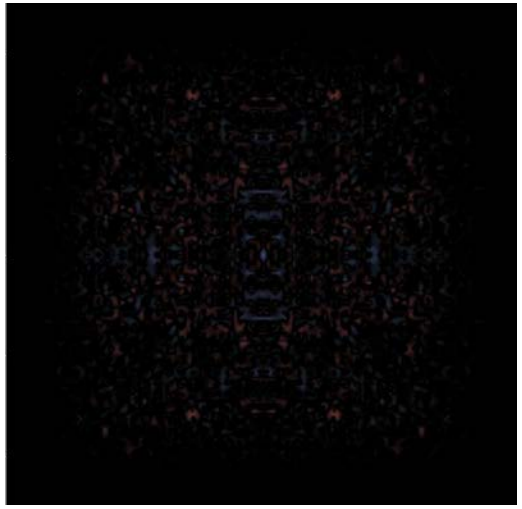
3D-printing and imperfections



Inverse design by machine learning

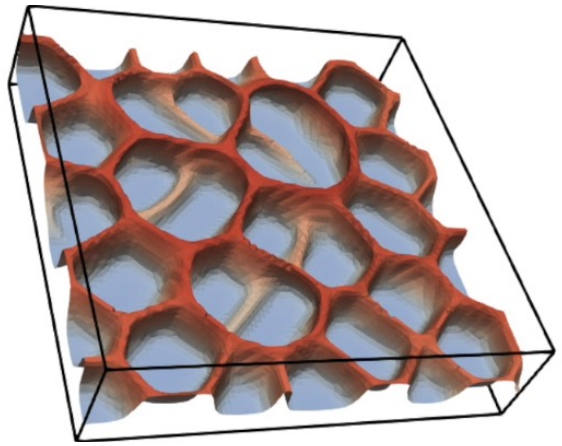


Material modeling

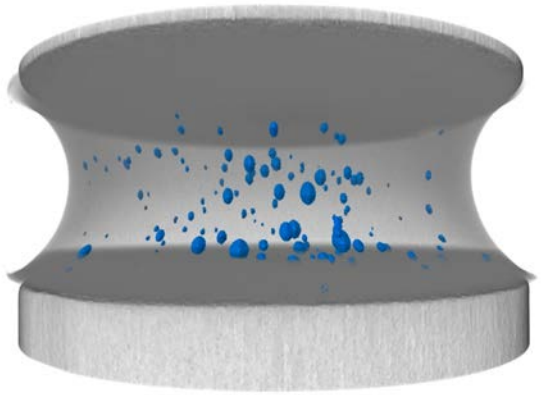


Wave motion

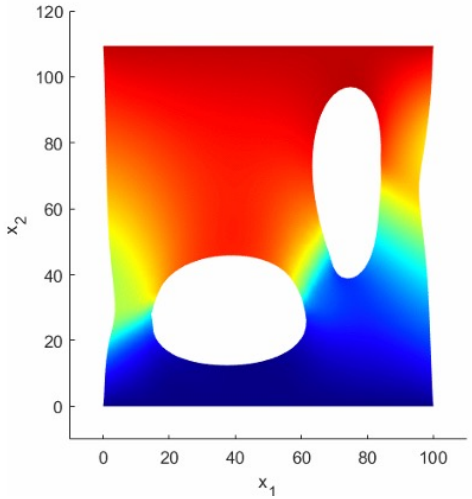
Prof. Laura De Lorenzis
Computational Mechanics Group

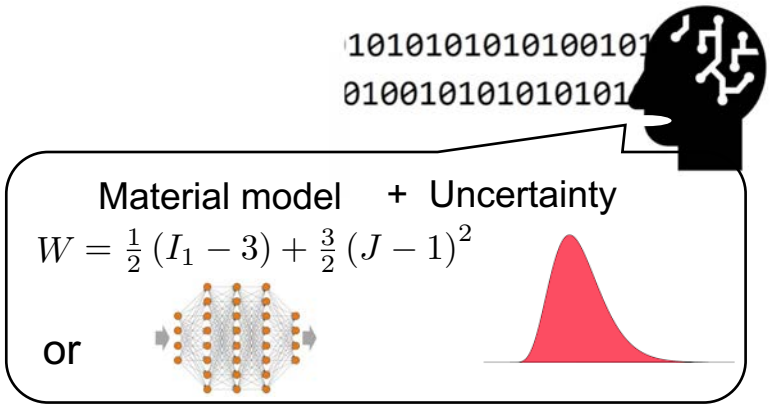


Experimental investigations on different types of fracture phenomena

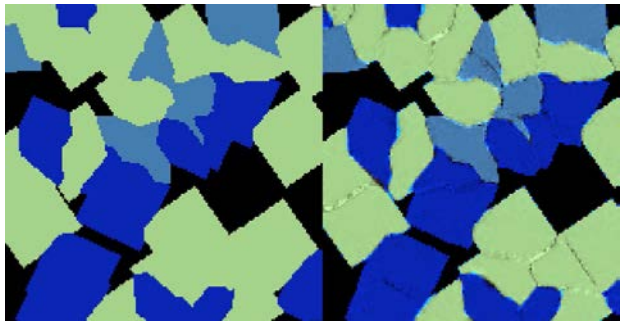


X-ray tomography + in-situ testing and Digital Volume Correlation for cavitation and fracture phenomena or for 3D full-field data collection on different material behaviors





Efficient Unsupervised Constitutive Law Identification and Discovery (EUCLID)



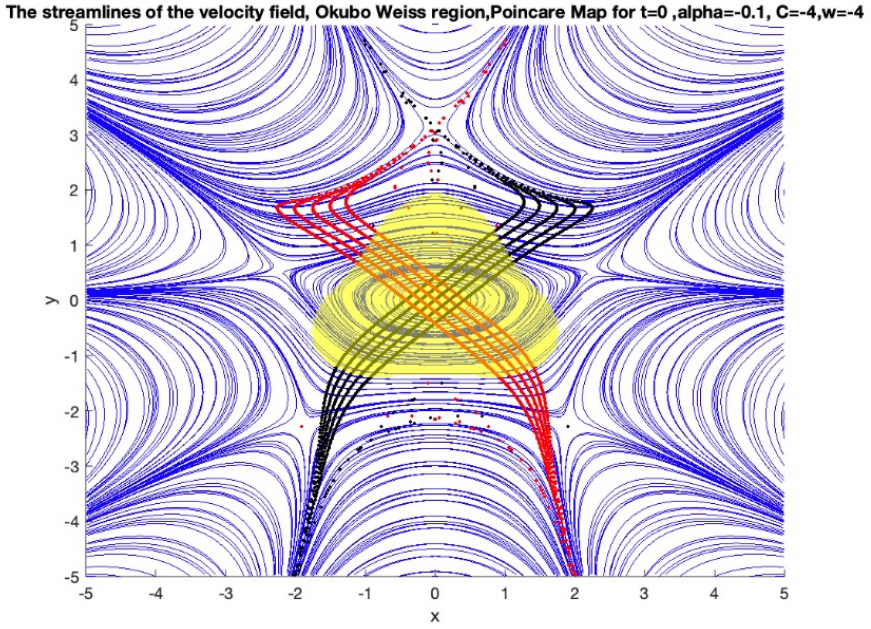
Neural Cellular Automata,
Physics Informed Neural Networks

Dr. Paolo Tiso
Nonlinear Dynamical Systems Group

Explicit Navier-Stokes solutions and their analysis via local vortex criteria and tools from dynamical systems

A quartic polynomial solution to the Navier-Stokes equation has the following form [1]:

$$\mathbf{u}(\mathbf{x},t) = \begin{pmatrix} \sin(4t) & \cos(4t)+2 \\ \cos(4t)-2 & -\sin(4t) \end{pmatrix} \mathbf{x} + \alpha(t) \begin{pmatrix} x^4 - 6x^2y^2 + y^4 \\ -4x^3y + 4xy^3 \end{pmatrix}$$



The intersecting stable and unstable manifolds of the fixed point of the Poincaré map show a very complex particle motion in stark contrast to the vortical motion suggested by both the instantaneous streamlines and the Okubo-Weiss criterion [1].

[1] *L. Hillegaart. Analysis of nonlinear dynamical systems applied on explicit polynomial solutions to the unsteady planar Navier-Stokes equation (BSc Thesis), 2020*

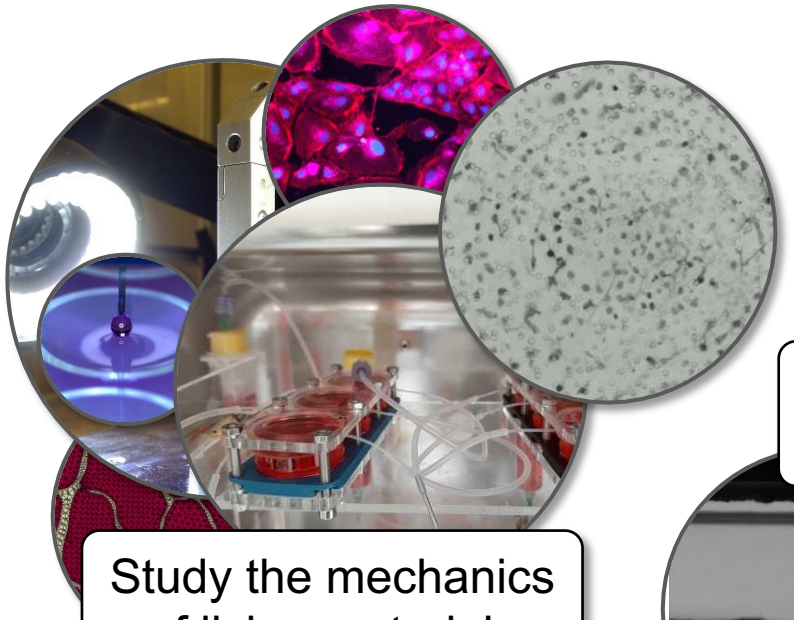
Prof. Edoardo Mazza
Experimental Continuum Mechanics

ECM | Experimental Continuum Mechanics

The ECM group …

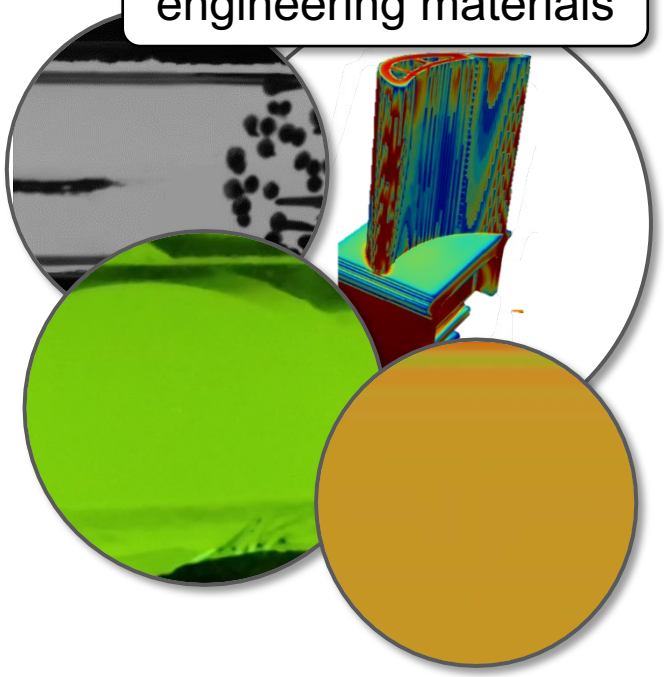
- investigates the **mechanics of biological and biomedical materials**, including implants, prostheses or scaffolds for tissue engineering.
- uses **advanced experimental and computational methods** to understand these material systems from sub-cellular to organ level.
- designs experiments and develops models to **analyze the mechanical integrity of engineering materials**.

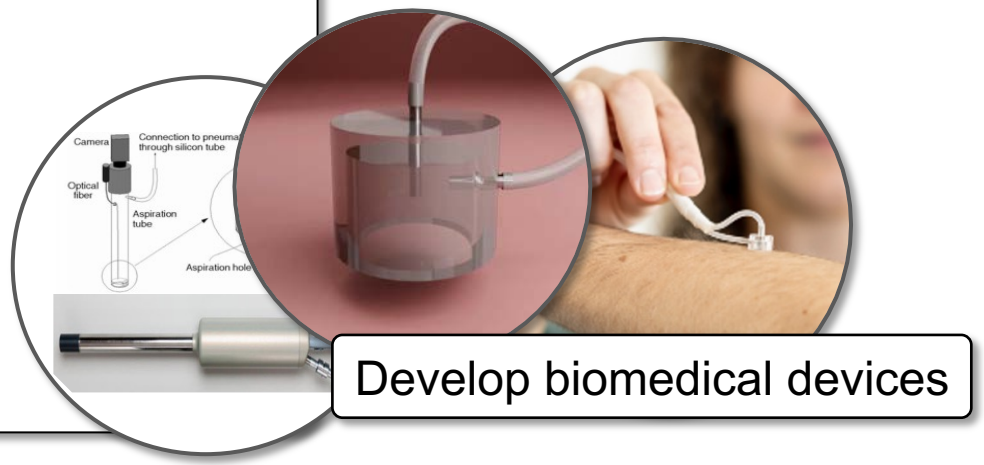
- offers **Bachelor projects** on



Study the mechanics of living materials

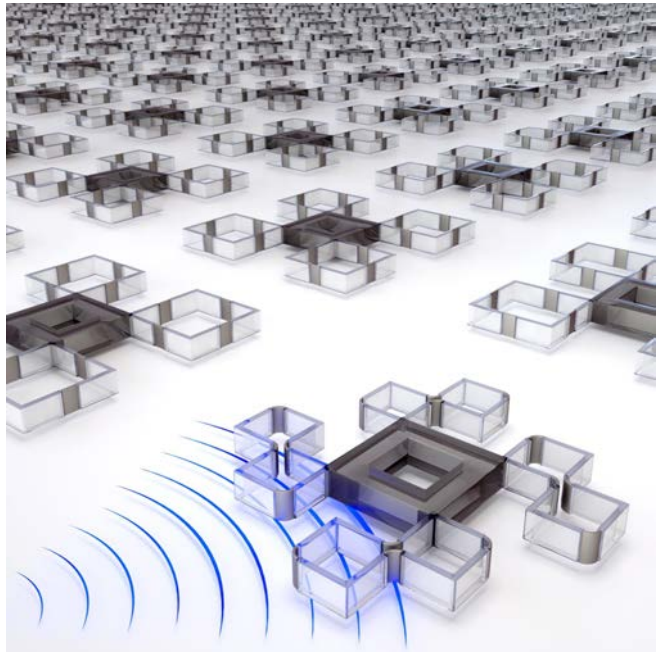
Analyze modern engineering materials

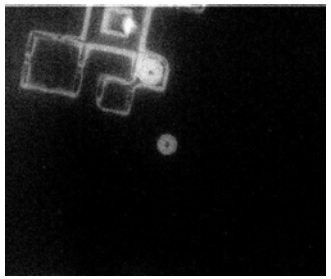


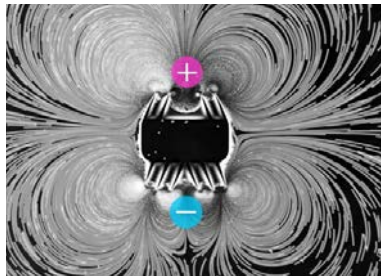


Develop biomedical devices

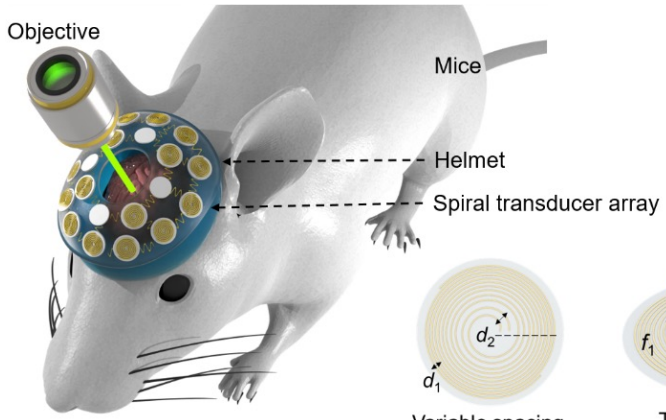
Prof. Daniel Ahmed
Acoustic Robotics Systems Lab

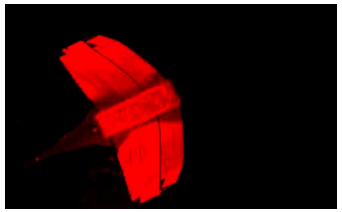




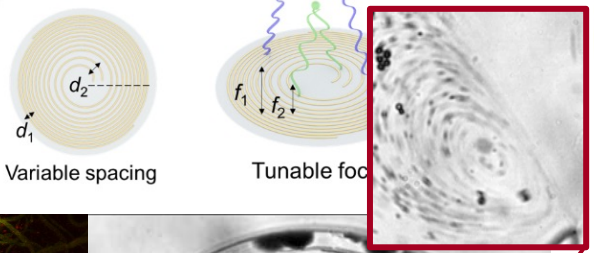


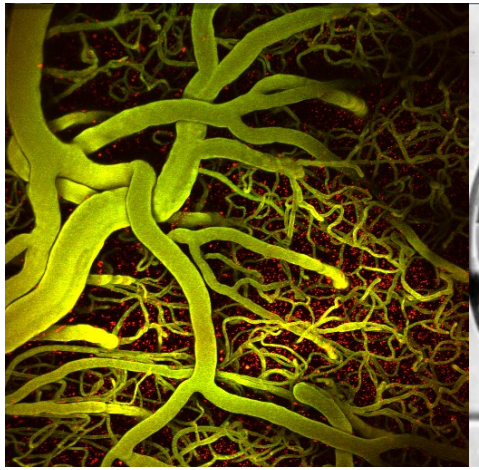
Fundamental of Acoustic µbots

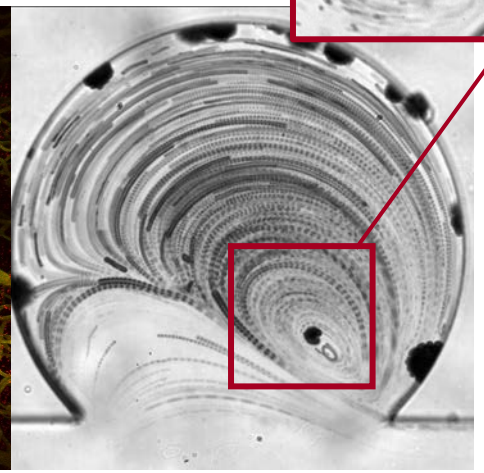




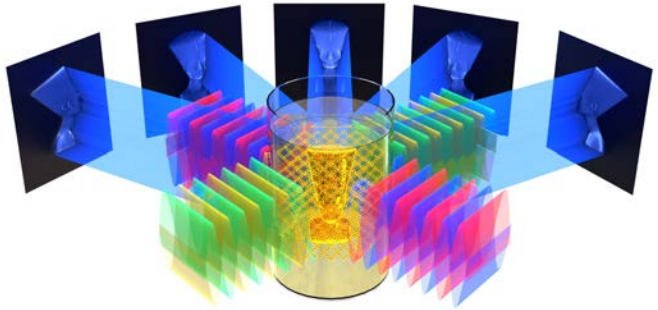
Acoustic actuator

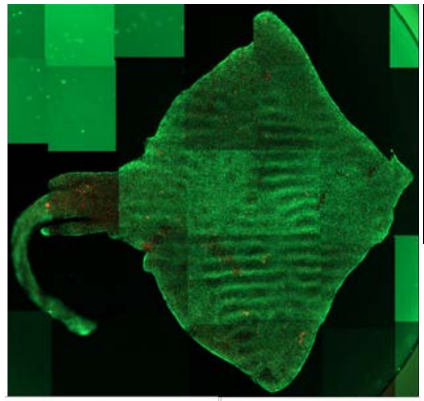


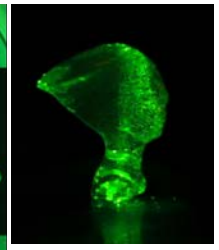




Translational Microrobots and Implants for Brain





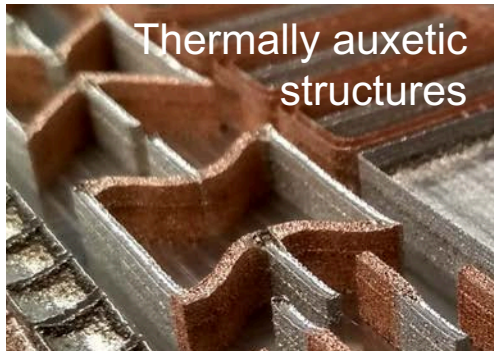


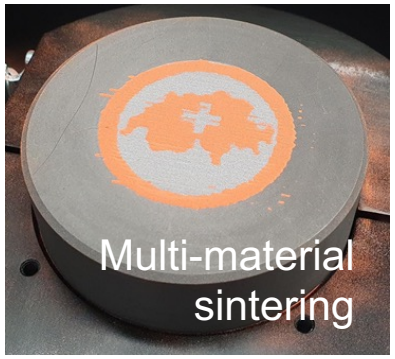
Sound-assisted Printers for Composites, Cardiac Constructs, etc.

Advanced Manufacturing

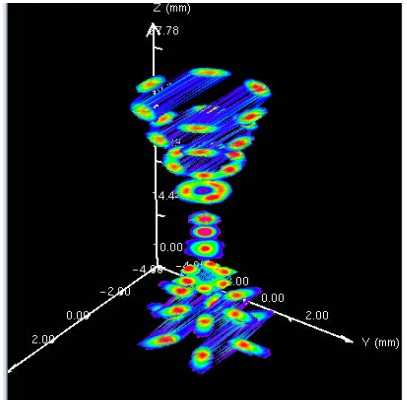
Professor Markus Bambach

Additive manufacturing



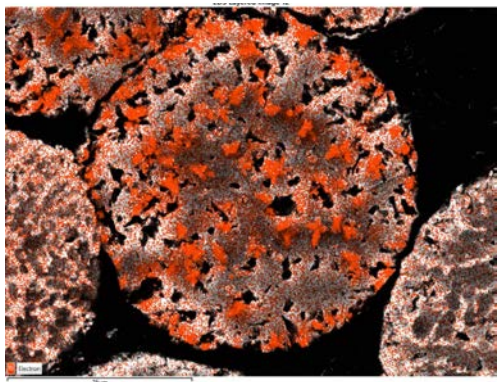


Laser materials processing

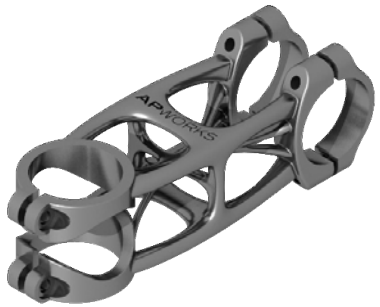


Directed energy deposition head with six individually adjustable diode lasers for beam shaping

Materials design / sustainable materials



New rare-earth metal free high-strength Al-alloys for AM

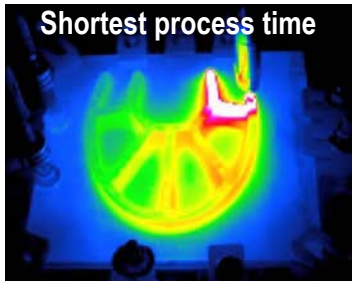


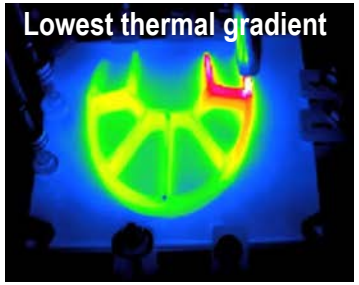
Lightweight design & structural performance

Computational and data-driven manufacturing

Adaptive SPH code (simulation of LPBF)

Data-driven printing sequence planning for minimization of temperature gradients





Outline

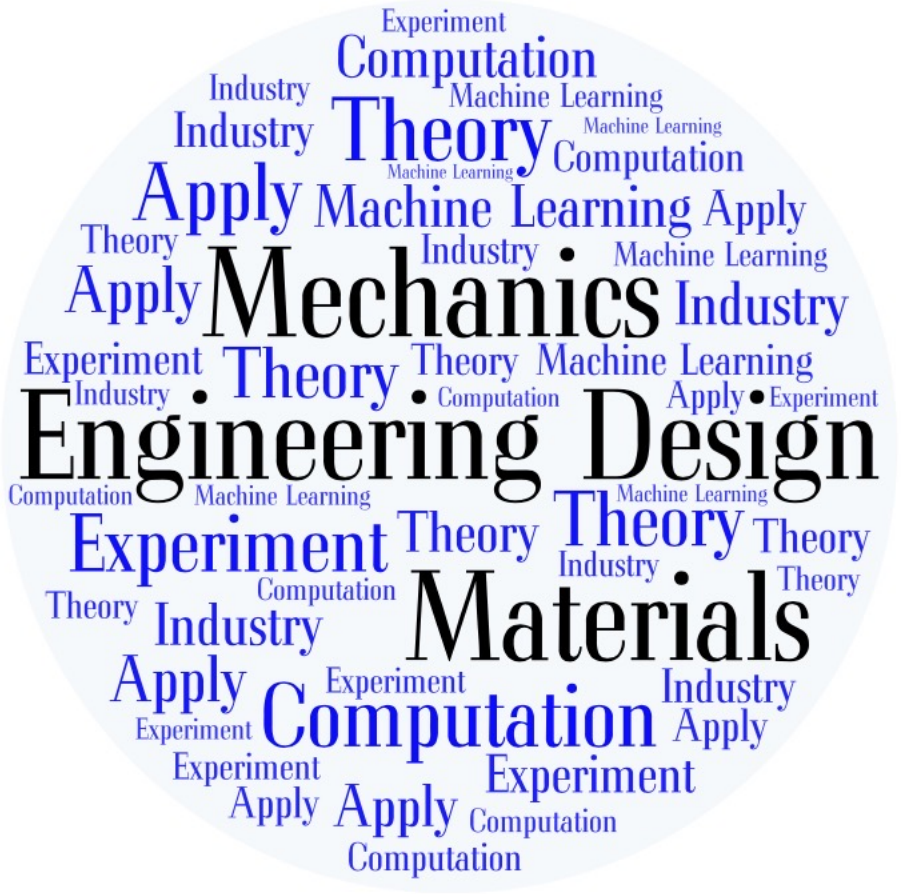
- Introduction and Motivation
- Lectures
- Bachelor Theses and Research
- **Beyond Your Bachelor Degree**

Relevant Industries

Image credit: Audi

- Automotive
- Aerospace
- Space
- Rail
- Robotics
- Manufacturing
- Additive Manufacturing
- Product Development and Consumer Products
- Buildings and Civil Structures
- Energy
- Sports Industries
- Biomedical and Medical Technology
- Many more!

Relevant Master Studies



- Mechanical Engineering
- Micro and Nanosystems
- Robotics, Systems and Control
- Biomedical Engineering
- Energy Science and Technology
- Integrated Building Systems
- …

Any Questions?