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CmME

Mechanical and Materials Engineering at the University of Groningen

Prof. dr. A.I. Vakis

M2i Conference 2019 Meeting Materials

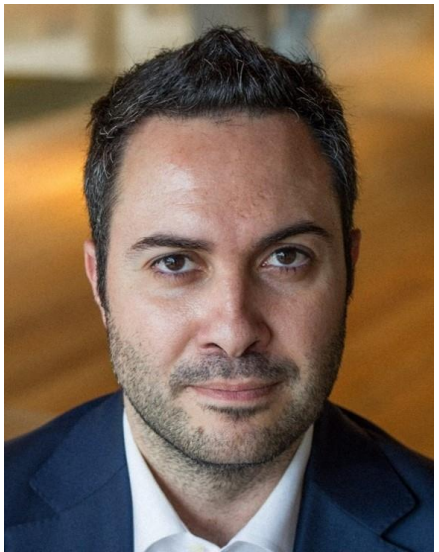
10 December 2019

Computational Mechanical & Materials Engineering

- **Anastasiia Krushynska**, wave dynamics & phononic materials
- **Francesco Maresca**, multiscale modeling of complex materials
- **Antonis I. Vakis**, mechanics & tribology of engineering systems

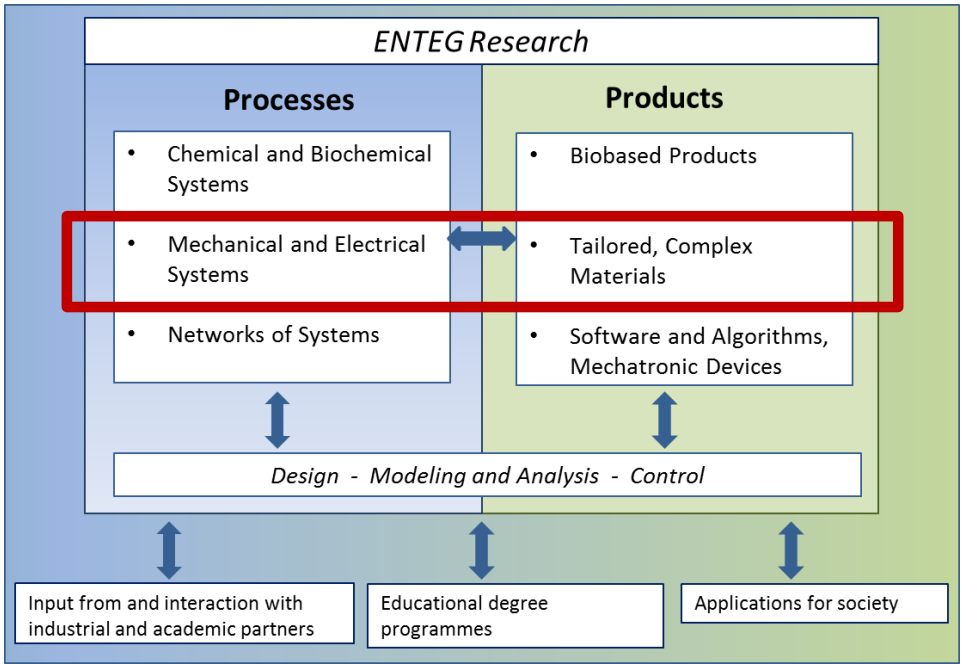
Engineering and Technology institute Groningen (ENTEG)
Faculty of Science and Engineering (FSE)
University of Groningen (UG)

Nijenborgh 4
9747 AG Groningen
The Netherlands, webpage



Embedding

- **Research:** FSE themes of advanced materials, energy, and data science & systems complexity
- **Research:** ENTEG domain of smart manufacturing of complex materials
- **Teaching:** Mechanical Engineering Master, Industrial Engineering & Management Bachelor and Master



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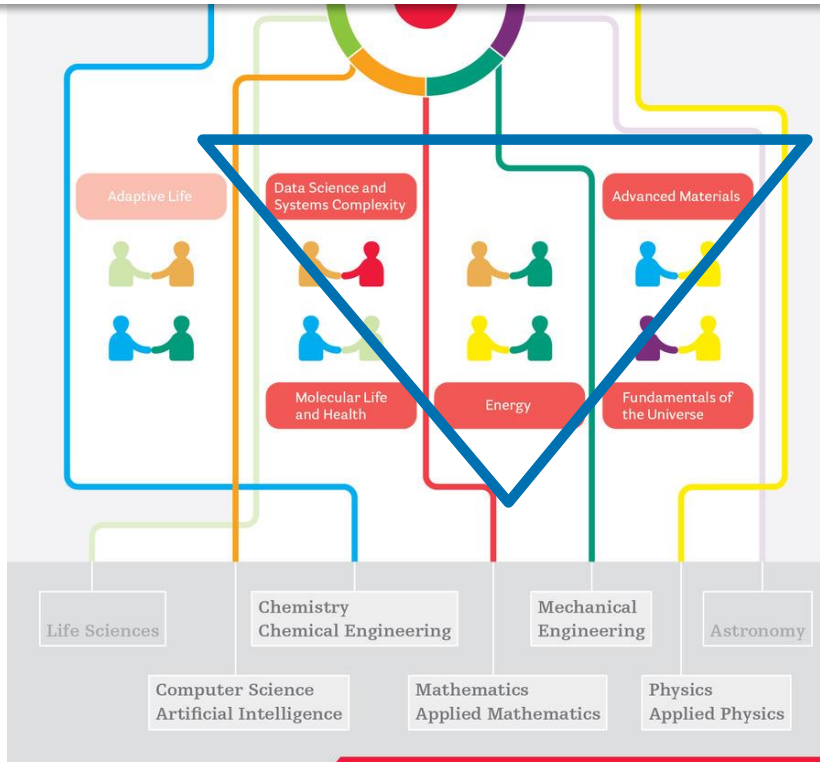
Our Mission and Strategy

At CMME, we engineer and model across scales –from complex (meta-)materials up to integrated energy technologies– to predict and optimize the performance of materials, components and systems



Faculty of Science and Engineering

Research areas

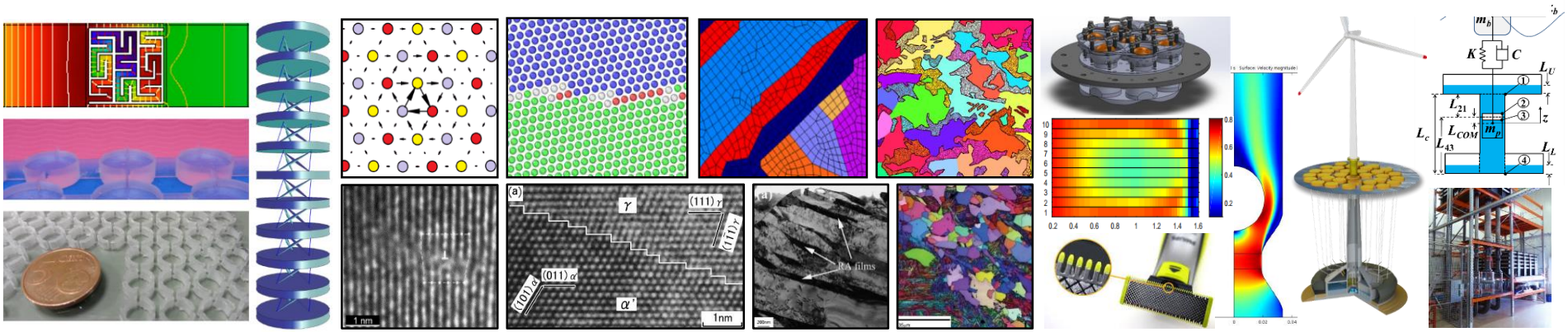
(Meta-)material design
- Vibration & wave control
- Acoustic metamaterials
- Phononic materials
- Shape memory alloys
- Multi-phase metals & steels

Modeling methods & tools
- Molecular statics/ dynamics
- Crystal plasticity
- Finite element methods
- Computational fluid dynamics
- Analytical & continuum models

Increasing scales

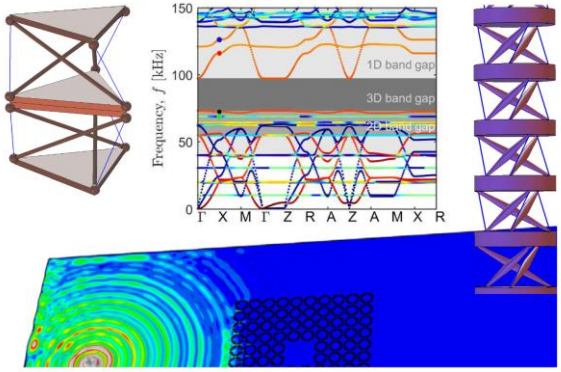
Multiscale methods

Engineering systems
- Mechanical design
- Dynamics & vibrations
- Mechanics & tribology
- Hydrodynamics & fluid flows
- Systems integration

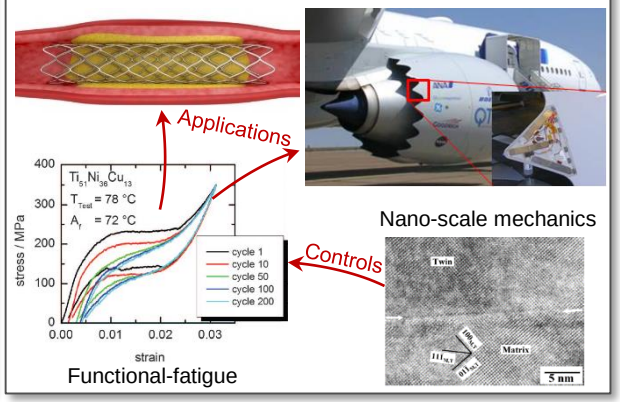


Projects

Twisted phononic materials



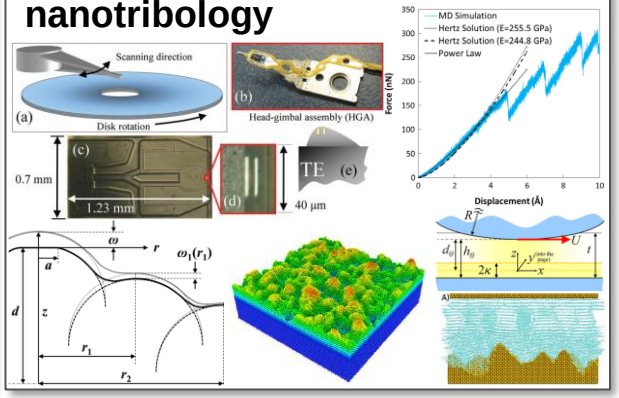
Shape memory alloys



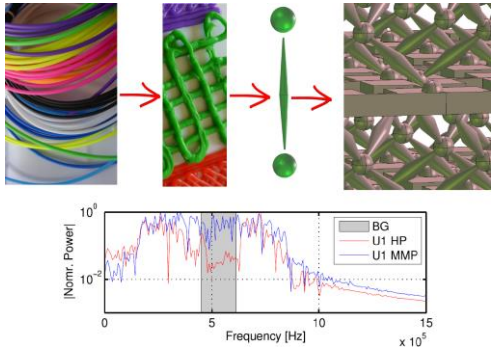
Nano-scale mechanics

Functional-fatigue

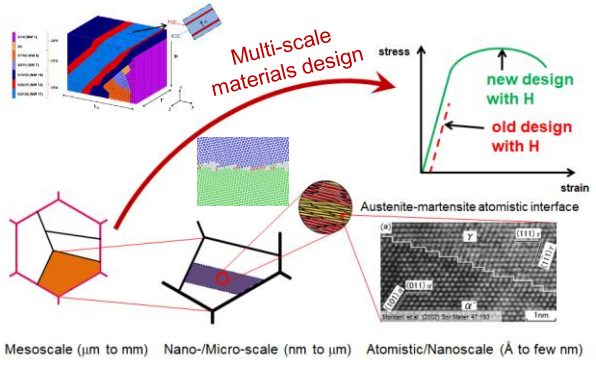
Applied and fundamental nanotribology



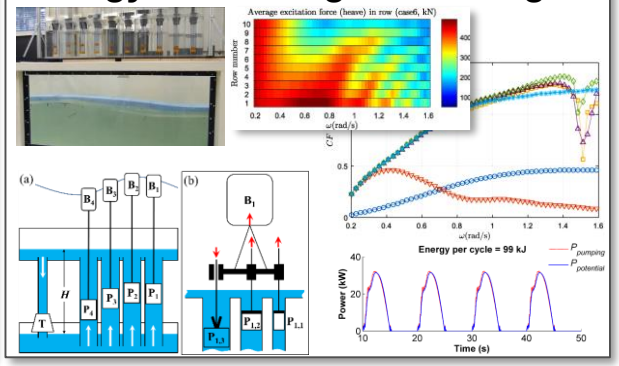
Micromechanics of additively manufactured metamaterials



Hydrogen-embrittlement



Hybrid technologies for ocean energy harvesting and storage



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Education in Materials Science

Lessons learned from inter- and multidisciplinary research

Motivating questions

- "How to teach the essentials of materials (production, structure, properties, sustainability) to engineers and scientists, and not only materials scientists, but also physicists, chemists, mechanical and design engineers, as students, but also from industrial practice"
- "How to transfer knowledge on materials from the respective points of view: academic, industrial, scientific, advanced methods, practice & theory, ethics, etc."

General observations

- Distinctions between disciplines –or between science and engineering– are blurred
- We must teach to multidisciplinary audiences with diverse backgrounds and strengths
- Education must become more experiential: reduce recitation, reduce rote memorization, introduce project-based learning
- Academy and industry can benefit from each other by collaborating on education (e.g. Master in Mechanical Engineering, see appendix)

Challenges

- New knowledge generated every day: great motivation but how to best utilize this?
- Inverted classroom concepts/trends: are they suitable for all topics and course units?
- Students seem to:
  - Lack sufficient preparation from high school in fundamentals, as well as critical thinking and logical reasoning
  - Find it difficult to keep motivation/ concentration
  - Have learnt to expect quick returns

What the stakeholders can do

- Educators should update course content to reflect the state-of-the-art in the field (e.g. greater participation in academic conferences and workshops)
- Academic institutions should offer targeted program selections (PDEng @university, professional education @HBO)
- Industry should stimulate and facilitate project-based learning (e.g. offering more internships)

Lessons from tribology

- Very inter- and multidisciplinary topic
- Lorentz workshop on "Micro/Nanoscale Models for Tribology" in Leiden, the Netherlands, between 30 January and 3 February 2017
- "Lack of communication between engineers, material scientists, applied physicists and chemists who work to solve similar tribological problems: differences exist in notation, language, methods, the way in which problems are posed and how solutions are presented"

Vakis et al., Tribology International, 128, 2018

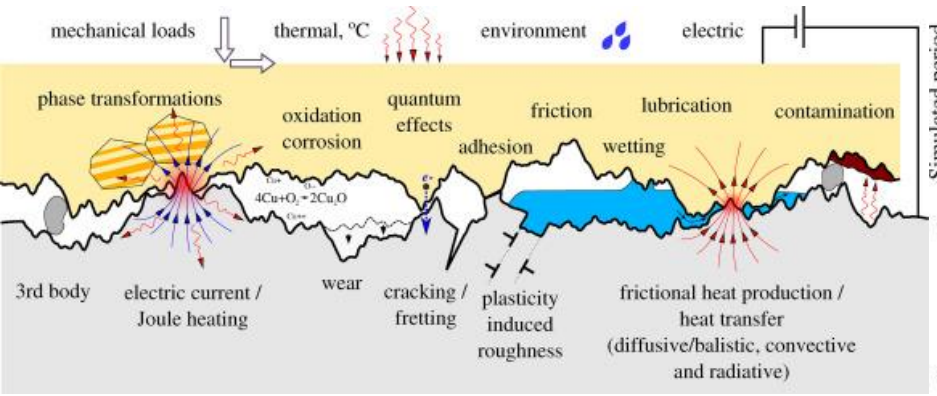
Lessons from tribology

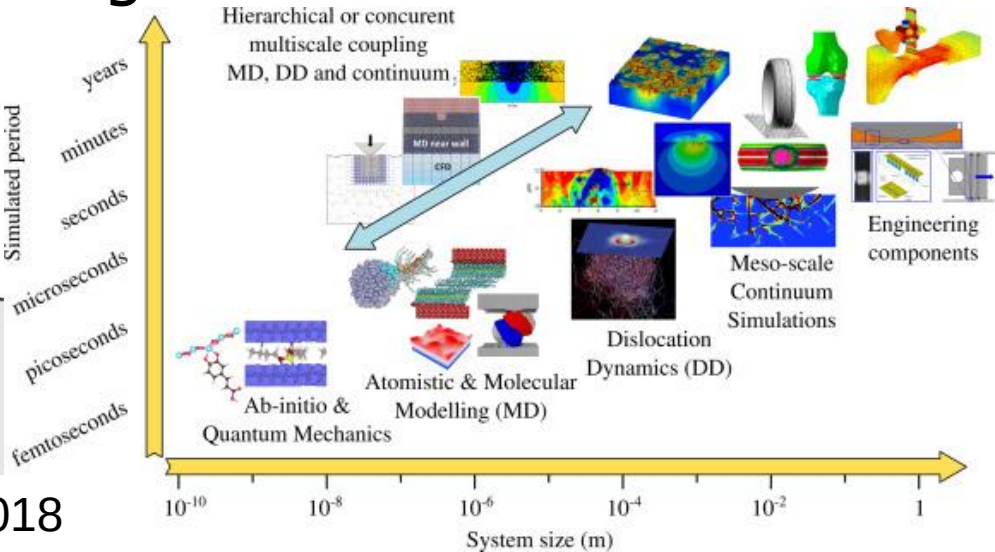
- "Difficulties are further enhanced by divisions between modelers and experimentalists, as well as those working on analytical versus computational methods –and also between the proponents and users of different theories, computational methods and tools– and depending on the research applications"
- Noteworthy developments
  - Contact mechanics challenge (Mueser et al. Tribology Letters, 65, 2017: well defined normal contact problem with short-range adhesion

Vakis et al., Tribology International, 128, 2018

Lessons from tribology

- Noteworthy developments (continued)
  - Review paper from workshop: overview of modeling challenges across domains as well as application-related questions from industry
  - But, we agree to disagree…





Vakis et al., Tribology International, 128, 2018

Lessons from tribology

- Plan
  - Organize inter- and multidisciplinary workshops for material science topics
  - Include participants for industry and become more international in outlook
  - Formulate research challenges and ask for contributions from academic community
  - Periodically report state-of-the-art in review papers and use these in education: e.g. ask students to perform literature review and identify what new has been done since last publication

Conclusions

- No magic bullet…
- Motivate students with new results
- Promote project-based learning and collaborate actively with industry
- …

- Redesign high school curricula!

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Appendix: Master of Science in Mechanical Engineering

Prof.dr.ir. Bayu Jayawardhana (Adjunct Director)
Prof. dr. Antonis Vakis (Curriculum Developer)
drs. Renske Vonk (Program Coordinator)
Geartsje Zondervan (Study Advisor)
Natascha Roberts (Secretary)

Overview

- Synergy of science and engineering enables novel & breakthrough technological solutions for addressing societal challenges: energy transition, sustainability & smart industry
- Year 1
  - 6 compulsory courses (track dependent)
  - Multiple elective courses (per track)
  - 1 elective course in business, management & society
- Year 2
  - Design project (20 ECTS)
  - Research project (40 ECTS)

Curriculum year 1

› Advanced Instrumentation (2019-)

Ia	Ib	IIa	IIb
Basic Detection Techniques	Advanced Instrumentation and	Analysis and control of smart systems	Experimental Design
Introduction to Data Science	Computational Mechanics I	Modeling and Control of Complex Nonlinear Engineering System	Applied Optics
Product design by the Finite Element Method	Structure at Macro, Meso and Nano Scale	Characterisation of Materials	Medical Imaging Instrumentation
Robotics for IEM	MEMS, NEMS and Nanofabrication	Scientific Visualization	Systems Engineering
Space Mission Technology	Surface Engineering and Coating Technology	Multibody and Non-Linear Dynamics	Opto-Mechatronics
	Multiscale Contact Mechanics and Tribology	Computational Mechanics II	
	Advanced Detection Techniques		
	Fitting Dynamical Models to Data		

Courses in Business, Management and Society (required to choose at least one course of 5 ECTS)

Ia	Ib	IIa	IIb
Technology based entrepreneurship	Strategic Management of Inf. Technology	Global Change	Sustainability for Engineers

Curriculum year 1

› Smart Factories (2019-)

Ia	Ib	IIa	IIb
Introduction to Data Science	Advanced Processing for Complex Materials	Analysis and control of smart systems	Experimental Design
Robotics for IEM	Computational Mechanics I	Multibody and Non-Linear Dynamics	Finite element modelling for advanced processing
Product design by the Finite Element Method	Surface Engineering and Coating Technology	Characterisation of Materials	Systems Engineering
Basic detection techniques	Advanced Detection Techniques	Advanced Polymer Processing	Data-driven optimization
Convex Optimization	Structure at Macro, Meso and Nano	Modeling and Control of Complex	Opto-Mechatronics
Modeling and Identification	Robotics for AI	Scientific Visualization	Polymer Physics
	Multiscale Contact Mechanics and Tribology	Computational Mechanics II	
	Fitting Dynamical Models		
	MEMS, NEMS and Nanofabrication		

Courses in Business, Management and Society (required to choose at least one course of 5 ECTS)

Ia	Ib	IIa	IIb
Technology based entrepreneurship	Strategic Management of Inf. Technology	Global Change	Sustainability for Engineers

Curriculum year 1

› Materials for Mechanical Engineering (2020-)

Ia	Ib	IIa	IIb
Introduction to Data Science	Surface Engineering and Coating	Engineering Materials	Experimental Design
Micromechanics	Computational Mechanics I	Multibody and Non-Linear Dynamics	Finite element modelling for advanced processing
Product design by the Finite Element Method	Advanced Processing for Complex Materials	Characterisation of Materials	Systems Engineering
Computational Physics	Structure at Macro, Meso and Nano	Fracture of Materials	CFD for Engineers
Atomic and Molecular Interactions	Multiscale Contact Mechanics and Tribology	Rheology	Polymer Physics
	MEMS, NEMS and Nanofabrication	Computational Mechanics II	

Courses in Business, Management and Society (required to choose at least one course of 5 ECTS)

Ia	Ib	IIa	IIb
Technology based entrepreneurship	Strategic Management of Inf. Technology	Global Change	Sustainability for Engineers

Curriculum year 1

› Process Design for Energy Systems (2020-)

Ia	Ib	IIa	IIb
Introduction to Data Science	Advanced Thermodynamics	Analysis and Control of Smart Systems	Experimental Design
Product design by the Finite Element Method	Computational Mechanics I	Multibody and Non-Linear Dynamics	Advanced Process and Energy Technologies
Advanced Reactor Technologies	Advanced and Sustainable Process Design	Advanced Powder Technologies	Finite element modelling for advanced processing
Chemical Reaction Kinetics	Surface Engineering and Coating Technology	Compressible Flows	CFD for Engineers
	Modeling of Energy and Material Systems	Advanced Polymer Processing	
		Computational Mechanics II	

Courses in Business, Management and Society (required to choose at least one course of 5 ECTS)

Ia	Ib	IIa	IIb
Technology based entrepreneurship	Strategic Management of Inf. Technology	Global Change	Sustainability for Engineers

Curriculum year 2

Ia	Ib	IIa	IIb
Design Project 20 ECTS		Research Project 40 ECTS	

- Common year 2 across all 4 tracks (2020-)
- Design project at industrial partner
  - Synthesis of possible optimal solution for a given process/product design problem in industrial context
  - Students apply various/multiple design concepts to new situations creating new solutions

Curriculum year 2

Ia	Ib	IIa	IIb
Design Project 20 ECTS		Research Project 40 ECTS	

- Design may involve:
  - Conceptualization and design problem analysis;
  - Data gathering and analysis from the field;
  - Quantitative analysis of the design through experimental design/statistical tools or numerical tools;
  - Rapid prototyping of the design and/or experiments

Curriculum year 2

Ia	Ib	IIa	IIb
Design Project 20 ECTS		Research Project 40 ECTS	

- Students embedded in a research group at one of the involved institutes
- Students discuss potential research project/topic with individual faculty members
- Consultation with the adjunct director or academic advisor for the suitability of the topic
- Supervision of both design and research projects by UG research group staff

Institutes and partners

- Engineering and Technology Institute Groningen (ENTEG)
- Zernike Institute for Advanced Materials (ZIAM)
- Kapteyn Astronomical Institute (KAI)
- Bernoulli Institute (BI)
- University Medical Center Groningen (UMCG)

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BIO COOPERATIVE Enabling Bio Business

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SBE SAMENWERKENDE BEDRIJVEN EEMSDELTA

LIFE Cooperative there's more to healthy ageing

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