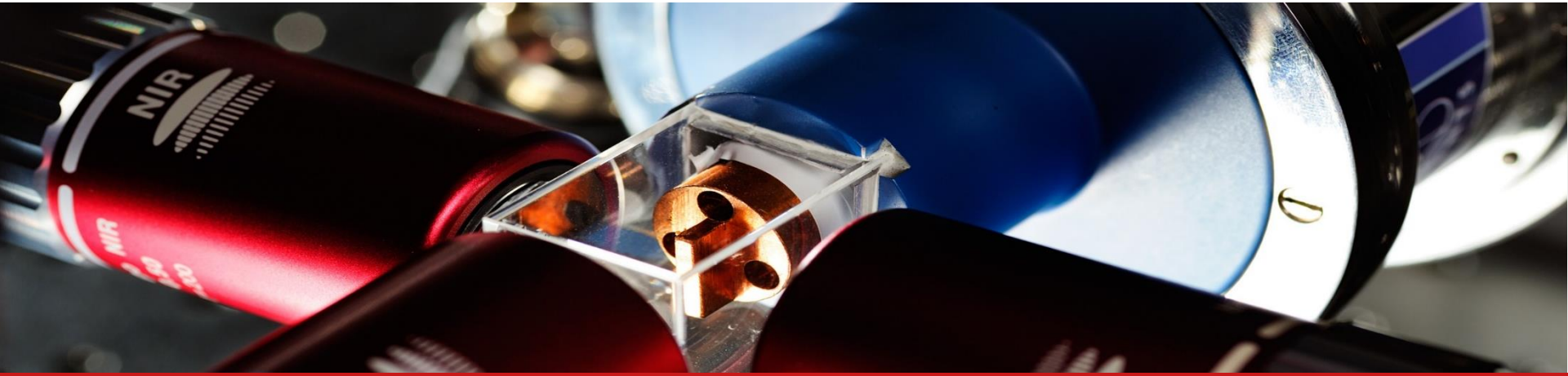


CS Group in-depth meeting

Control Systems, Department of Electrical Engineering

September 19, 2023

Scientific staff CS Group

Prof. Siep Weiland
Spatial-temporal systems, model reduction

Prof. Paul Van den Hof
Data-driven model learning in dynamic networks

Dr. Mircea Lazar
Model predictive control, cyber-physical systems

Dr. Roland Toth
LPV and nonlinear systems; machine learning and AI

Dr. Leyla Özkan
Process control and electrification of processes

Dr. Tijs Donkers
Automotive systems, energy management

Dr. Maarten Schoukens
Nonlinear modeling and control; machine learning and AI

Dr. Sofie Haesaert
Data-driven modeling, control of cyber-physical systems of systems, AI

Dr. Zhiyong Sun
Distributed coordination and networked control systems

Dr. Valentina Breschi
Data-driven control, data-driven model learning for hybrid Systems, machine learning

Dr. Amritam Das
Multi-physics systems, Physics-enabled learning for Control, Neuroengineering

Prof. Hans Butler (ASML)
Mechatronic systems

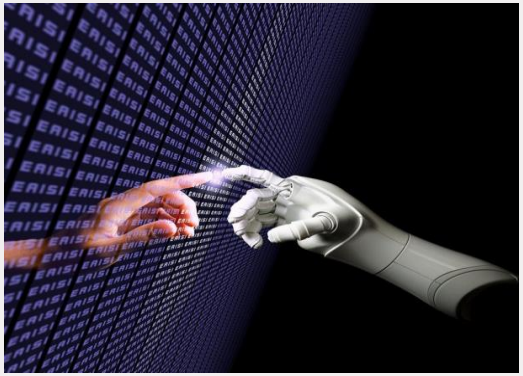
Prof. Henk Jan Bergveld (NXP)
Embedded control in energy management

What is Control?

- Making systems smart (intelligent…)
- Combining (multi)physical modeling with data-driven (machine) learning
- Implementing smart (optimization) algorithms
- Dealing with interconnected / networked / distributed / multi-agent systems
- On the interface between EE / ME / Math / ChemEng / CompSc
- Dominant in key industries: high-tech systems, automotive systems, energy systems, industrial production, robotics, drones
- Becoming more complex/challenging because of multiple sensing/actuation
- A key player in AI for Engineering Systems (new TU/e institute EAISI)
- Always providing terrific job opportunities

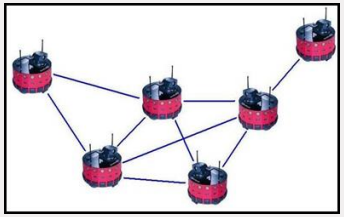
Research partners

Eindhoven Artificial Intelligence Systems Institute



High-Tech Systems Center

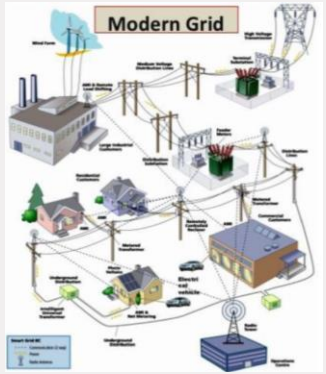
Control Systems of the future



- Involve highly complex systems that are interacting / communicating (over networks)

- Have important safety and operational constraints

- Require autonomy, adaptation and learning in uncertain environments, AI



IEEE, Electric Power Grid Modernization Trends

- Combine: data analytics, communication, computation and control, building on system theory and system modeling

- Will balance between model-based control and data-driven control

TU/e

Profiles & Research projects

Control Systems – Profiles

To help you choose your direction and associated education program,
the CS group has created 4 profiles:

- Profile 1: Estimation & Control of Energy Storage & Conversion Systems
- Profile 2: Control of Autonomous and Connected Systems
- Profile 3: Digital Twinning and Data-Driven Learning
- Profile 4: Control and Learning of High-Tech Systems

Note: of course you can also compile your own education program.

Profile 1

Profile 1:

Estimation & Control of Energy Storage & Conversion Systems

Digital twinning, constrained control, and estimation for energy storage and conversion Systems

Key applications and domains:

- Battery management systems
- Complete vehicle energy management
- Flexible and Autonomous Model based Operation Support Technology

Keywords: Data and Information Driven Dynamic Modeling and Digital Twinning; Control; Estimation; Optimization methods; Model and Data-driven Predictive Control

Profile 1:

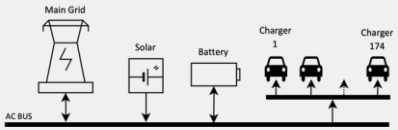
Estimation & Control of Energy Storage & Conversion Systems

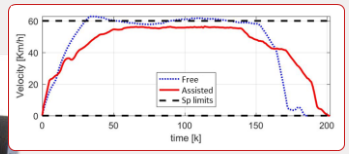
Digital twinning, constrained control, and estimation for energy storage and conversion Systems

Some MSc projects examples:

- Model Predictive Control of Vehicle Charging Stations
- Experiment Design for parameter estimation of the Doyle-Fuller-Newman (DFN) model
- Computationally Fast Eco-driving and Energy management
- Energy-Management with Eco-driving using More-Detailed Road Information
- Self Optimizing Control for Thermal Systems

…….and many more!





Profile 1:

Estimation & Control of Energy Storage & Conversion Systems

Digital twinning, constrained control, and estimation for energy storage and conversion Systems

Involved researchers:

Dr. Tijs Donkers
Automotive systems,
energy management

Dr. Mircea Lazar
Model predictive control,
cyber-physical systems

Dr. Leyla Özkan
Process control and
electrification of processes

Prof. Siep Weiland
Spatial-temporal systems,
model reduction

Prof. Henk Jan Bergveld (NXP)
Embedded control
in energy management

Profile 2

Profile 2:

Control of Autonomous and Connected Systems

Intelligent control and decision making in autonomous and connected systems

Key applications and domains:

- Cyber-physical systems
- Autonomous driving and platooning
- Distributed renewable energy systems
- Multi-robot platforms
- Multi-robot motion planning
- Networked robotics and drones
- Networked formation and flocking
- Sampled-data control
- Formal methods (fundamental & applications)

Keywords: Intelligent motion control; Formal methods; Model predictive and learning control; Distributed autonomous systems; Networked dynamic (control) systems; Distributed autonomy; Swarm intelligence; Hybrid systems

Profile 2:

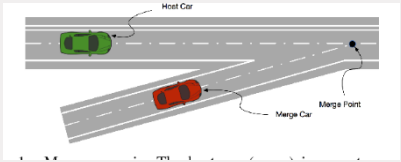
Control of Autonomous and Connected Systems

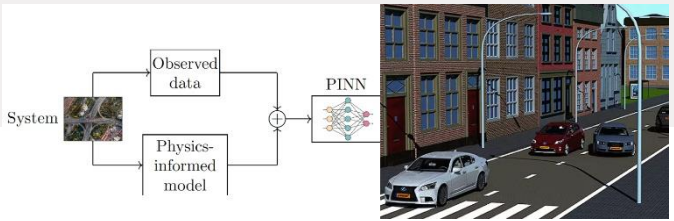
Intelligent control and decision making in autonomous and connected systems

Some MSc project examples:

- Autonomous flying and navigation of mini-drones via ChatGPT
- Automating control synthesis for an RC race car
- Safe On-Ramp Merging: A Multi-Agent Formation Control Approach
- Controller design methods for sampled-data and networked control systems
- Privacy Preserving Physics Informed Learning for City-Wide Traffic Network

…….and many more!





Profile 2:

Control of Autonomous and Connected Systems

Intelligent control and decision making in autonomous and connected systems

Involved researchers:

Dr. Sofie Haesaert
Data-driven modeling, control of cyber-physical systems of systems, AI

Dr. Zhiyong Sun
Distributed coordination and networked control systems

Dr. Tijs Donkers
Automotive systems, energy management

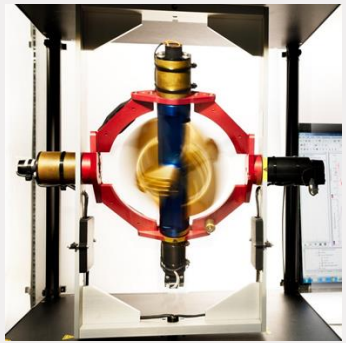
Dr. Amritam Das
Multi-physics systems, Physics-enabled learning for Control, Neuroengineering

Profile 3

Profile 3:

Digital Twinning and Data-Driven Learning

Modelling dynamic systems and data-driven learning for decision and control



Key applications and domains:

- High-Tech
- Autonomous Vehicles
- Power Electronics
- Power and Distribution Networks
- Industrial Processes
- Dynamic network applications

Keywords: Machine Learning; Data-Driven Modelling and Control; Modelling; Reinforcement Learning; Digital Twinning; Modelling Dynamics; Diagnostics; System Identification; Topology Identification

Profile 3:

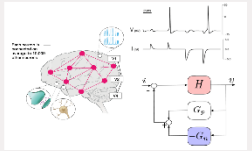
Digital Twinning and Data-Driven Learning

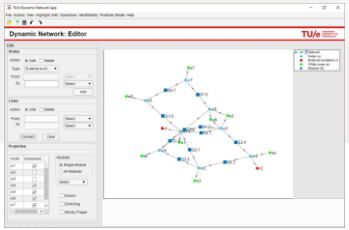
Modelling dynamic systems and data-driven learning for decision and control

Some MSc project examples:

- Data-driven model-augmentation and control of the Space Rider Vehicle
- Unveiling the dynamical behavior of networks of neurons with jump models
- Learning Neurophysiological Models of Human Brain
- Modelling for diagnostic of wafer scanners
- Printed Circuit Board (PCB) Testing
- Matlab toolbox development for dynamic networks

…….and many more!





Profile 3:

Digital Twinning and Data-Driven Learning

Modelling dynamic systems and data-driven learning for decision and control

Involved researchers:

Dr. Valentina Breschi
Data-driven control, data-driven model learning for hybrid Systems, machine learning

Dr. Roland Toth
LPV and nonlinear systems; machine learning and AI

Dr. Maarten Schoukens
Nonlinear modeling and control; machine learning, AI

Prof. Paul Van den Hof
Data-driven model learning in dynamic networks

Dr. Amritam Das
Multi-physics systems, Physics-enabled learning for Control, Neuroengineering

Profile 4

Profile 4:

Control and Learning of High-Tech Systems

Performance enhancement through control and learning

Key applications and domains:

- High-precision motion systems
- Additive manufacturing
- Applications on integrated mechanical
- Electrical
- Thermo-dynamical
- Optical
- Acoustic phenomena (lithography, electron microscopy, aerospace applications)
- Piezo actuation/sensing
- Learning control

Keywords: Mechatronic systems; multi-physical modeling; manufacturing systems; dealing with/managing complexity of spatial-temporal and nonlinear systems; parameter-varying systems

Profile 4:

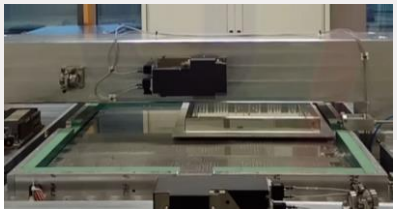
Control and Learning of High-Tech Systems

Performance enhancement through control and learning

Some MSc project examples:

- Physics Guided Neural Networks for Feedforward Control: Rotating 2 Mass-spring Philips system
- Integrated Wafer stage calibration (ASML)
- 3D printing for plastics, ceramics, food and concrete
- Learning-based motion control of wire bonders
- A proximity-based regularization strategy for data-driven predictive control of nonlinear systems
- Flexible mode regulation (POI control), Learning-based commutation

…….and many more!



Profile 4:

Control and Learning of High-Tech Systems

Performance enhancement through control and learning

Involved researchers:

Dr. Valentina Breschi
Data-driven control, data-driven model learning for hybrid Systems, machine learning

Dr. Roland Toth
LPV and nonlinear systems; machine learning and AI

Dr. Mircea Lazar
Model predictive control, cyber-physical systems

Prof. Siep Weiland
Spatial-temporal systems, model reduction

Dr. Amritam Das
Multi-physics systems, Physics-enabled learning for Control, Neuroengineering

Prof. Hans Butler (ASML)
Mechatronic systems

Courses per profile

CS profiles S&C – courses

Profile 1: Estimation & Control of Energy Storage and Conversion Systems
Profile 2: Control of Autonomous and Connected Systems
Profile 3: Digital Twinning and Data-Driven Learning
Profile 4: Control and Learning of High-Tech Systems

	Quartile	Code	Responsible lecturer	Profile 1	Profile 2	Profile 3	Profile 4
Core courses							
Control Engineering	Q1/Q3	4CM00	Witvoet				✓
System theory for control	Q1	4CM10	Heemels	✓	✓	✓	✓
Modeling Dynamics	Q1	5CSA0	Weiland	✓	✓	✓	✓
Multibody and non-linear dynamics	Q2	4DM10	vd Wouw				
Stochastic processes, filtering and estimation	Q2	5SC29	Breschi	✓	✓	✓	✓
Supervisory control of cyber physical systems	Q3	4SC080	Reniers	✓	✓		
System identification	Q3	5SMB0	Schoukens	✓		✓	✓
Specialization courses							
Nonlinear Optimization	Q1	2DME20	Keijsper	✓			
Model Reduction	Q2	5LMA0	Weiland	✓		✓	✓
Control Principles for Engineering Systems	Q2	5SMC0	Haesaert		✓		
Bayesian Machine Learning and Inf. Proc.	Q2	5SSD0	de Vries			✓	
Model Predictive Control	Q3	5LMB0	Lazar	✓			
Robust Control	Q3	5LMC0	Das		✓		✓
Analysis and design of Networked Systems	Q4	4DM70	Steur		✓		
Hybrid Systems	Q4	4CM20	Heemels		✓		
Machine Learning for Systems and Control	Q4	5SC28	Schoukens			✓	✓
Elective courses							
Energy Management	Q2	5XWC0	Donkers	✓			
Optimal Control and Reinforcement Learning	Q2	4SC000	Guerreiro Tomé Antunes		✓	✓	
Advanced Motion Control	Q2	4CM60	Oomen				✓
Advanced Process Control	Q3	5LMG0	Ozkan	✓			
Physical and Data-Driven Modelling	Q3	4CM40	Tiels	✓		✓	✓
Model Predictive Control	Q3	5LMB0	Lazar		✓		✓
Machine Learning for Systems and Control	Q4	5SC28	Schoukens	✓			

CS profiles EE – courses

Profile 1: Estimation & Control of Energy Storage and Conversion Systems
Profile 2: Control of Autonomous and Connected Systems
Profile 3: Digital Twinning and Data-Driven Learning
Profile 4: Control and Learning of High-Tech Systems

	Quartile	Code	Responsible lecturer	Profile 1	Profile 2	Profile 3	Profile 4	Remarks
Core courses								
Modeling dynamics	Q1	5CSA0	Weiland	✓	✓	✓	✓	Must have
Complex Analysis	Q1	2DME30	Habets		✓		✓	Nice to have (choose 2)
Nonlinear Optimization	Q1	2DME20	Keijsper	✓				Nice to have (choose 2)
Statistical Signal Processing	Q1	5CTA0	Turco					Nice to have (choose 2) Choose elective **Stochastic processes, filtering and estimation** instead
Numerical methods in electrical engineering	Q1	5CPA0	de Hon					Nice to have (choose 2)
Specialization courses								
Control Principles for Engineering Systems	Q2	5SMC0	Haesaert	✓	✓	✓	✓	
System identification	Q3	5SMB0	Schoukens	✓	✓	✓	✓	
Elective courses								
Control Engineering	Q1/Q3	4CM00	Witvoet				✓	
System theory for control	Q1	4CM10	Heemels					
Stochastic processes, filtering and estimation	Q2	5SC29	Breschi	✓	✓	✓	✓	Not when **Statistical Signal Processing** has been chosen as a Core course
Model Reduction	Q2	5LMA0	Weiland	✓		✓	✓	
Bayesian Machine Learning and Inf. Proc.	Q2	5SSD0	de Vries			✓		
Energy Management	Q2	5XWC0	Donkers	✓				
Optimal Control and Reinforcement Learning	Q2	4SC000	Guerreiro Tomé Antunes		✓	✓		
Advanced Motion Control	Q2	4CM60	Oomen				✓	
Advanced Process Control	Q3	5LMG0	Ozkan	✓				
Physical and Data-Driven Modelling	Q3	4CM40	Tiels	✓		✓	✓	
Model Predictive Control	Q3	5LMB0	Lazar	✓	✓		✓	
Robust Control	Q3	5LMC0	Das		✓		✓	
Supervisory control of cyber physical systems	Q3	4SC080	Reniers		✓			
Analysis and design of Networked Systems	Q4	4DM70	Steur		✓			
Hybrid Systems	Q4	4CM20	Heemels		✓			
Machine Learning for Systems and Control	Q4	5SC28	Schoukens	✓		✓	✓	

Expectations

What can you expect as a student in our group?

- You will be assigned to one of our mentors who will discuss your course program with you.
- Our mentors are:


Prof. Siep Weiland

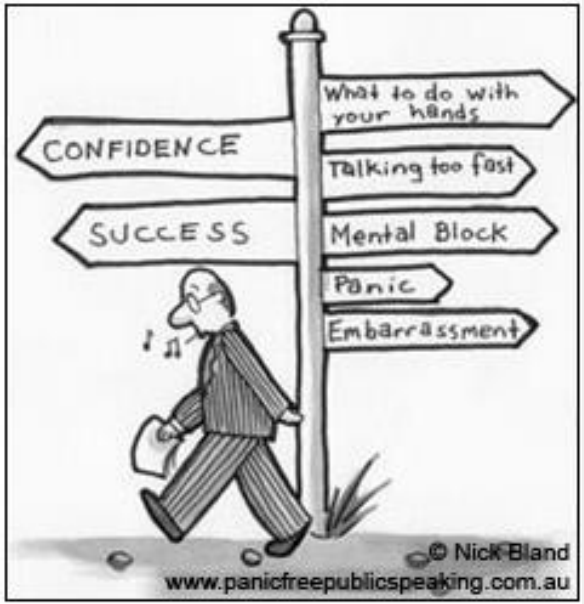

Prof. Paul Van den Hof


Dr. Tijs Donkers

What can you expect as a student in our group?

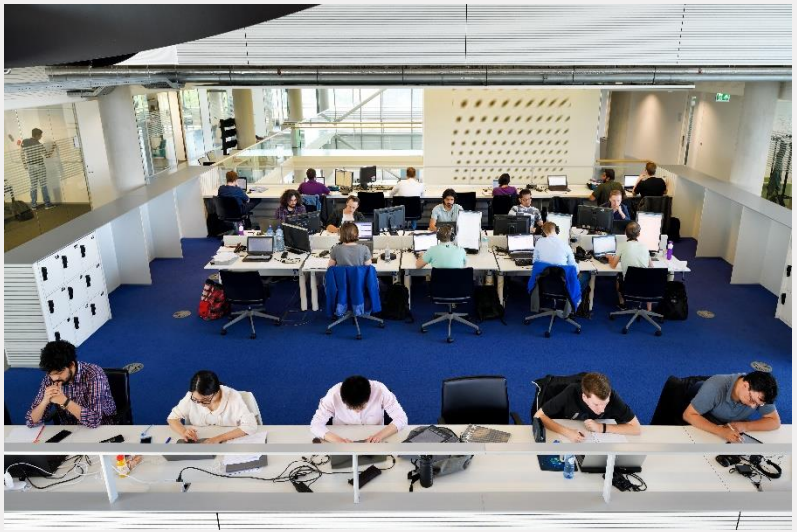
Monthly CS MSc workshop:

- Train your presentation skills
- Train your discussion skills
- Use your fellow students as sources of knowledge
- Get inspired by interesting guest speakers from the industry and get to know your possible future field of work



What can you expect as a student in our group?

- Great support and regular supervision sessions.
- Large and diverse selection of internships and graduation projects to choose from
- Possibilities to present your thesis at a conference
- Reserved desk space within the group



What can you expect as a student in our group?

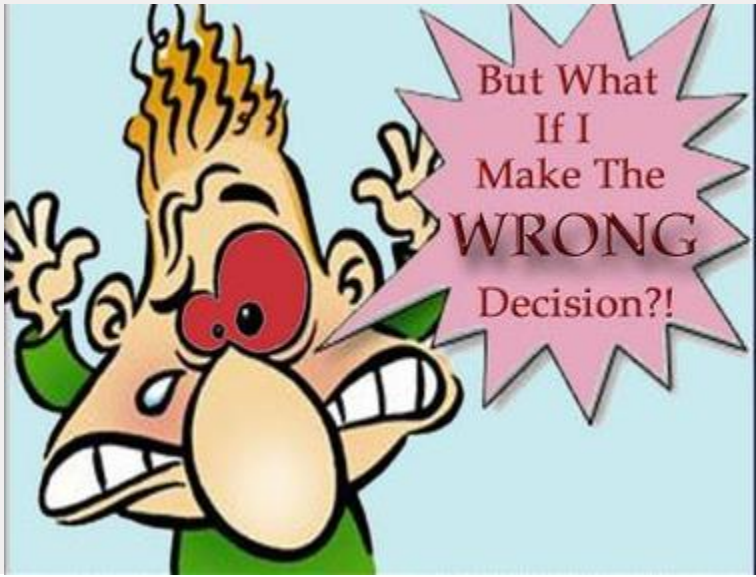
- In April 2024 the **CS Match-making event** will take place to help you choose your internship and graduation project and connect you to your supervisor
- Group sessions with CS staff members of your choice:
  - Detailed information about their research area
  - Information about possible internships and master end projects
- One-on-one session with a staff member to discuss the project of your choice

What do we expect from you?

- Effort and commitment
- Select topics you really like
- Be efficient and plan to finalize on time
- Avoid having to do (multiple) exams during your project
- Develop yourself as a professional
- Put maximum value to your diploma

How to choose your specialisation?

- Control Systems (CS)
- Electromechanics and Power Electronics (EPE)
- Control Systems Technology (CST)
- Dynamics and Control (DC)



Q & A sessions