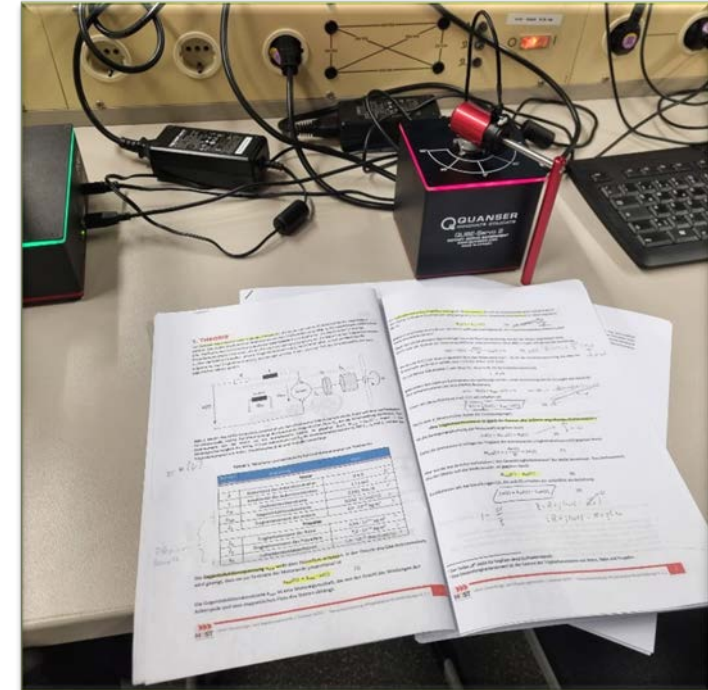
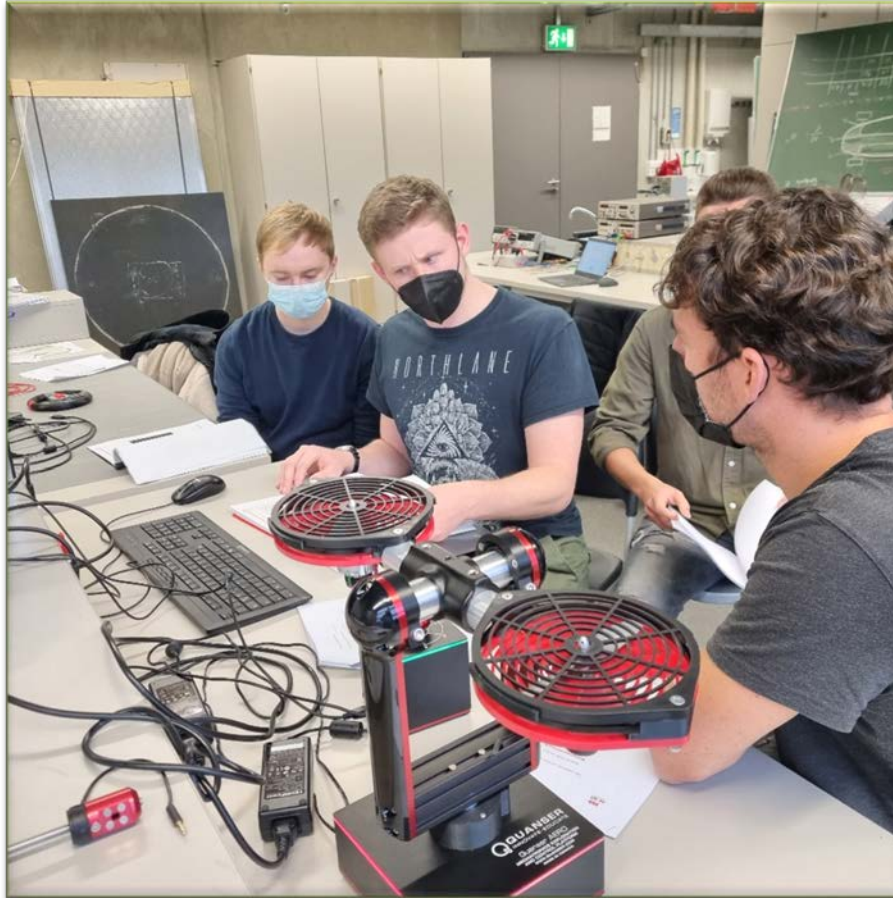


Distance learning in undergraduate control systems labs by virtual twins

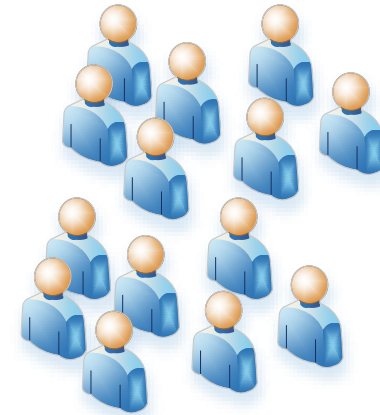
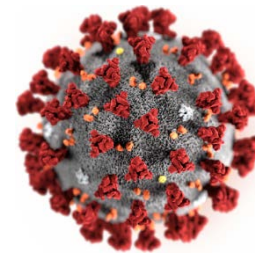
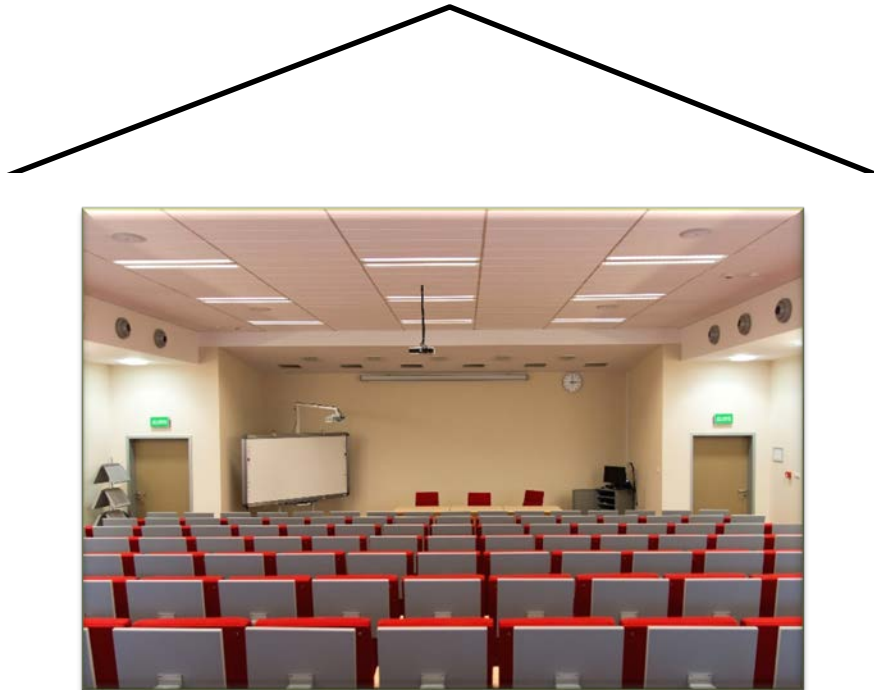
Jan-Christian Kuhr, Stralsund University of Applied Sciences
Martina Müller, Stralsund University of Applied Sciences



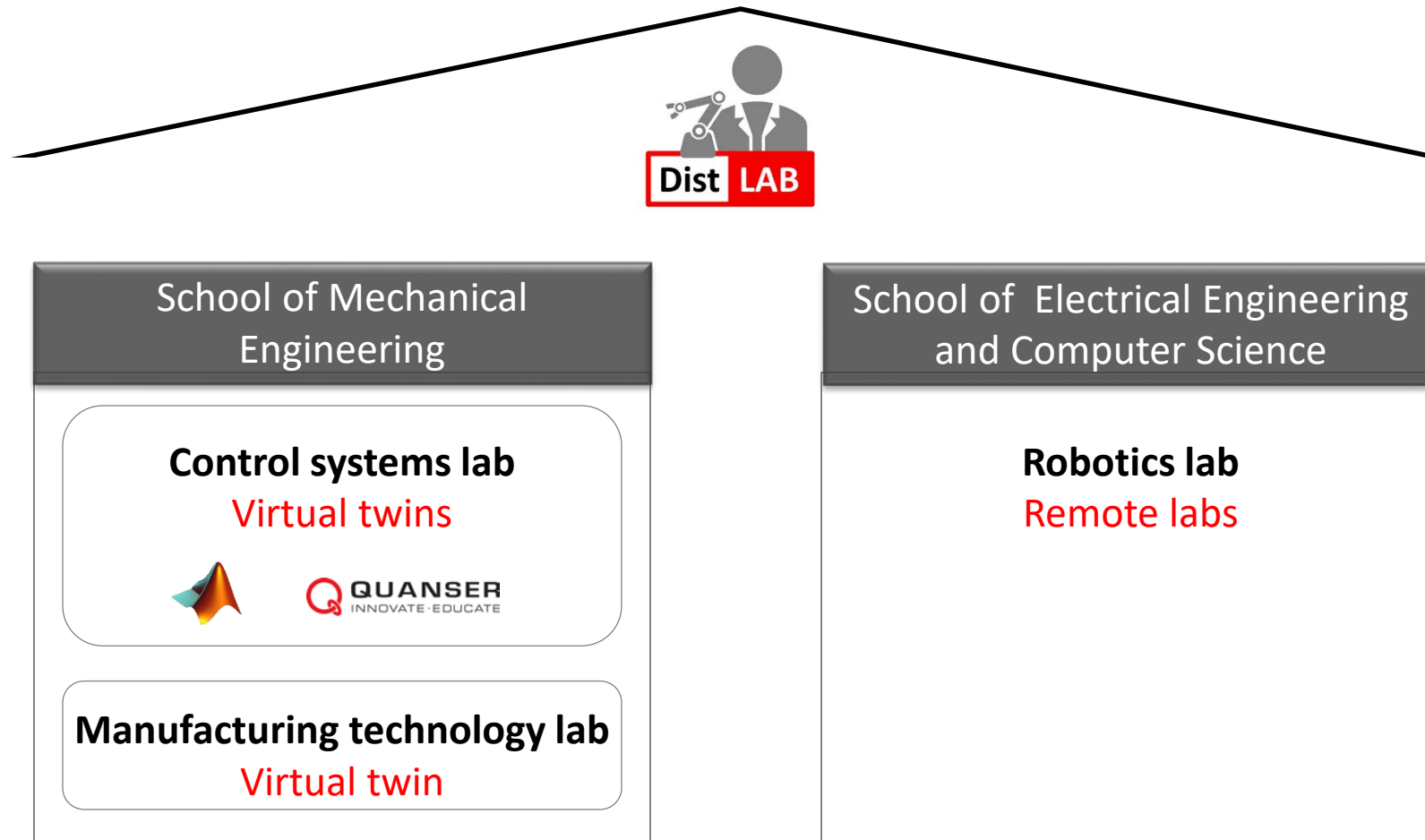
Hands-on labs are an indispensable part of the education of engineering students



The Corona pandemic has largely kept students out of lecture halls and lab rooms.
This calls for putting more emphasis on solutions such as **distance learning**.



The **DistLab project** at Stralsund University focuses on distance learning in control systems labs and in robotics labs. It is currently going to be implemented by two faculties.



Control systems labs are a vital part of the mechanical engineering curriculum. They are mandatory for all undergraduate students in the 5th semester.

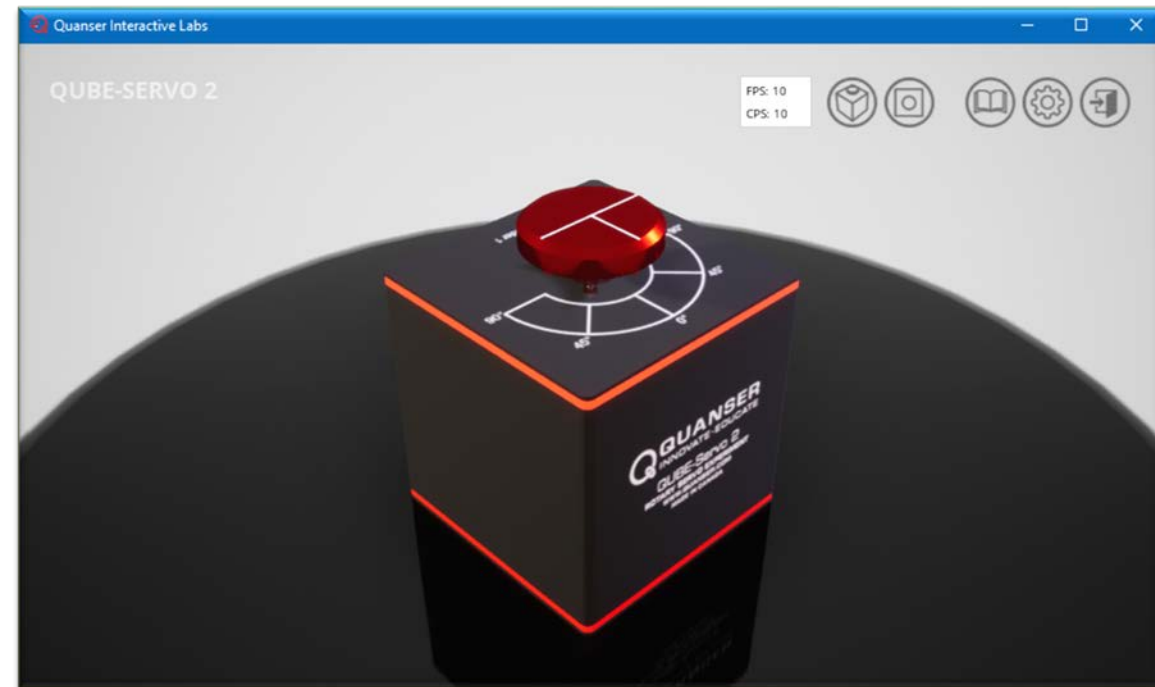


A **virtual twin** is a high-fidelity digital copy of a real lab experiment, such as a servo motor that rotates a shaft. A virtual twin behaves almost identically as its counterpart

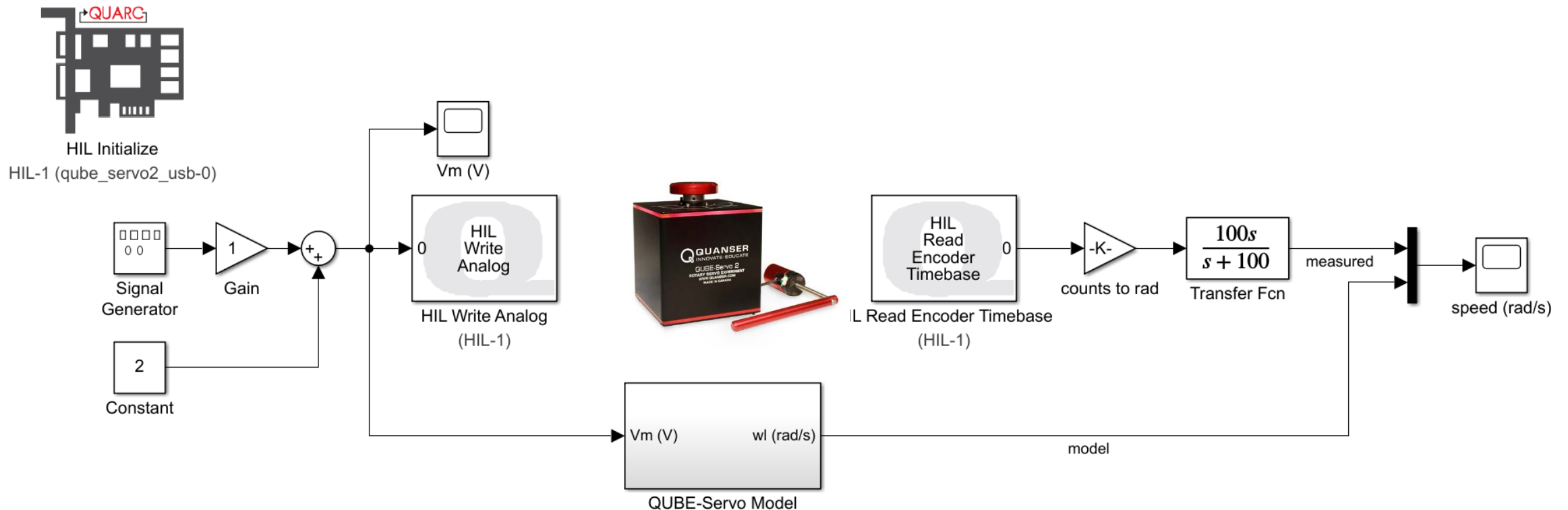
real twin



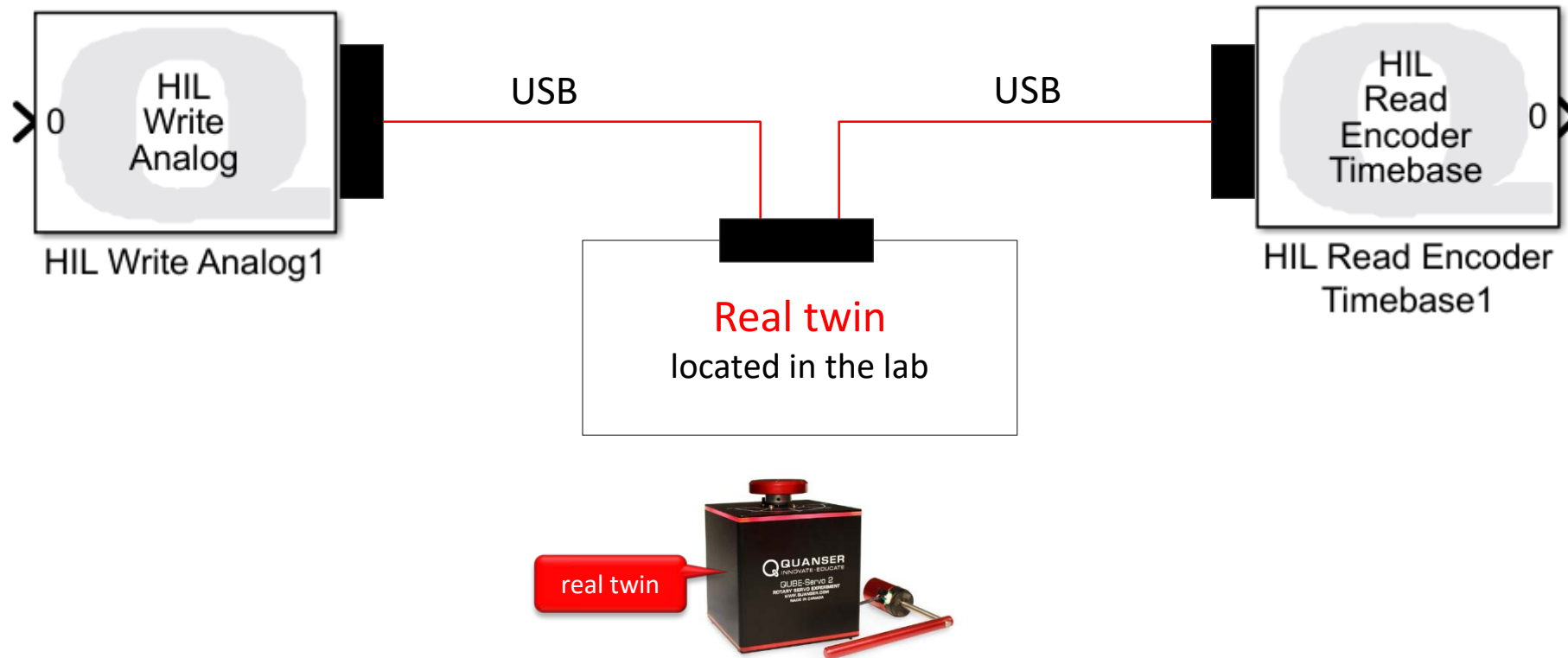
virtual twin



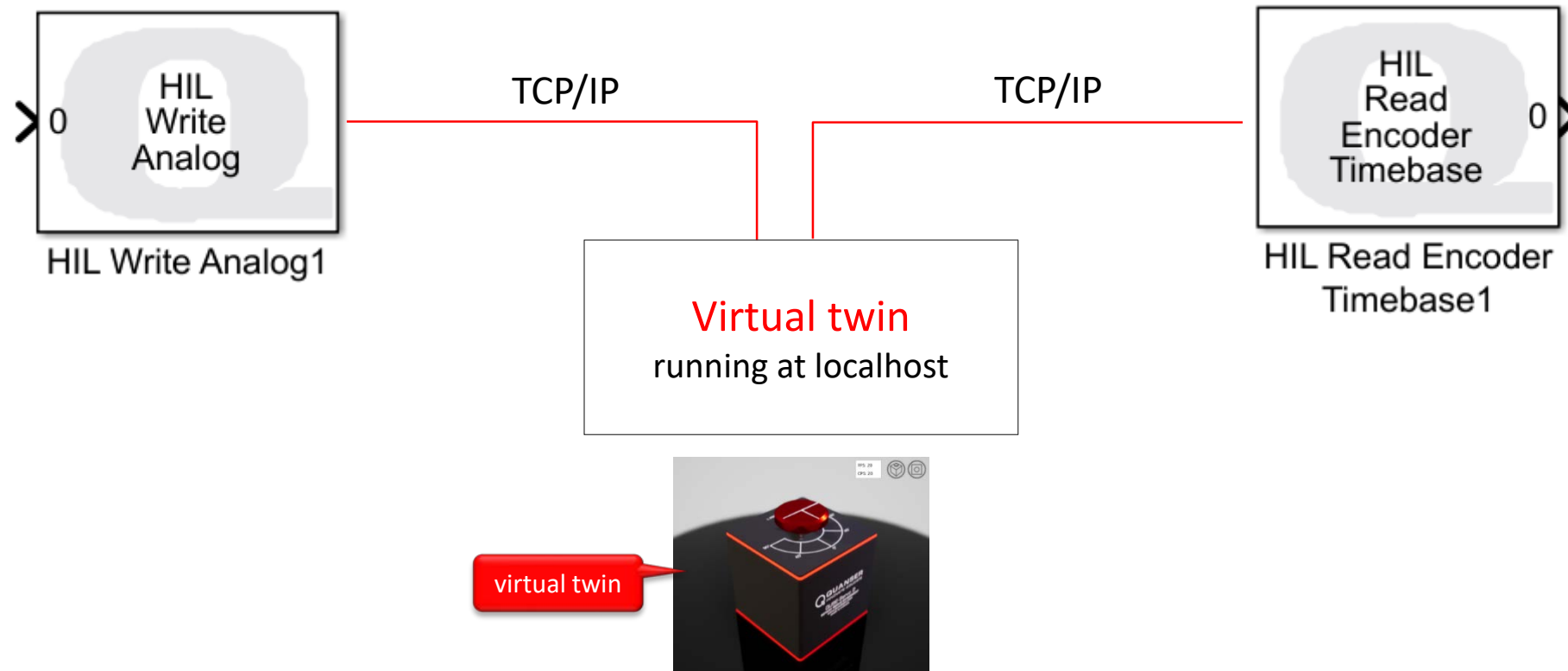
In classical **hardware-in-the-loop** systems (HiL), the hardware – such as servo motor rotating an inertia disk – is placed between the HiL write and the HiL read block



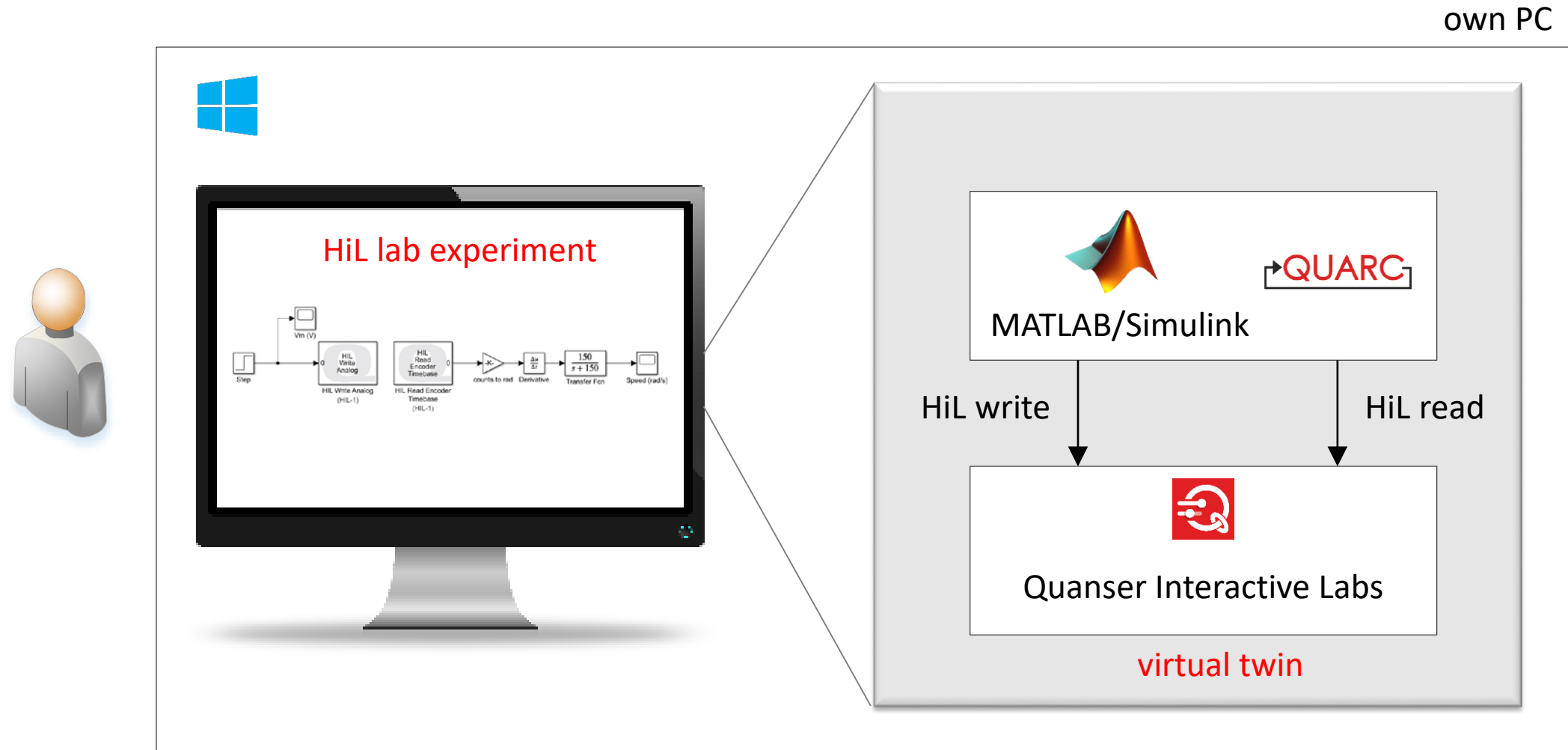
When **on-campus**, HiL write and read calls are executed via a USB interface against the real twin



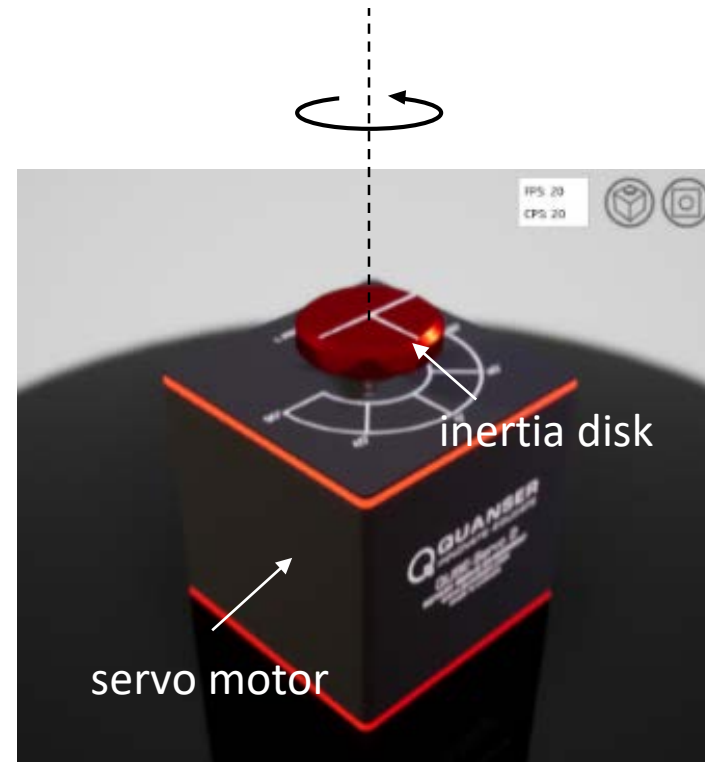
For **distance learning**, the situation is different. HiL write and read calls are executed via the TCP/IP protocol against the virtual twin running on the local machine



To run virtual labs **off-campus**, each team member has to install software, including a **virtual twin**, on his or her own PC

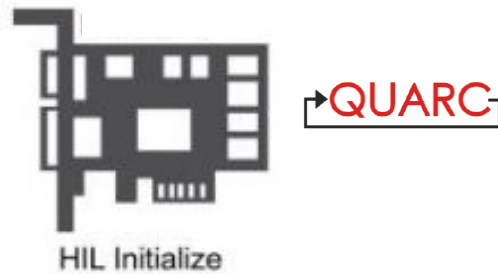


The virtual twin of the Quanser QUBE contains a servo motor and an inertia disk



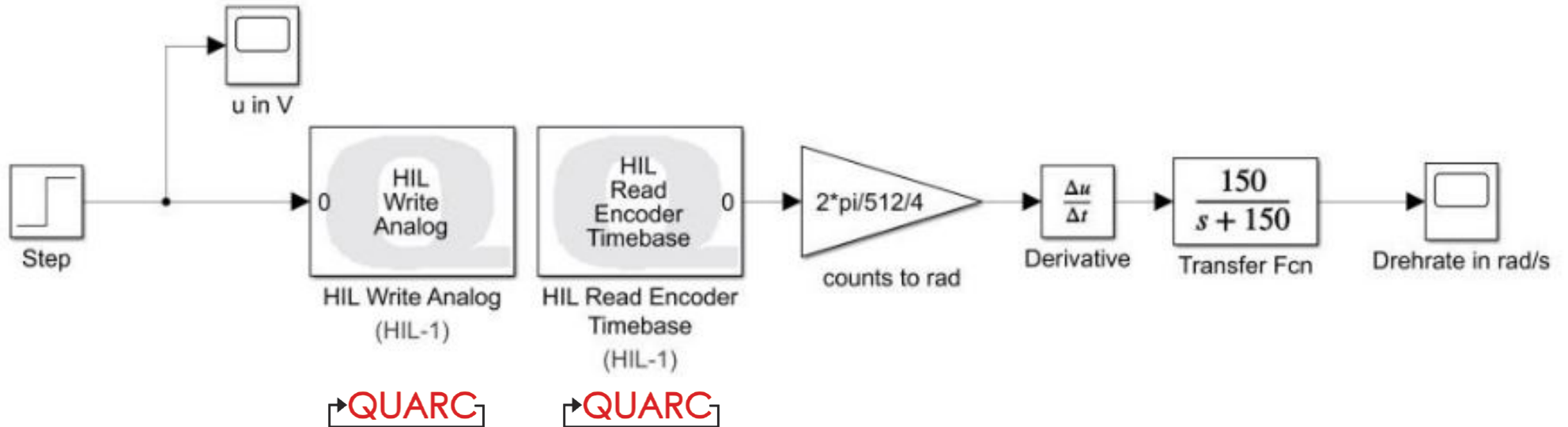
virtual twin

For the virtual labs, students must also install QUARC – a real-time control software running on top of Simulink

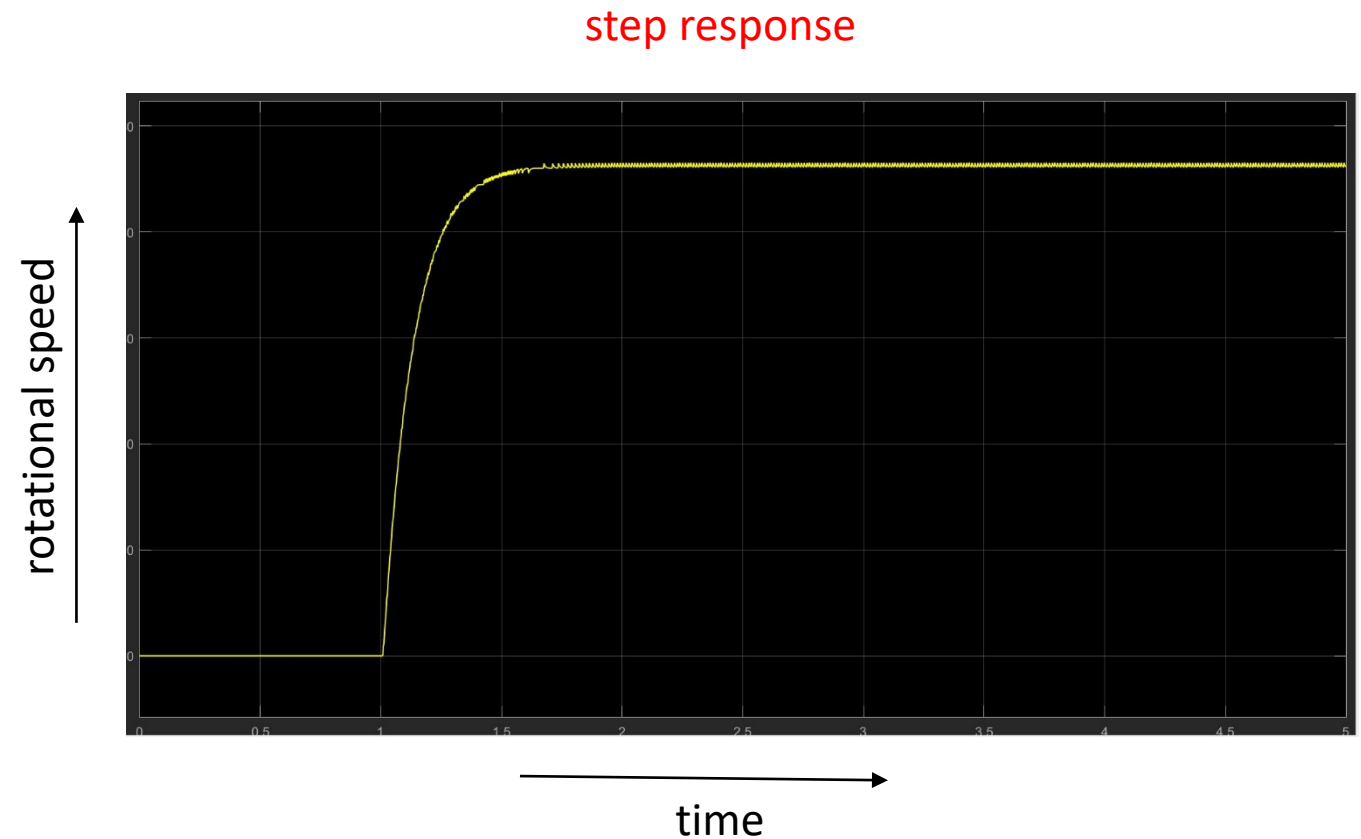
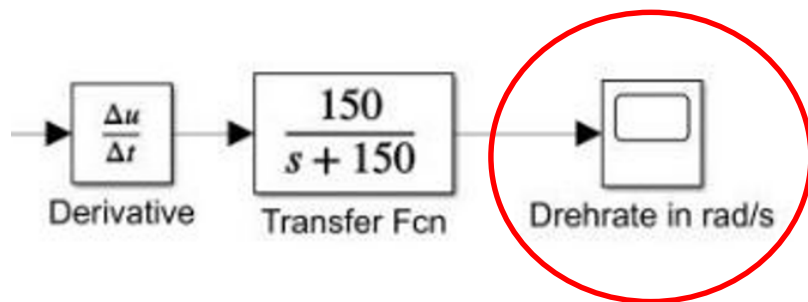


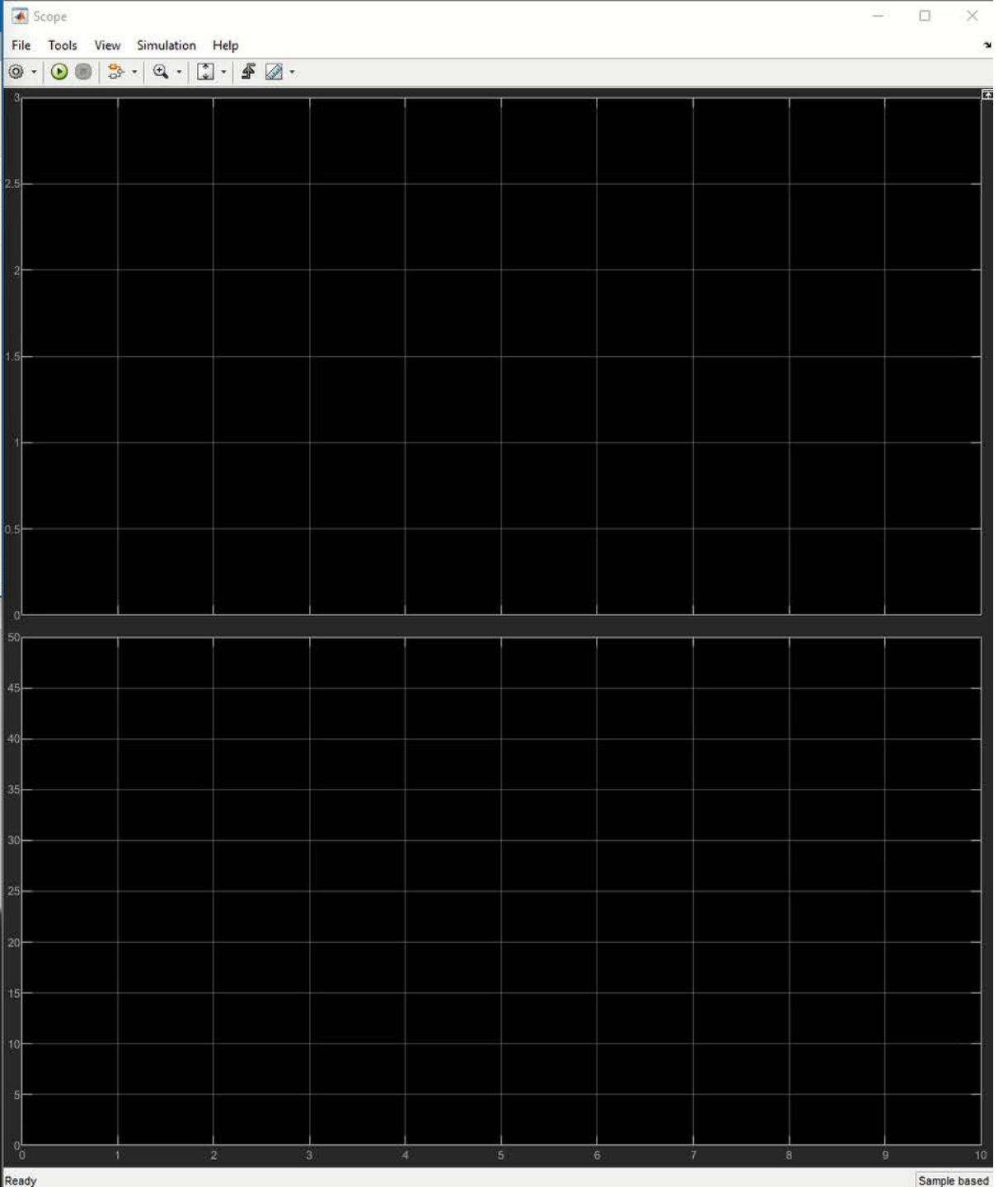
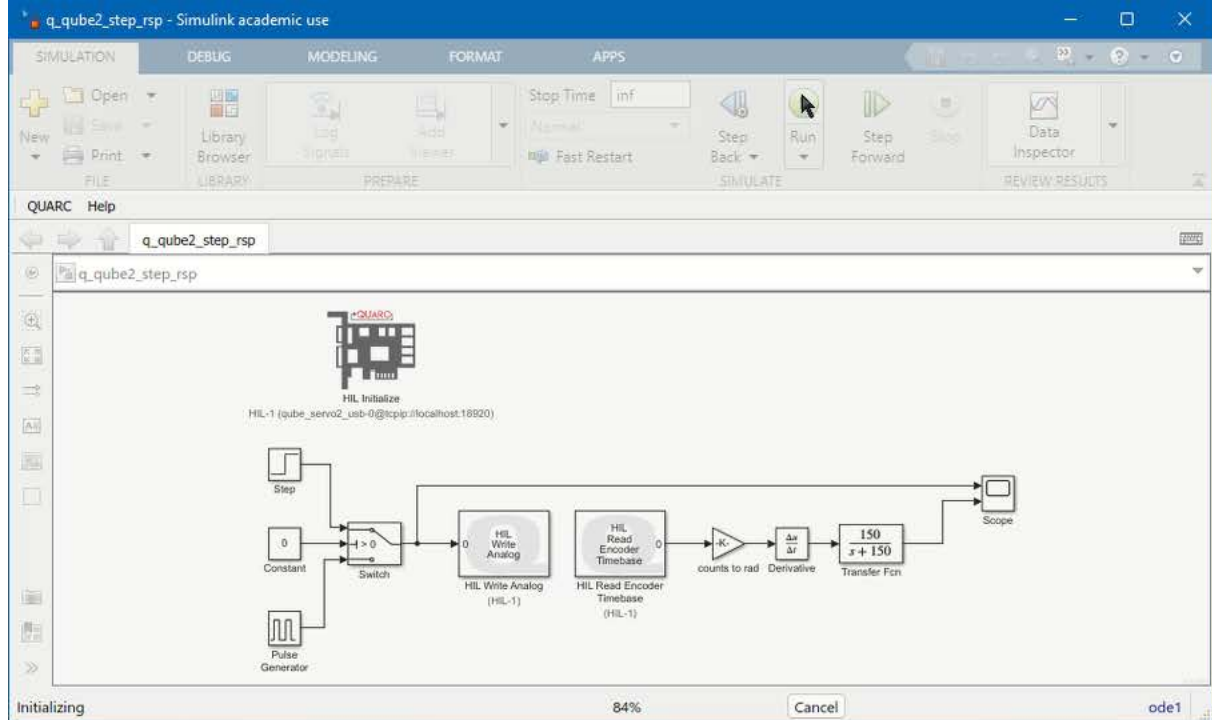
HIL-1 (qube_servo2_usb-0@tcpip://localhost:18920)

MATLAB®
& SIMULINK®



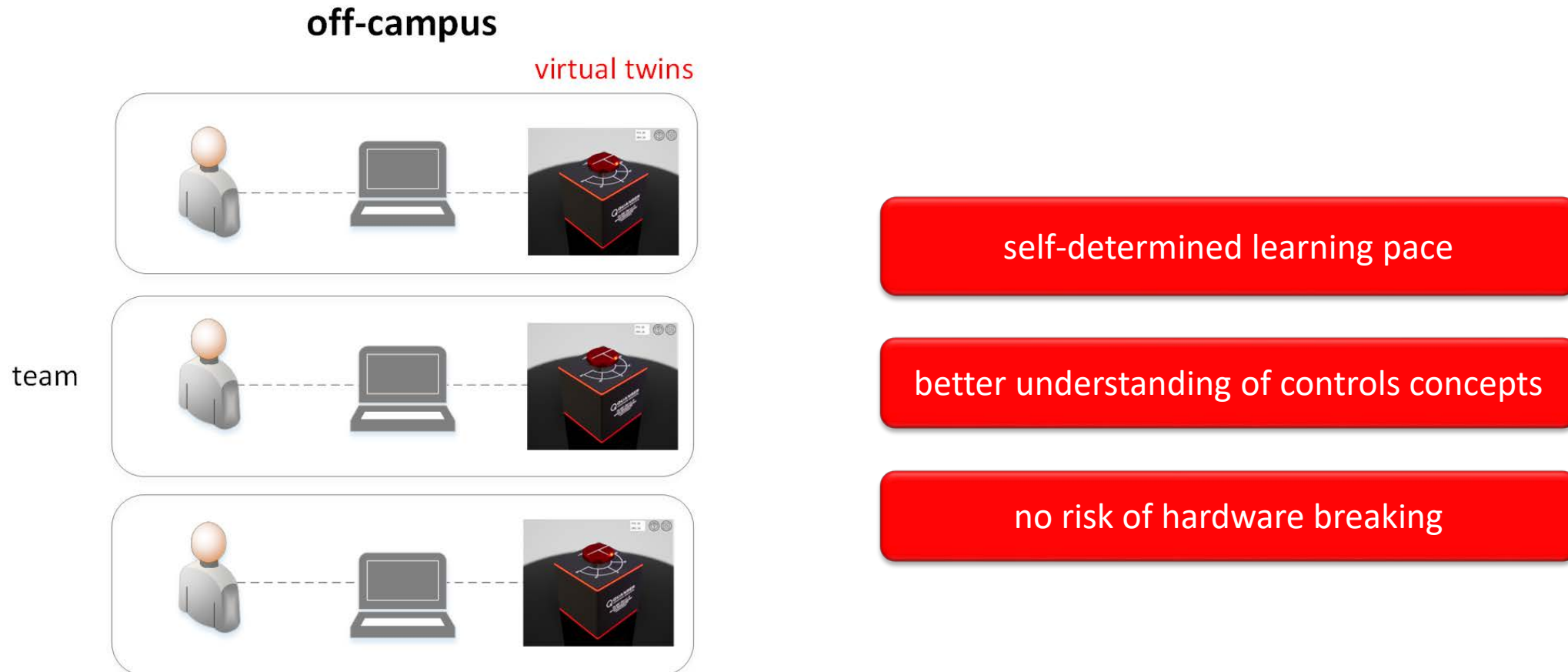
In the lab, students investigate the first order **step response** of the servo motor







When **off-campus**, each team member carries out the labs against a **virtual twin**. This gives a number of benefits, such as self-determined learning pace



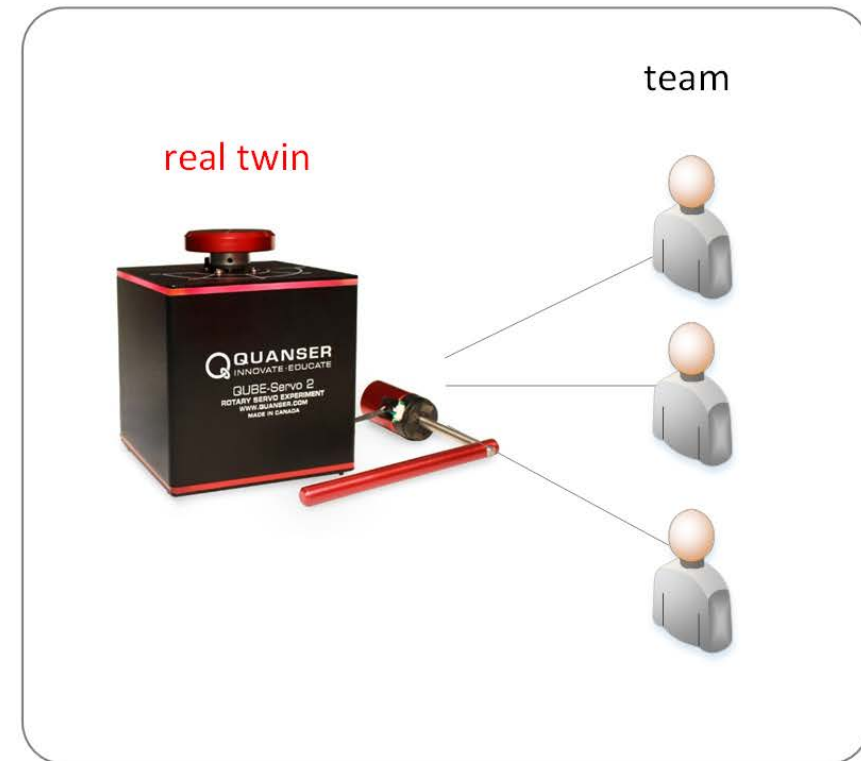
Once **on-campus**, the team repeats the labs that have been worked out earlier by using the virtual twin. Real and virtual twin behave almost identically

Virtual and real twins interoperable

Hands-on experience on hardware

Single hardware device shared by each team

on-campus



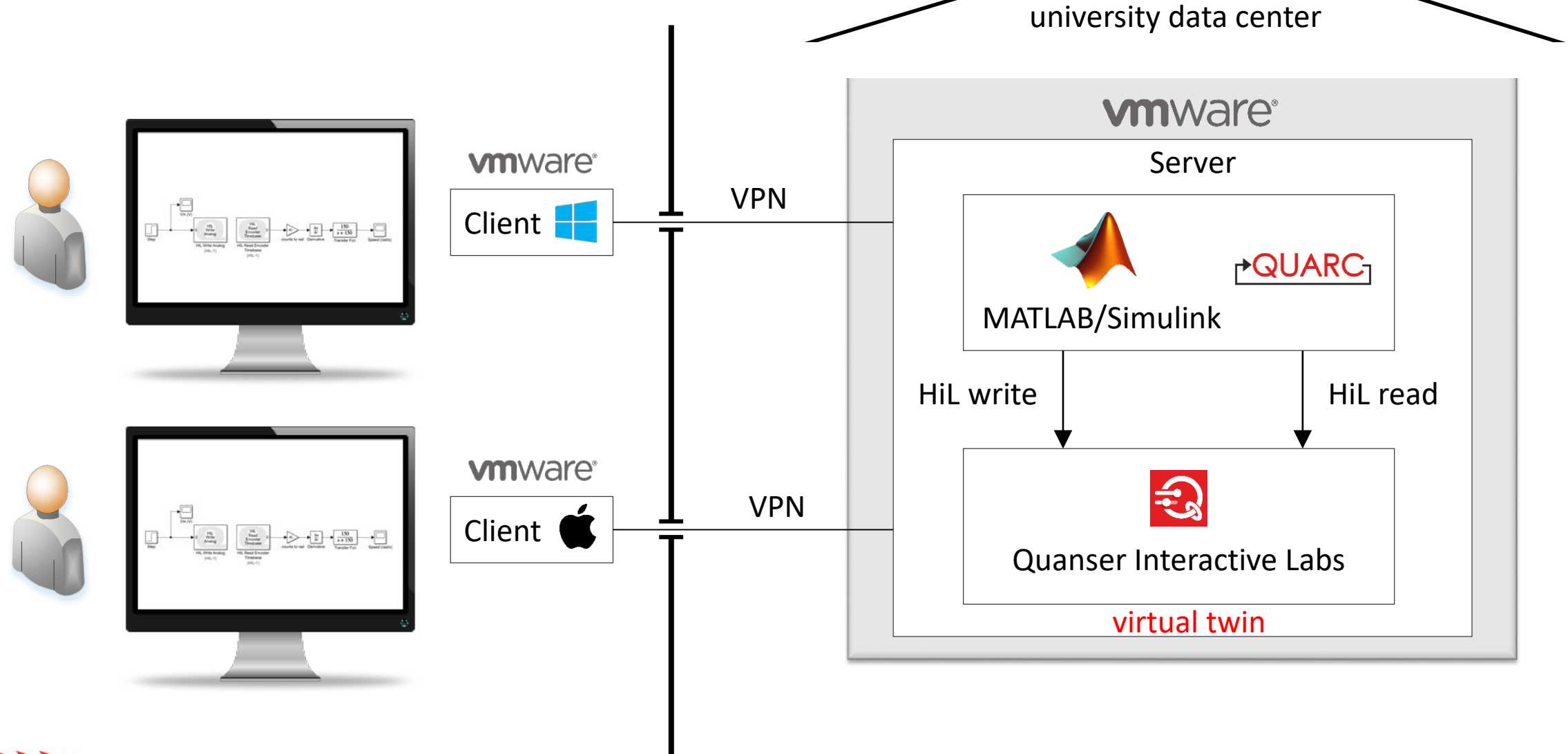
Key findings I

- In times of the pandemic, distance learning by means of virtual twins allowed for a significant reduction of lab attendance time without sacrificing content depth.
- On-campus lab experience is effectively supplemented by off-campus learning
- Students acquire experimental expertise at self-determined learning speed.
- Experience from two semesters has shown, that students very much welcome the distance learning format as a supplement to hand-on labs. This is why distance learning via virtual twins will be kept even if the pandemic is over and no lab access restrictions apply.
- The DistLab project at Stralsund University is set to significantly expand the idea of distance learning by remote labs and virtual twins.

Students provided valuable first feedback on the conversion of the control systems lab to include virtual twins for distance learning



In the future, the virtual twin as well as MATLAB will be **centrally hosted** by the university's data center



In the **future**, DistLab will extend the ideas of distance learning in control systems labs by implementing further pairs of real and virtual twins from Quanser

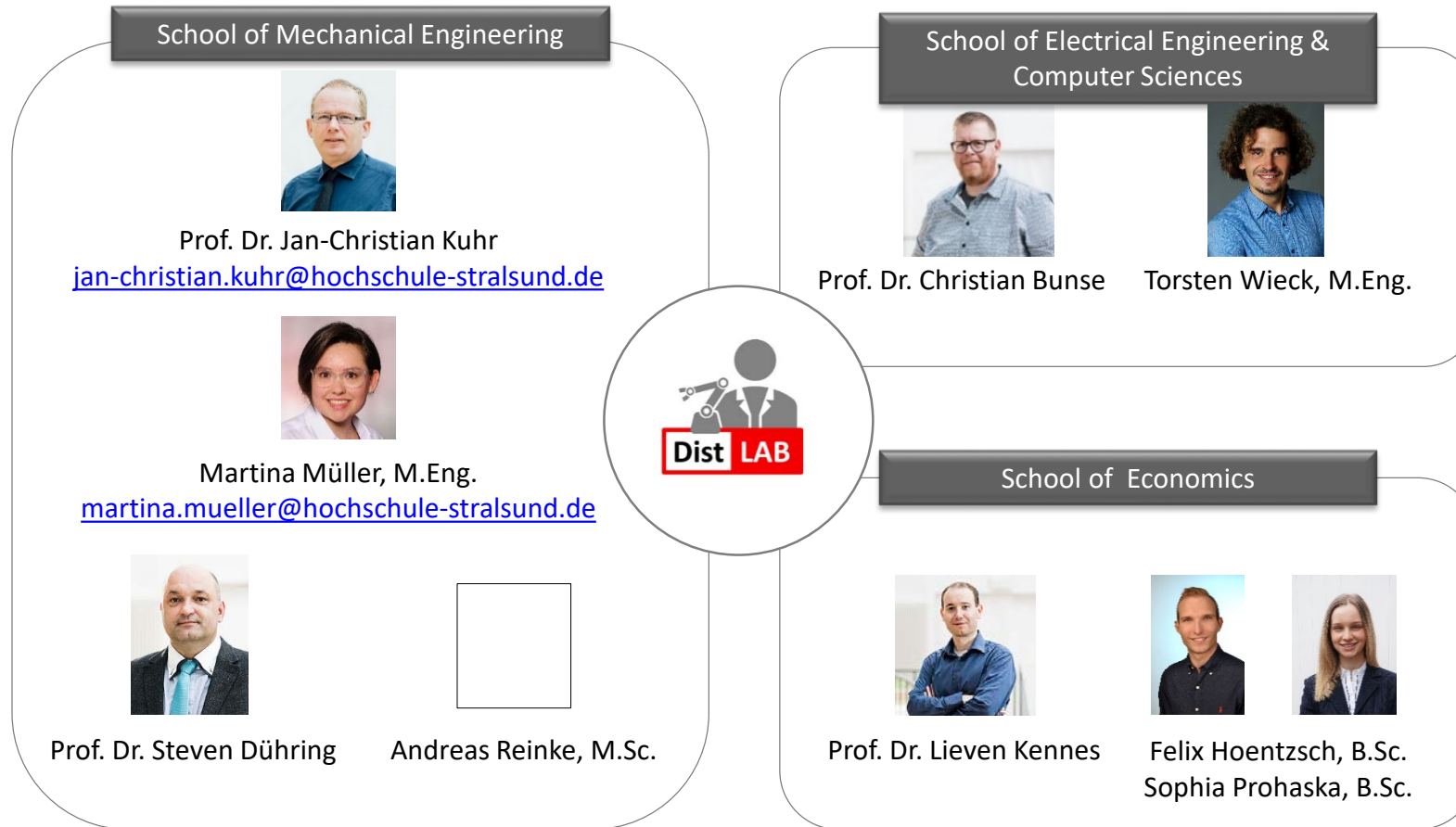


Pairwise real & virtual twins to be implemented

Key findings II

- In the current implementation, each student must install MATLAB/Simulink, QUARC and QLABs – the software for running the virtual twin – on his or her own PC. This leads to a number of issues:
 - a) QLABs requires Windows operating system. However, many students are running MacOS or Android, which are both incompatible.
 - b) The performance of the virtual twin has been found to strongly depend on the individual configuration of the team member's computers. This sometimes leads to dissatisfactory results. It may happen that two students, running the same Simulink code, are getting different outputs from the scopes.
- These issues call for a revised solution where all of the software is centrally hosted such that students only require a virtualization client – such as VMWare – to use these resources.

Thanks to the whole DistLab team at Stralsund University of Applied Sciences



Thanks to Melda Ulusoy, MathWorks, for valuable comments

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Thank you

