



Training Guide

Module 4

Technical Skills Upgrade

Implementation:

6th – 9th of May 2019

in Rio de Janeiro, Brasil

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1 Introduction

This module is dedicated to capacity building to achieve a “Technical Skills Upgrade”. The main focus will be laid on test facilities used in the automotive industry. So the training will start with an overview of test facilities in general and particular with the example of the proving ground of FH Joanneum and Hochschule Düsseldorf. The presentation will be continued answering the question how to build a test facility. Examples of projects conducted at the European partner institutions and examples of courses are presented. In a workshop the participants will have the opportunity to make up their minds how they advantageously could implement testing in class and in research.

At HSD, research and teaching are closely linked. The aim is to create a win-win-situation for all parties: the students, the teaching and the industry. In theory, that works as follows:

The industry provides its practical know-how and maybe also equipment and/or money. In contrary, the university provides theoretical know-how, as well as the laboratories and the manpower of the students. That, in turn, creates opportunities for both sides: The industry has the chance of innovation leadership by perhaps newly developed products and resulting patents and the university improves its reputation and gets many possibilities for cooperative projects and student exchanges or even PhD programs, as well as maybe financial means. The main benefit for the students consists in the possibility to collect practical experiences and work on real applications. In addition to that, both sides get to know each other better, especially with regard to possible future employment relationships. Therefore, industrial involvements and activities together with industry or in industry are part of the HSD concept.

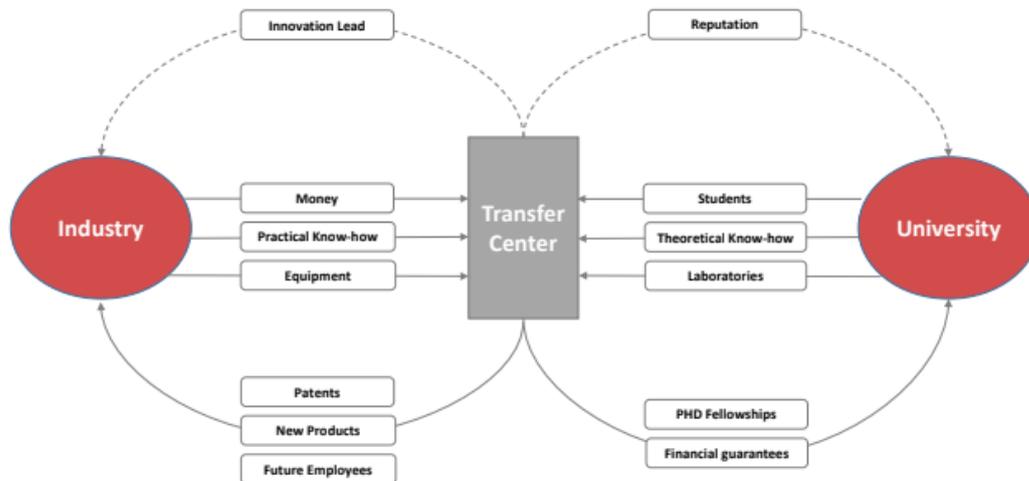


Figure 1 Transfer between university and industry

In the second trainings sessions, the specific lectures were already presented. In the following, the supporting facilities and the equipment at HSD are the topics.

Almost every department has its own laboratories and testing facilities. Focus of the ASCENT project and this training are of course the engineering and high technology departments, which are at HSD the departments of mechanical and process engineering as well as the department of electrical and information technology. Actually, they share the same building and also the facilities and the know-how are shared in some cases. All of the establishments are used by employees as well as by professors and students. Both, contract work and study work, are carried out there. In the following, the function, use and organization of the facilities will be presented more detailed.

1.1 Learning objectives

After attending this training, students (participants) should have better insight what the kinds of tests are state-of-the-art and what are their possibilities to make use of implementing testing facilities on their premises.

The training will show examples of testing facilities, how they are used and outputs are typical. The focus of this training will be laid on the planning and realization of testing facilities in an university. So the main features of any test cell and its environment will be presented. Hints will be given to avoid typical pitfalls. The funding process of the facility

will be described and the way how to earn money with testing, i.e. a typical project workflow from offer to invoice will be shown.

At the end of this training the participants will be able to implement and run convenient test facilities on their premises.

1.2 Methodology & Concept

The training will make use of an interactive didactical approach to get the participants involved as much as possible.

Each topic of the training will be presented briefly by the trainers to get all participant on the same level of knowledge. The presentation will be followed up by group activities or discussions. This way it will also be possible to get involved in individual questions that might come up some topics.

Furthermore, the topics and discussions itself are focused on contemporary questions and problems of current engineering processes, this should increase the motivation of the participants to contribute actively in the discussions and activities.

The trainers will also try to link the different topics together as much as possible, as this greatly contributes to get the necessary overview on the current trends in engineering.

2 Testing Facilities at FH JOANNEUM

The testing facilities are part of the institute for Automotive Engineering and comprises 12 test cells, a mechanical workshop and a car workshop. The test cells are: Chassis dynamometer, a climate chamber, a SHED chamber with refueling station, an acoustics laboratory, two 2-motors test beds and a 3-motor test bed for transmission testing, two engine test rigs, a skid resistance tester, a tilting test bed, a balancing rig, and facilities for material investigation.

3 How to build a test facility

When planning and building a test facility many issues have to be considered. The most important ones are outlined here.

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Planning started approx. in 1995. At the beginning the building was constructed and only a few test cells and laboratories were installed. The invest for the building was 17,5 billion EUR and the test rigs cost nearly the same. At that time the existing infrastructure was: Engine test bay with a water brake, engine test bay with transient AC dyno, chassis dynamometer, climate chamber, SHED chamber, acoustic laboratory without lining, electric/electronic laboratory, measurement technology lab, mechanical Workshop.



Figure 2 Proving ground of FH JOANNEUM in 2019

3.1 Test facility specification

There are 3 levels of specification

- Operational specification, i.e. what is it for?
- Functional specification, i.e. what does it consist of and where does it go?
- Detailed functional specification, i.e. how does it all work?

For establishing the operational specifications one should consider the following questions:

What are the primary and secondary purposes for which the facility is intended?

What is the geographical location, altitude, proximity to sensitive or hostile neighbors (industrial processes or residential), and seasonal range of climatic conditions?

What is the realistic range of units under test (UUT)? How are test data to be displayed, distributed, stored, and post-processed?

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How many individual cells have been specified, and is the number and type supported by a sensible workflow and business plan?

What possible extension of specification or further purposes should be provided for in the initial design?

May there be a future requirement to install additional equipment and how will this affect space requirement?

How often will the UUT be changed and what arrangements are made for transport into and from the cells, and where will the UUT be prepared for test?

How many different fuels are required and are arrangements made for quantities of special or reference fuels?

What up-rating, if any, will be required of the site electrical supply and distribution system? Be aware that modern AC dynamometers may require a significant investment in electrical supply up-rating and specialized transformers.

To what degree must engine vibration and exhaust noise be attenuated within the building and at the property border?

Have all local regulations (fire, safety, environment, working practices, etc.) been studied and considered within the specification?

Have the site insurers been consulted, particularly if insured risk has changed or a change of site use is being planned?

Consider discussion with:

- Local planning authority
- Local petroleum officer and fire department
- Local environmental officer
- Building insurers
- Local electrical supply authority
- Site utility providers.

Bear in mind in case officials overreact (which will be likely due to experience):

An engine test cell, using volatile fuels, is a "zone 2" hazard containment box. While it is possible and necessary to maintain a non-explosive environment, it is not possible to make its interior inherently safe since the unit under test is not inherently safe; therefore, the cell's function is to minimize and contain the hazards by design and function and to inhibit human access when hazards may be present.

When thinking of the future use of the test facilities the following issues will support the decisions to be made:

- The installed base, relevant to your own industrial sector.
- Does one or more of your major customers exclusively use a particular control system? (Commonality of systems may give a significant advantage in exchange of data and test sequences.)
- Level of operator training and support required.
- Has the control system been proven to work with any or all of intended third-party hardware?
- Is communication with the control modules of the units under test required and is it possible via the designated “comms bus”?
- How much of the core system is based on industrial standard systems and what is the viability and cost of both hardware and software upgrades? (Do not assume that a “system X lite” may be upgraded to a full “system X”.)
- Requirements to use pre-existing data or to export data from the new facility to existing databases.
- Ease of creating your test sequences.
- Ease of channel calibration and configuration.
- Flexibility of data display, post-processing, and exporting options.

3.2 Request for tenders

This process is unavoidable when funding for any public body, e. g. a public university. Having established the beforementioned specifications the following documents will have to be prepared:

- Part 1: General terms and conditions
- Part 2: Terms and conditions of contract
- Part 3: Schedule of services (Technical Specification)

Part 1 deals with the terms of tendering procedure: Start, end, acceptance, etc. Further legal basic information is put down on paper: How to deal with questions, the way of communication, etc.

Part 2 contents issues as form and content of documentation, warranty, acceptance and so on.

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Part 3 describes in detail what the deliverables are.

It is strongly recommended to prepare the following documents as printed forms in advance. Besides this list acts as a useful checklist and records of the procedure:

1. Register of arrived offers
2. Attendance list for opening of offers
3. Checklist for opening of offers
4. Memorandum in writing of opening of offers
5. Single record for each offer
6. Evaluation sheet, e. g. an Excel file
7. Acceptance of tender.

3.3 Checklist for planning

The following topics will have to be addressed when planning any test facility in greater or smaller detail:

1. Description of UUT (information only): Purpose of tests: Education, R&D, type approval. Frequency of tests. Customers.
2. Building: Noise protection. Electric installation. Floor, pan. Crane runway. Fire protection. Gas alert system. Tank system, storage system.
3. Power Absorber: Static, dynamic. One, two or four quadrant. Torque flange. Rrpm sensor. Lock-out device. Substructure. Frequency inverter, controller.
4. Mechanical components: Flooring and subfloor construction. Rigging of UUT. Shaft connections. Shaft guard. Brackets, supports.
5. Cooling systems: Cooling of power absorber. Cooling of frequency inverter. Conditioning of combustion air. Conditioning of fuels. Conditioning of lubricants.
6. Supply with operating resources: Cell ventilation. Combustion air supplies. Exhaust gas system: OEM type, suction funnel, volume flow, trap, silencer, fire protection. Fuel supply: Pressure, piping, fittings, leakage testing, fire protection. Shop-air supply: Compressor, piping, connections. Water supply: Pressure, piping, fittings, leakage testing. Disposal of pan sump.
7. Electrical design requirements: Electrical signal and measurement interference. Earthing system design. Layout of cabling. Integration of AC dynamometer systems. Power cable material and bend radii. Electrical power supply specification. Electrical cabinet ventilation. Safety standards.
8. Measurement instruments: Range, accuracy, dynamic properties, data acquisition (analog, digital): Force sensors, displacement sensors, acceleration/vibration measurement. Torque measurements: Torque flange, in-line shaft, trunnion-mounted dyno. Speed measurements: Speed, crank angle sensors. Fuel consumption. Combustion air mass flow. Blow-by gas flow. Exhaust gas analysis, soot, opacity, particle mass, particle number. Pressure measurements. Temperature measurements. Indicating systems: Combustion analysis. Wear testing: Radionuclide technique (RNT), non-RNT. Weather data.
9. Operation: Machinery and control system: Starting, stopping, manual control, "unmanned" running, emergency stop function, computerized monitoring of test cell, service status displays. Open-/ closed-loop control of engine and power absorber. Test control software,

test sequence editing. Data acquisition and transducer chain: Channel names, calibration, transducer boxes.

10. Documentation
11. Regulations to be adhered to
12. Packing, transport
13. Construction, installation, commissioning, inspection and approval
14. Briefing and training (course, in-house, on-the-job).

3.4 Summary and hints

- Plan effort of several years or > 1000 working hours
- Building and machinery is treated separately, i.e. several requests for tenders
- Start investigation (state of the art, costs, lead time) ahead(!) of official request procedure: Afterwards communication is forbidden
- The more accurate the request for tenders (refert to Part 3) the less surprise what you get
- Keep chronological records of all important steps, statements and decisions
- You may need several attempts
- Good luck!

4 Layout of a test chamber

Testing and proving

There are various methods and tasks existing when it comes to testing and proving of vehicles and their subsystems, Tab. 1.

Table 1 Overview of testing and proving

Method \ Task	Real road	Proving ground	Test rigs	Dummy in the loop	Software/ hardware in the loop	Man in the loop	Virtual rigs
Overall vehicle	Long-time tests	Functional tests	Aerodynamic, noise,...	Crash	Vehicle dynamics	Driving simulation	Energy management
Systems	Complex systems	Driveability	Engine, brakes,...	Pedestrian safety	Power grid, control units	ADAS	Mock-ups
Assemblies	Alternating conditions	Suspension tuning		Exhaust systems	Suspension control unit	Ergonomy	Functions of subsystems
Parts Materials Operating m.	Behaviour under service conditions	Behaviour under defined conditions	Behaviour	In-vitro and in-vivo tests	Fault detection of parts	Olfactory tests	Geometry of parts

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Further testing can be distinguished by functional tests versus long-time tests, component tests vs. assembly/system tests, laboratory and rig vs. driving tests, model tests vs. 1:1-tests and so on.

Test facilities

According to the vast variety of testing methods and tasks there are countless testing facilities and rigs. From a small mobile damper dyno to a huge full-scale wind tunnel ranges the palette. The output can be a single number, a digital result (yes/no) or multi-page report. The different systems necessary for running and measuring an combustion engine can be seen in Figure 3 as an example.

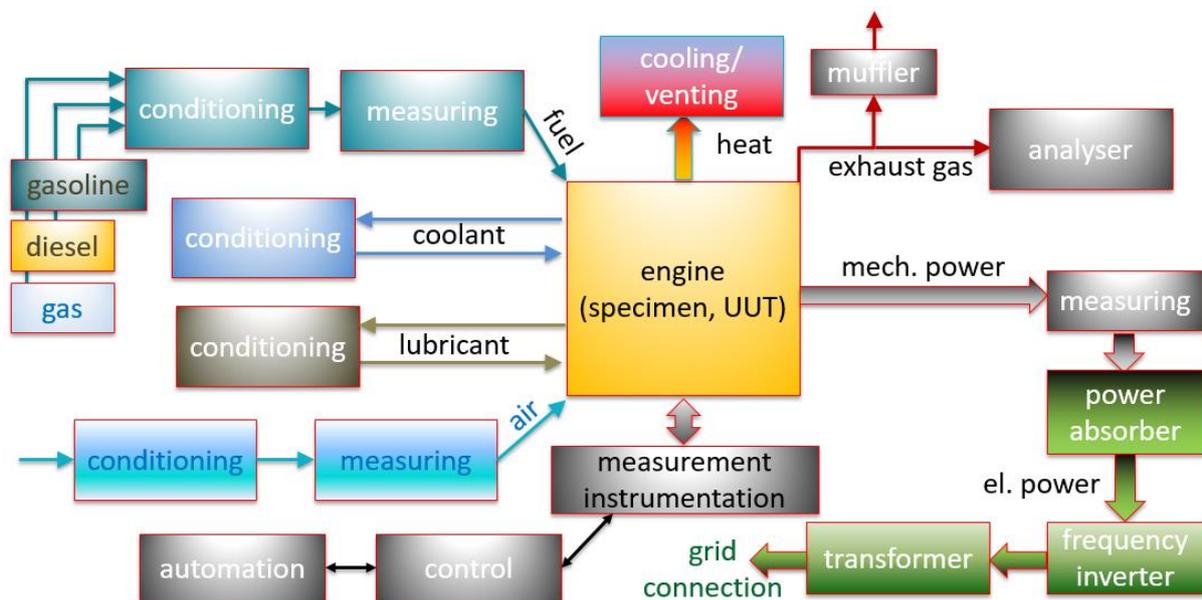


Figure 3 Functional view of a engine test rig

Test cell

Cell sizing is critical. Two main considerations may help:

- A cramped cell is a permanent source of danger and inconvenience.
- A too large a cell in contrast is prone to be misused as storage space.

As a rule of thumb the unobstructed walkway should be 1 m wide, all round the rigged UUT.

Figure 4 demonstrates as an example a typical test cell floor plan for an engine test rig.

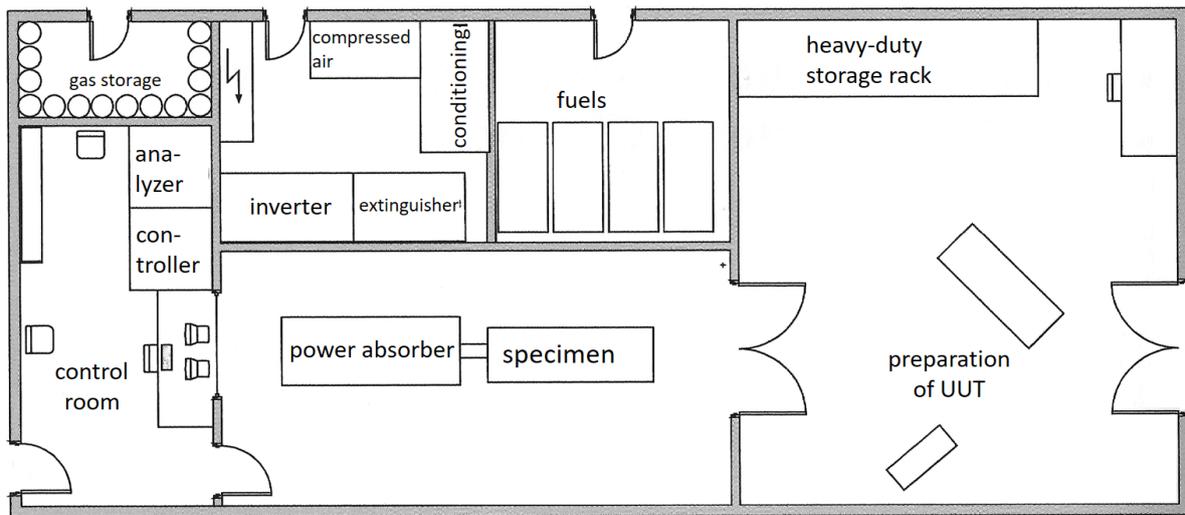


Figure 4 Floor plan of typical test cell.

5 Examples of projects conducted at FH JOANNEUM

During the presentation several projects will be presented. The projects are distinguished by their origin: Industrial, R&D related and educational based projects.

6 Management of a test facility

Based on a typical workflow from the offer to the final invoice the tools and steps for managing test related projects will be introduced. An online survey helps to understand the needs of customers and to realise one's strengths and weaknesses. An accreditation is worth to be considered particular in the case that cooperation with OEM's is planned.

2 The laboratories and testing facilities at Hochschule Düsseldorf

This chapter will be about the equipment of HSD and how it is organized and financed. At first, different types of facilities and equipment are presented. After that, the process of purchasing and organization at HSD is shown.

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Computer labs

The so called “computer labs” are mostly used for teaching, for example CAD or ERP classes. Those rooms are usually locked but can be opened on demand, for example if the students want to practice by themselves or have to work out certain projects.



Figure 5 computer lab

Machine hall

All of the department’s machines are located in the machine hall, which is located on the ground floor of the building. Both, contract work and study work, are carried out there, for example in form of metal-cutting, grinding or milling activities. In addition to that, there are also many testing facilities, for example for exploring cutting techniques in an agricultural context. Many employees and doctoral students work there, but also students during practical training sessions for example.



Figure 6 machine hall

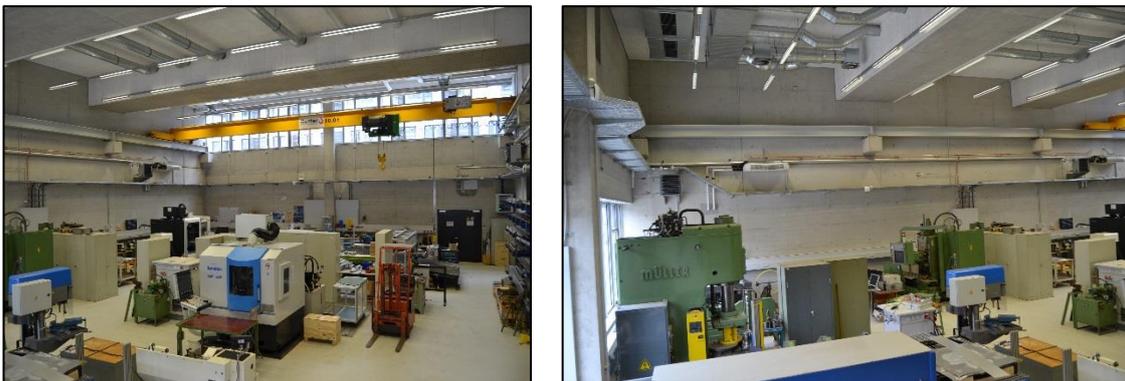


Figure 7 machine hall

Laboratories

Laboratories mostly belong to institutes or research centers and are often used for meetings as well as for lectures and for practical training sessions, too. Prof. Niemann for example manages the institutes “Flix” and “FMDauto”.

Flix is an institute for production management and optimization. On the one hand, there are tools to visualize, like a drone, an eye-tracker and associated software and on the other hand there are facilities to demonstrate, like the miniFab as Industry 4.0 example. The focus is especially on visualization. The equipment of the Flix laboratory will be explained in detail in a later chapter.

In addition to this guide, a guide for the drone and the associated software is provided.

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Figure 8 Flix laboratory workstations



Figure 9 planning table

FMDauto is an institute for product development and innovation. The main topics at the moment are cutting techniques in agricultural context. For that, the institute has several testing stands and measuring devices, equipped with measurement technologies, for example sensors. Currently, two doctoral students are working on that topic and many students for smaller projects or for their final papers.

In addition, there are many other laboratories, for example for environment measurement techniques and chemical process engineering. Furthermore, there is the so called “Competence Center Automation Düsseldorf” at HSD, short CCAD. Besides, there is the laboratory with the learning factory, which is supervised by Prof. Langmann from department electric and information management. The learning factory shows the process of a filling plant

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for little bottles, inclusively their quality control and their packaging. On the one hand the students can learn there about process flow and on the other hand about programming and process controlling.

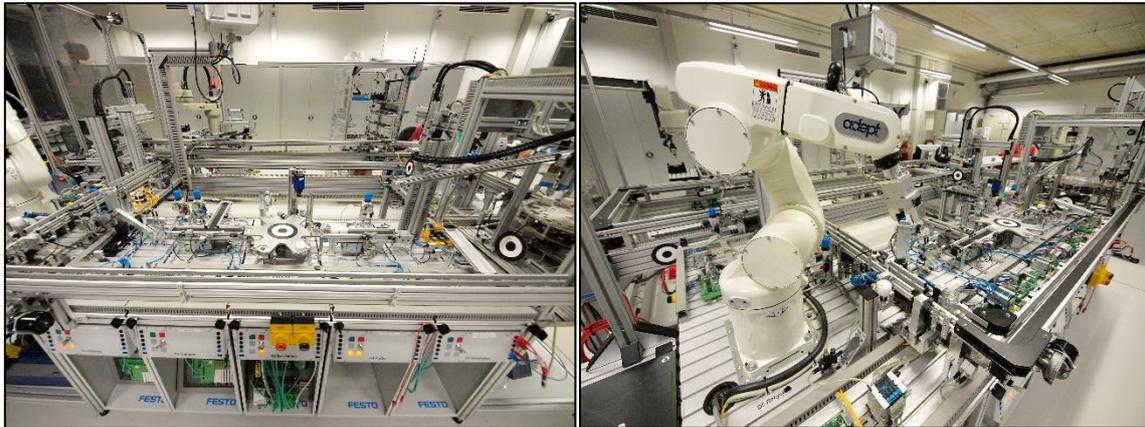


Figure 10 FESTO learning factory



Figure 11 FESTO learning factory

In addition, also events are created, which involve the three in the beginning managed parties. For example the university organizes “open house days” where especially the laboratories can be visited by (potentially new) students and other externals. Also, the professors organize for example excursions for the classes to the firms, where both parties can get to know each other. Or the students can go to fairs for example. Sometimes, if the professors have good connections to the industry, they organize some “take-over” lessons, where the students are taught than by an industrial partner.

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2.2 Financing

There are different possibilities for financing the equipment of laboratories and other research institutions. One possibility consist in third-payed funds, like the ASCENT project belongs to one. Besides, the professors get a start budget at HSD when they start their job there. From that budget they have the possibility to buy equipment. Prof. Niemann for example bought the planning table for the Flix institute. Of course, also internal savings from professors or departments can be used for that. Another possibility would be writing an application for large instruments and equipment or acquisitions requests. The last named, together with a third-payad funding, was used to buy the FESTO learning factory. For very big project like that, departments can also join forces. Also possible are donations or gifts of companies and sponsors. Not uncommon, it can be a nice and relatively cheap advertising opportunity for the firms to put their name on products in the university.

2.3 Organization

The process of purchasing and equipping is standardized and prescribed by the university. At first, an applications must be written and handed in with several offers. Next, those documents will be controlled by the administration. When the laboratory is fully equipped, it is mainly managed by the supervising professor and his or her employees.

3 Examples of results

In the following, a few successful projects are presented.



Figure 12 Tic Tac Toe and Black Jack

On first sight, the two examples above may not look like serious industrial applications, but actually, there are similarities. Both applications deal with collaborative robots. Besides, in both

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cases the robot must analyze the situation and chose its next action based on that. In addition, the robots had to be taught, where the ground is and to handle the pencil respectively the cards with care. By building those applications, the students learned about programming robots and for the firm that means experts with those robots and not least promotion for them.

4 Detailed analysis of the FLIX laboratory at the Faculty of Mechanical and Process Engineering

In this chapter, a detailed analysis of the laboratory equipment of the FLIX (Laboratory for Lifecycle Excellence) laboratory is given. The FLIX laboratory is located in the faculty of machine and process engineering of the University of Applied Science Dusseldorf (HSD). On the one hand, the main research area lies in the area of production management, optimization, visualization and simulation, and on the other side associated business innovations, such as smart services. The focus of this chapter will be on production visualization and simulation, eye tracking, AR & VR and a Mini Factory for the explanation of Industry 4.0.

4.1 Production visualization and simulation

For a better visualization of production environments and a realistic simulation, they are photographed by a drone and a software automatically creates a 3D model. This can be integrated into simulation- and planning software or used as a demonstrator.

Model overview

A drone is an unmanned aerial or underwater vehicle that flies autonomously or remotely. A distinction is made between a large number of different designs. In addition to the currently most common version as a multicopter, there are, for example, even fixed-wing, tilt-wing and unmanned helicopter (DHL Trend Research 2014). Above all, the simple handling and the dimensioning as well as the costs are decision criteria here.

Laboratory equipment

Due to the research focus on process optimization and simulation, a way should be found to easily visualize production environments for a graphic simulation. 3D scanners were not considered due to the complex and time-consuming pre- and post-processing and because they are complex to operate. In principle, there were two software solutions, which can

guarantee 3D visualization in industrial quality. The Autodesk ReCap and the 3DFZephyr, we decided to use 3DFZephyr because Autodesk is a cloud-based solution and not all companies currently consider cloud services as secure. With the requirement that aerial photography is necessary for optimal 3D models, we decided to use a drone. The company DJI is the world leader in the field of drones and the Phantom 4 Pro is currently the optimal drone in terms of safety in flight (by countless sensors) and quality of the camera.

Real application examples

At present, an exemplary user scenario for industrial applications is being prepared. The aim is to visualize production halls or machines in a realistic manner for training and planning purposes. For this case, the machine hall of the University of Applied Sciences Dusseldorf is being visualized in order to further develop competencies and to familiarize students with the use of the software and hardware.

Experience shows that especially a limited space and the lack of GPS signal in closed rooms leads to difficulty keeping track in the drone control. Furthermore, bad lighting conditions (windows, reflections, shadows, etc.) are responsible that some images in the software cannot be assigned. Here, individual images must be shot and added later or the images have to be post-processed.

Another application scenario, in which drones are used at the HSD, is the measurement of pollutant levels in the air. A drone equipped with gauges is used to at HotSpots in Dusseldorf to determine values.

Further application possibilities

In the distribution of areas in which drones are used, becomes apparent that the planning and maintenance of large areas, such as infrastructure or agriculture, are the main application fields. Further examples of application are (PwC 2016):

- Planning and Surveillance of Energy, Infrastructure, Construction Sector and Telecommunication
- Agriculture, Forestry and Mining
- Environmental Protection
- Emergency Response, Police Insurance and Development Aid
- Media and Entertainment like Film and Photography
- Implications in Logistics: Intralogistics, Urban First and Last Mile, Rural Delivery

4.2 Eye-Tracking

Fields of application for eye-tracking technology in industrial environments are virtual reality, market and consumer research, professional performance and user experience and interaction.

Eye tracking systems can generally be divided into two areas; screen-based eye trackers and head-mounted eye tracker. The latter one is suitable for production-related application because of their flexibility in utility, place unbound and the person can still move freely. On a superficial view, the functionality of eye tracking systems is as follows (tobii dynavox):

- The eye tracker sends out near infrared light
- The light is reflected in the eyes
- Those reflections are picked up by the eye tracker's cameras
- Through filtering and calculations the eye tracker knows the direction in which the person is looking

Laboratory equipment

Previously, we had Tobii eye tracking glasses in use, but this was due to complicated calibration not suitable for permanent industrial use and we have switched to SMI. The SMI glasses can be calibrated to the user within a few minutes is easy to use and provides reliable data, which can be used for further statistical evaluations. However, we now expect the sales



Figure 13 Existing and planned eye tracking systems of the Flix Laboratory

launch of the Microsoft HoloLens 2, which sets new standards in VR with combined eye tracking.

Application examples

The HSD has conducted several projects with argument reality and eye-tracking eyewear. The following examples come from the automotive sector.

In the first project, the final quality control of a paint shop of a major European producer of transporters has been analyzed. The objective was to minimize the time and effort needed to check the transporter for paint damages and to reduce the failure rate of not seen damages to the paint. For that the sequence of how the quality control inspection is performed, is analyzed,

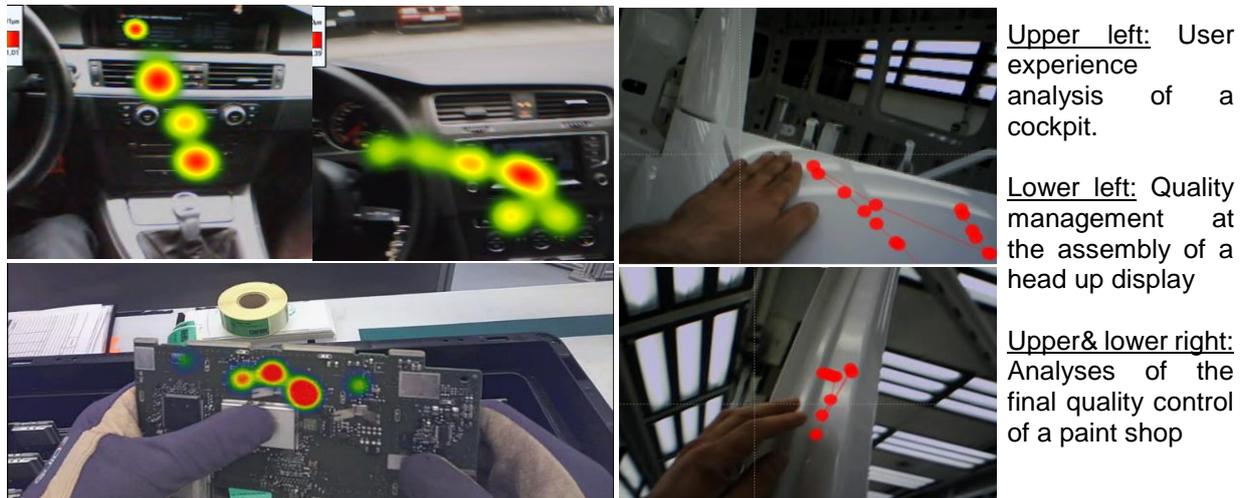


Figure 14: Examples of eye tracking applications in industry

as well as the control length of sensitive areas of the transporters, where damages of the paint are often found at a later quality control (Niemann, J. & Schlösser, M. & Fussenecker, C. 2016).

Findings of the data analysis from the 18 test employees:

Itinerary used is not equal to the one on the standard work sheet

„Practice“ shows a more user-friendly itinerary

Visualization shows that most parts have not been controlled properly

Too less time has been spent on checking “sensitive” areas.

In another project, an automotive supplier for head up displays was analyzed. The most important finding was that the worker used dirty gloves to assemble electronic components. A student team carried out a project on the user experience in cars. These determined what the first impressions in the car cockpit are.

Further application possibilities

Further application possibilities are workplace improvement from the worker's point of view, occupational safety (perception of safety boards etc.), quality control, design studies and usability.

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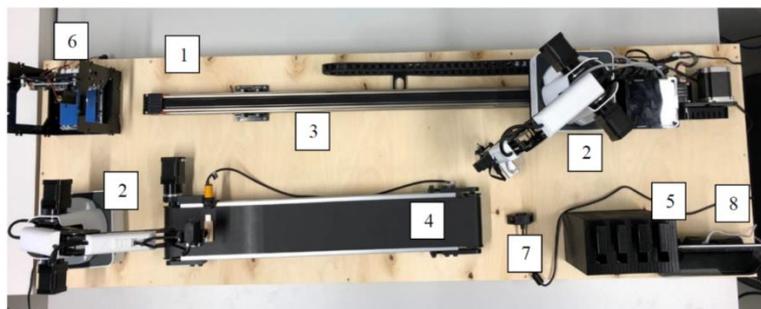
4.3 Minifab

After the short introduction of the Minifab in WP 2 of the Ascent project, this chapter will focus on the structure and application scenarios. The Minifab serves to convey the fundamentals of Industry 4.0 to interdisciplinary teams and non-automation technicians (Niemann, J. & Schlösser, M. & Fussenecker, C. & Turek, S. 2017).

Laboratory equipment

The project of the miniature factory was implemented to make production tangible and to show the principles of Industry 4.0 with a practical example. By running through different production steps, the interaction and communication of the single factory components can be illustrated. In addition, the students are led to the procedure of software development.

The miniature factory basically consists out of nine major components: a base plate, two robots, a sliding rail, a conveyor belt system with photoelectric switch, a storage system, an engraving machine, an USB port and a central control unit (see figure 3).



Number	Component	Task	Number	Component	Task
1	Base plate	Basis	5	Storage system	Raw material supply
2	Robots	Moving parts	6	Engraving machine	Engraving HSD logo
3	Sliding rail	Range extension	7	USB Port	Data transmission
4	Conveyor belt system	Connection workstations	8	Raspberry Pi	Central control unit

Figure 15: MiniFab: A miniature factory for Industry 4.0 teaching purpose

As interface and computing unit a Raspberry PI in combination with a touch panel are used. The Dobot Magican is a robot for teaching purpose with an open source software. The program and the visualization are realized by Codesys. For this purpose, the communication protocol is transformed into easily usable program modules, which can be translated into different languages such as structured text or function block diagram.

Real application examples

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As shown in figure 4, there are many areas of application such as layout planning, automation, safety concepts, production visualization and optimization as well as the possibility to work in interdisciplinary teams from programmer to production manager.

As shown on the left in figure 4, the layout was analyzed and optimized, based on a simulation software. The final version of the layout is the basis for the current miniature factory. Thanks to the continuous improvement process and comparison of the individual variants, the overall transport route could be optimized to a minimum of 1.1 meters.

Another project dealt with the security concept. For this, the components have to be considered differently. Robots are with a maximum force of 18 N far below the limit according to EN ISO 10218 standard. Thus, the factory can theoretically be operated without a physical deviation between human and machine as severe injuries are excluded. However, the risk of injuries should not only be minimized but also completely ruled out. Therefore, it is recommended to use additional sensors which bring the process to a standstill as soon as a person comes too close. One of the main security risks is the engraving machines, the laser have to be shielded from the environment but need to be accessible for the robot.

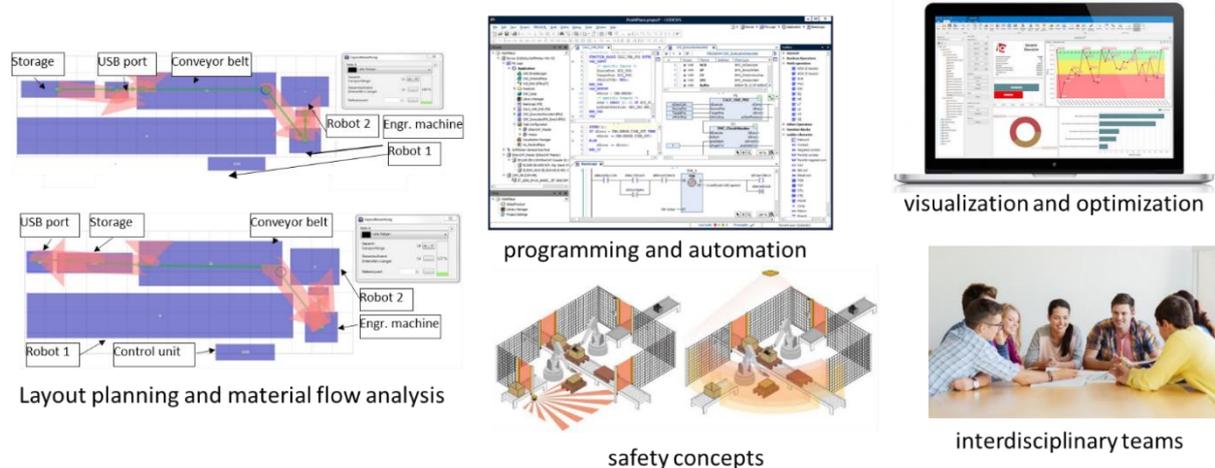


Figure 16: Application examples of the MiniFab

Currently we are creating a code to control the MiniFab including third-party devices through Codesys. For this, modular program modules are developed, which can be derived from the Dobot Communication Protocol. These can then be linked in the logic and easily adapted if necessary. The learning depth of the users can then be individually adjusted and include either adjustments at the lowest program level or only logical links. Due to the direct application, the result is immediately recognizable. Thus, Scrum approaches to project management can be realized well.

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Further application possibilities

The target is a mobile learning environment, which can be used in the industry, research, teaching and as a demonstrator. The areas of application are extended to the realization of further Industry 4.0 applications, such as Smart Servicers. If required, the MiniFab should be customizable and modular combinable in order to the customer needs.

8 Mechatronic Teaching

„Mechatronics is the synergetic integration of mechanical engineering with electronic and intelligent computer control in the design and manufacturing of industrial products and processes“ → definition in IEEE/ASME Trans. on Mechatronics (1996). The Synergetic Integration of mechanical and electronic engineering as well as intelligent computer control systems brings a better solution - figure 4.

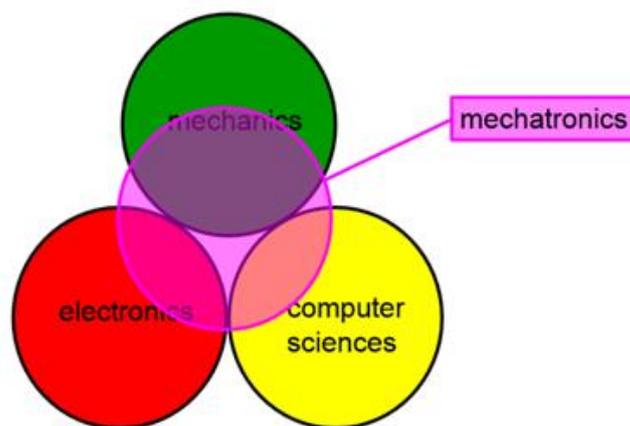


Figure 4: The 3 special fields of mechatronic

This combination is important for automotive engineers, because a modern vehicle is a complex mechatronic system. It consists of a lot of mechatronic subsystems. E.g.: Antilock brake system (ABS), Electronic Stability Control System (ESC), Engine Control Unit and etc. It is very important, that the different Subsystems are having the possibility to communicate with each other. Therefore, bus systems like CAN, Flexray, LIN are still in use.

Mechatronic Education at FH Joanneum – Institute of Automotive Engineering

In the 4th Semester of the bachelor course the laboratory tutorial “Mechatronic Laboratory” will be teaches. The aim of the Laboratory Tutorial is to understand, how a mechatronic system works. Therefore, the students must work with an embedded system. They reach the goal with the following steps:

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- Couple mathematical/physical knowledge with software technology
- Understand imperfections and limits (A/D-, D/A converter, quantizing effects, cycle time influence)
- Encoding of signals (Data types, fixed point arithmetic)

The main task is to develop automotive software for an embedded system during the following steps:

- Apply the V-model to mechatronics – figure 5.
- Using requirements to define the product before design phase.
- To understand Model-based software development methodology using Matlab/Simulink.
- Ability to develop embedded software: Step by Step Model in the Loop (MIL), Software in the Loop (SIL) and Hardware with target code.

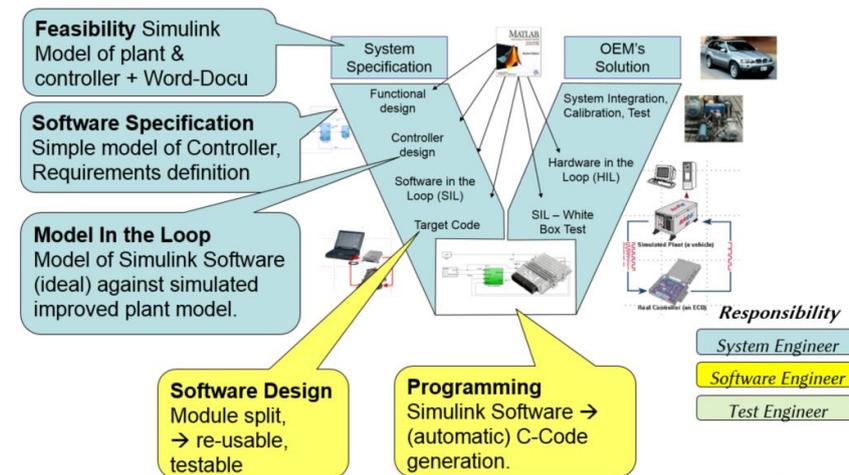


Figure 5: V-Model for mechatronic applications

MIL is the first step. The model describes a “perfect” reality. For example, in MIL are no effects out of the Data Acquisition (DAQ), ECU-Cycle time and so on will be considered.

SIL is the logical consequence out of MIL, with the extension of all “imperfections”.

Throughout the separation in MIL and SIL is it possible, to test the virtual model in an early state of the development process.

In both cases MIL and SIL, the environment (motor, gearbox, clutch...) is virtual given and will be simulated by a plant-model.

It is important to understand the application process for an embedded system. This is normally based up on a fieldbus communication between an application software (CANape,

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INCA...) and the target device (ECU) as well as a standard calibration protocol, for example CCP (CAN Calibration Protocol).

According to the V-Model, the development process starts with the system specification. A detailed description of all ECU input- and output-signals as well as the dynamic ranges is important. Additional hardware, for example for sensors or actuators, must be recorded. For a better orientation, a graphical discretion might be useful – figure 6.

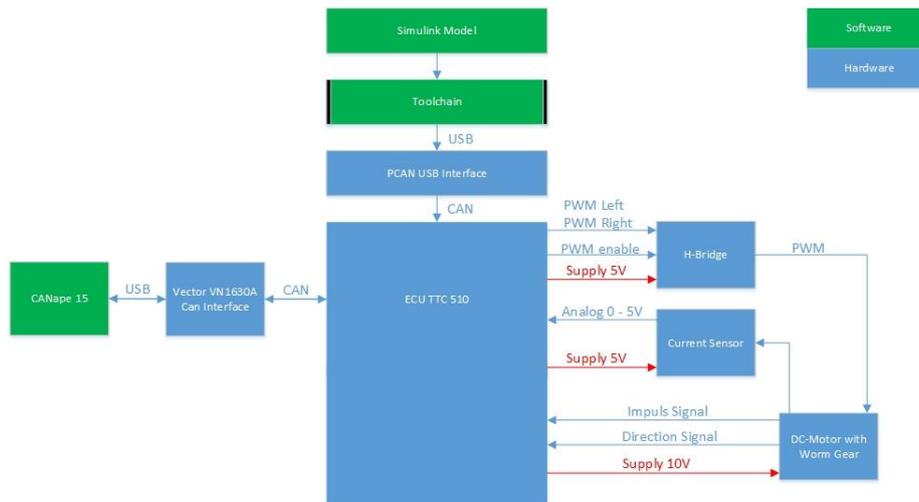


Figure 6: Schematic representation

The task of automotive engineers is functional development. The software to control the ECU comes directly out of Simulink. That requires that the all necessary software products (compiler, linker, downloader...) are installed and works correctly.

A Simulink-library, fitting to the ECU, can be used to select inputs- and output ports. This blocks can directly have imported to the Simulink-model. After virtual testing against a plant-model, the software generation process out of the Simulink-model can be start. The result is a C-code. The compiler, suitable to the target device, creates the *.hex-file. This is the result and can now uploaded to the ECU – figure 7.

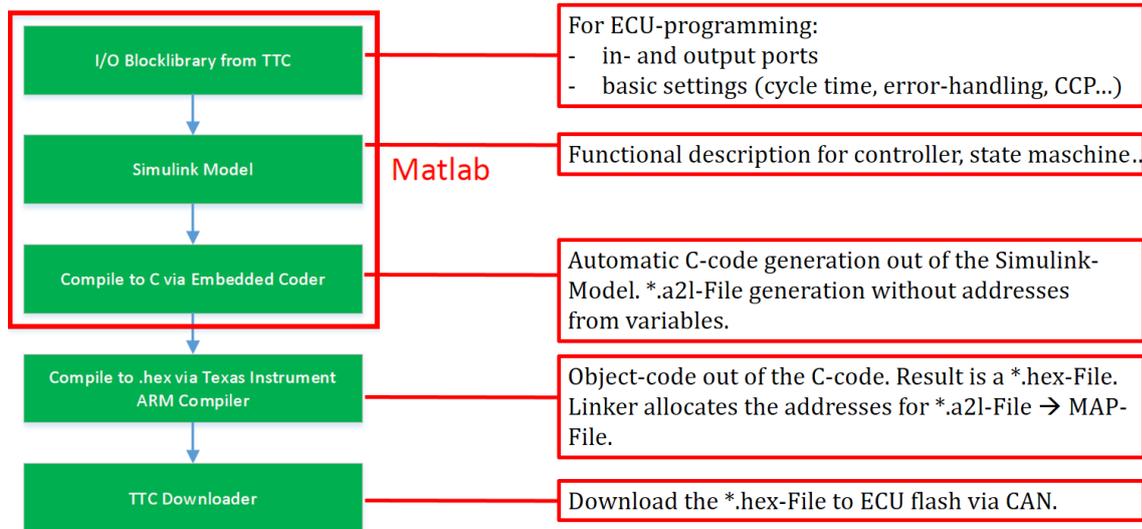


Figure 7: Software tools in use

To calibrate the ECU with CCP or XCP (extended calibration protocol) a *.a2l-file is needed. The *.a2l-File, according to the ASAM2-standard, is mainly important for the application software (in figure 8 *CANape*). The addresses, datatypes and scaling of variables are stored in the *.a2l-File.

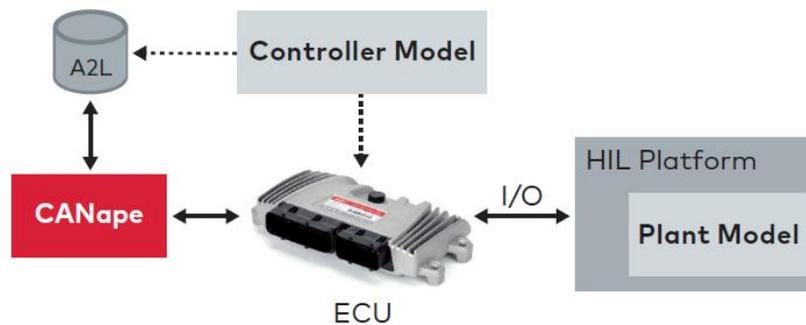


Figure 8: Example of an application setup [1]

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Glossary

- UUT: Unit under test. The specimen which will be investigated.
- OEM: Original Equipment Manufacturer. The enterprise responsible for branding, designing, assembling and selling cars.
- Planning table: screen in the size of a table to visualize for example layouts of machine halls
- Learning factory: factory only for illustration and demonstration
- AR: augmented reality
- VR: virtual reality
- FLIX: Laboratory for Lifecycle Excellence at the Faculty of Mechanical and Process Engineering of the University of Applied Science Dusseldorf
- HSD: University of Applied Science Dusseldorf