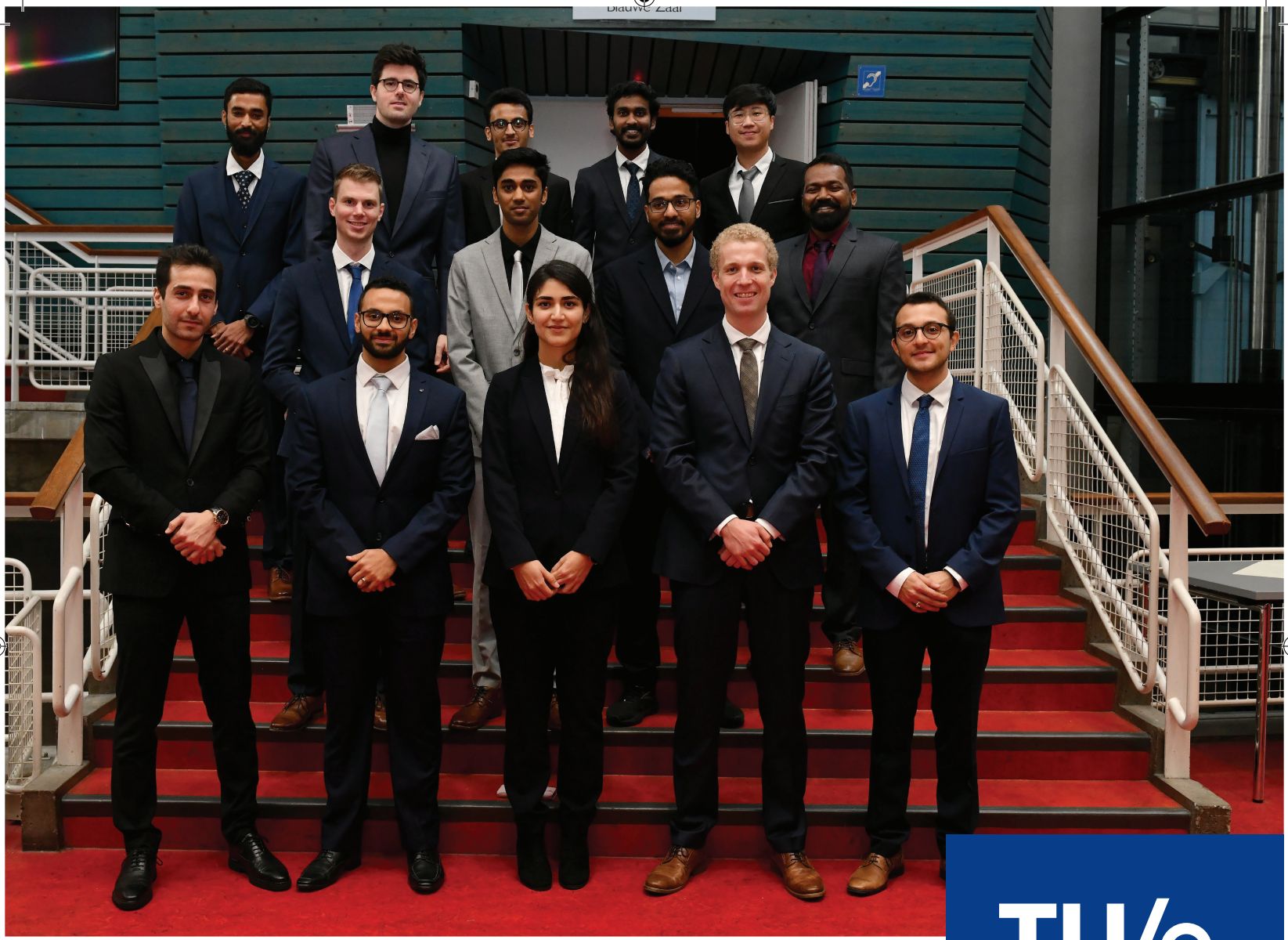


TU/e

EINDHOVEN UNIVERSITY OF TECHNOLOGY

ENGD PROJECTS 2022

Automotive/Mechatronic Systems Design

The EngD Automotive Systems Design, existing since 2011, is an accredited and challenging two-year doctorate-level engineering degree program. Since 2015 the subtrack Mechatronic Systems Design is part of this program. During these programs trainees focus on strengthening their technical and non-technical competencies related to the effective and efficient design and development of technologies and applications for modern high-tech automotive and mechatronic systems. In particular, there is a focus on the multidisciplinary design aspects of project-based research and engineering in high-tech automotive and mechatronic systems, reflected in the key contributions by four TU/e departments. For more information please visit tue.nl/asd.

Automotive/Mechatronic Systems Design - EngD Projects 2022

DR.IR. CAMILO RINDT
IR. RISKE MEIJER
ELLEN VAN HOOF-ROMPEN, MSC

The 2020-2022 generation ASD/MSD trainees

The EngD-program Automotive/Mechatronic Systems Design is embedded in the department Mathematics and Computer Science, and supported by the departments Mechanical Engineering, Electrical Engineering, and Applied Physics. The program is also supported by the Eindhoven Artificial Intelligence Systems Institute (in particular by the team of the High Tech Systems Center). The program is driven by the rapid changes in the Dutch high-tech ecosystem with huge challenges in terms of multidisciplinary product and process design and engineering.

With great pleasure we present to you the results achieved by the fourteen graduates of our program, seven of whom are in the track of Automotive Systems Design, and seven in the track of Mechatronic Systems Design. These graduates started the program end of 2020.

The variation in disciplines is reflected in the 14 graduation projects that are presented in this booklet. The subjects of these projects are in the fields of automated driving/parking, smart vehicle services regarding energy/fuel consumption, electric busses, drivetrains, Model Based Systems Engineering, measurement systems, perception systems, system control, vehicle-level architecture, and digital twinning.

Most of these EngD-projects were funded and proposed by the high-tech industry, of which a part was co-funded. Some of the projects were part of a funded consortium project. One of the projects was performed internally.

As you will notice the projects are diverse, complex and challenging. They require our trainees to deliver products and designs that meet high demands in a multidisciplinary setting. We are proud that our trainees live up to the high expectations from industry. We wish them all the best and a successful career.

In case you are also interested in an EngD-project within our program, please, contact **asd@tue.nl**, and we will organize an introduction meeting with you.

Camilo Rindt	Riske Meijer	Ellen van Hoof-Rompen
Scientific Director	Program Manager	Management Assistant


THE NETHERLANDS
LITHUANIA
GERMANY
BELGIUM
POLAND
CZECH REPUBLIC
UKRAINE
FRANCE
AUSTRIA
MOLDOVA
SWITZERLAND
HUNGARY
ROMANIA
CROATIA
SERBIA
BULGARIA
PORTUGAL
ITALY
NORTH MACEDONIA
SPAIN
GREECE
CYPRUS
2158
WORLD W
EINDHOVEN
UNIVERSITY OF
TECHNOLOGY
TU/e

"A concept like Buurauto-Noom is not available today or tomorrow, but follows small steps. Each step has its own dynamics and challenges. First determine the requirements, then adapt and build the car. Then test and test and test. The research carried out by Alireza and Mahmoud is a great example of one of these steps and helps Buurauto to eventually reach its goal."

Ing. Johan Janse
Director at Buurauto
Buurauto-Noom Project Manager

CHALLENGES

Safety is the most important issue when it comes to autonomous driving. Software and hardware should be carefully tailored together to make sure the system performs optimally. As the complexity of the scenarios increase, the design becomes more complicated. Extensive testing needs to be done to ensure reliability of the whole system. Moreover, detailed and extensive documentation is needed to acquire the required permits from road authorities to ensure the integrity and safe operation of the vehicle on public roads.

RESULTS

An infrastructure-independent automated valet parking system was designed and implemented into the TU/e's Toyota Prius, capable of autonomously driving from an initial position to the user's requested location at low speeds. This included but was not limited to stakeholder, system, risk, and safety analyses as well as software design and implementation, system integration, parameter tuning, and real-world testing. The resulting architecture consists of localization, object detection, collision avoidance, path planning, vehicle control, and communication modules.

BENEFITS

The designed AVP system would allow the Buurauto-Noom consortium to use this feature in order to gather insightful data on the public reaction towards autonomous driving and innovative shared mobility concepts. Such data paves the way for future mobility projects. Moreover, it contributes to the Buurauto's broader vision of deploying further innovative projects towards improving the sustainability and efficiency of shared cars through better urban space and car distribution management as well as using vehicle batteries as alternative energy resources.

ALIREZA MOAYYEDI, MSc EngD &
MAHMOUD ABDELHADY, MEng EngD

Project Buurauto-Noom

DESIGN AND IMPLEMENTATION OF AN INFRASTRUCTURE-INDEPENDENT AUTOMATED VALET PARKING SYSTEM INTO A TOYOTA PRIUS

A major obstacle for shared cars to get more commonly adopted is their immediate availability and ease of use. Users need the cars to be ready at the right time and in the right place for the service to be more useful than owning a car themselves. Currently, this is usually not the case as users need to spend time and effort to find and get access to a shared car. Project Buurauto-Noom's vision is to address the abovementioned issue by making shared cars available by driving autonomously from where they are parked to the user's requested pick-up location. From a broader perspective, such a feature will further improve the sustainability and efficiency of shared cars as better urban space and car distribution management can be achieved.

This functionality is similar to the application of AVP (automated valet parking). AVP systems enable the vehicle to drive autonomously from a drop-off point to a parking spot and vice versa. However, currently most commercial AVP applications are based on infrastructure-dependent technologies e.g., a parking garage equipped with cameras to detect obstacles or empty parking slots. Buurauto-Noom aimed to design and implement an AVP system independent of any external infrastructure using a Toyota Prius as a development platform. The main goal was to demonstrate it on a public road with the two sub-goals of showing the technical feasibility of the AVP concept as well as collecting data on public reactions towards the presence of an autonomous car driving in a neighborhood.

CHALLENGES

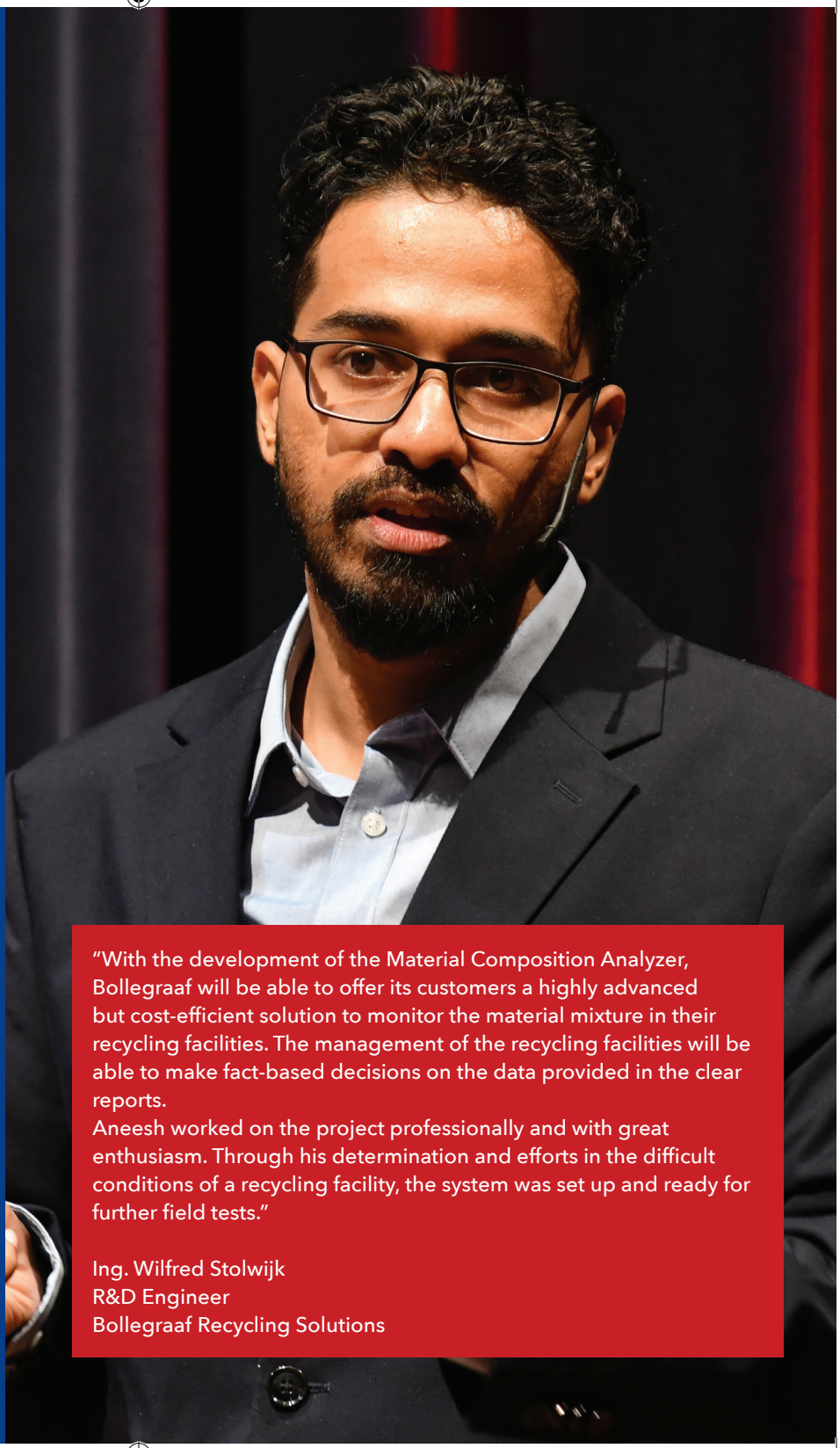
The main challenge in this project was to design a lightweight system that could be easily installed at different conveyor locations and analyze the waste composition of waste streams, dealing with large material flow rates and a variety of impurities. The goal was to build a verifiable prototype that could be readily tested with customer facilities within a year. Developing the system on a lightweight ARM-architecture processor with limited hardware capacity was also an interesting challenge.

RESULTS

By the end of the project, the system was developed in two stages, a simple proof-of-concept prototype that was applicable to plastics identification, and a second-stage prototype that was developed for installation and testing at a paper and cardboard sorting facility in the Netherlands. In-house accuracy and speed tests indicated that the system could be used for field tests with minimal modifications and model training. As of October 2022, further field tests are ongoing with three units installed at the sorting facility.

BENEFITS

With the compact and lightweight standalone analyzers that have been developed in this project, it is now possible for Bollegraaf and sorting facilities to monitor the waste stream quality in real-time at different sorting locations, and easily collect data for further model training. It would be possible to evaluate input material quality and the efficiency of the sorting line and identify faults in the sorting machinery.



"With the development of the Material Composition Analyzer, Bollegraaf will be able to offer its customers a highly advanced but cost-efficient solution to monitor the material mixture in their recycling facilities. The management of the recycling facilities will be able to make fact-based decisions on the data provided in the clear reports.
Aneesh worked on the project professionally and with great enthusiasm. Through his determination and efforts in the difficult conditions of a recycling facility, the system was set up and ready for further field tests."

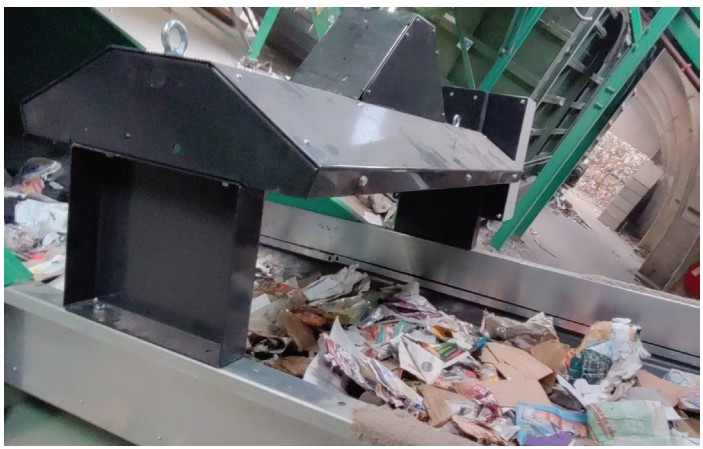
Ing. Wilfred Stolwijk
R&D Engineer
Bollegraaf Recycling Solutions

ANEESH ASHOK KUMAR, MSc EngD

Material Composition Analyzer for Waste Streams in Sorting Applications

Recycling is one of the most effective ways to deal with waste management, and the rising costs of natural resources. A major challenge faced by the industry is improving output quality and minimizing the loss of useful material during recovery. To assess the quality and quantity of recovered recyclable material, waste sorting or material recovery facilities conventionally evaluate their output quality by manual inspection, which is unreliable and often unsafe.

The goal of this project was to develop a smart scanning system to analyze and estimate the composition of waste flow in such a material recovery facility. The industrial partner, Bollegraaf Recycling Solutions, was interested in developing a cost-efficient system that could be easily installed at different locations in a sorting facility. The analysis of waste stream composition at different stages in the sorting process would help better estimate the efficiency of the sorting and the quality of the recovered material and be a step in the direction of plant optimization.



The author, Aneesh Ashok Kumar, was involved in the design and development of such a prototype together with Bollegraaf, using a camera and AI based approach to identify different material classes via object detection, and to estimate the waste-stream composition.

"Abhishek worked on defining the necessary high-level architecture changes for a vehicle platform to be compatible with Level 4 autonomous driving. The Level 4 capable vehicle platform had to be optimized to minimize the development and unit costs, energy consumption, weight, and development time. Given Lightyear's unique architecture, such as its four in-wheel motors, Abhishek's project can be considered a novel approach. Abhishek's approach was successful and proved that such complex changes are possible and feasible given the above constraints. Such would not have been possible if Abhishek had not owned this project with such dedication and motivation."

Manuel Ribeiro, MSc
Lead Autonomous Driving Engineer
Lightyear

CHALLENGES

The development of systems for higher levels of autonomous driving involves several uncertainties. A robust methodology is needed to develop vehicle platforms for Level 4 autonomous driving to consider critical factors influencing its design to ensure its safety and reliability. The solutions enabling the Level 4 capable vehicle platform should consider the tradeoffs between cost, development time, weight, and energy consumption.

RESULTS

This project developed a design methodology that aids in architecting systems to enable Level 4 autonomous driving. The system architectures enabling Level 4 autonomous driving capabilities within the vehicle platform were designed using the developed methodology. The architectures were later verified using methods such as Fault Tree Analysis to show that it provides the necessary fail-operational capabilities for Level 4 autonomous driving.

BENEFITS

The developed design methodology can also be used to design systems for lower levels of autonomous driving to ensure that the vehicle platforms meet the requirements for safety and reliability. The designed fail-operational vehicle platform helps to reduce energy consumption, enhance vehicle safety and enable quicker transitions to Drive-by-wire systems in the future.

ABHISHEK BALAKRISHNA BHAT, MSc EngD

Assessment and Preliminary Vehicle-Level Architecture Design of an SAE Level 4 Rated Vehicle Platform

The future mobility ecosystem is heading towards connected, automated, shared, and electric vehicles. In the case of shared and automated systems, the Automated Driving System providers are working with automotive OEMs to enable disruptive services such as Robotaxis. The Robotaxis are rated for Level 4 autonomous driving and offer consumers affordable and sustainable mobility choices. It acts as a catalyst to enable transitions to multi-modal mobility systems.

When moving towards Level 4 driving, the vehicle platforms need to transition from fail-safe to fail-operational architectures. The Level 4 capable vehicle platform should provide the required steering, braking, and propulsion demanded by the Automated Driving System, even in the cases of single-point and latent faults. The vehicle platform should house the necessary safety mechanisms to detect, isolate, and recover from faults within the prescribed Fault Tolerant Time Interval to prevent the vehicle from going into a hazardous state.

This project states the implications of Level 4 autonomous driving on the design of Lightyear's vehicle platform. The systems contributing to Level 4 driving capabilities within the vehicle platform were architected. It also incorporates safety mechanisms identified based on analysis techniques described by ISO 26262 and SOTIF standards. The Fault Tree Analysis of the developed architecture shows that it is free from common mode failures and provides the necessary fail-operational capabilities for Level 4 autonomous driving.

CHALLENGES

Developing a generic energy forecasting model that reaches the accuracy target, is a challenging task even in confined simulation environments. Designing software that implements such a model in real-world conditions introduces many practical challenges, impacting the accuracy and robustness of the software. Completing the implementation on time, while addressing the challenges with a lack of software domain knowledge, was a challenging process.

RESULTS

The realized cloud-based software uses a generic energy consumption forecasting model, relying on solely the mass of the vehicle, which is estimated while driving. Moreover, it utilizes the repetitive nature of bus trips by generating a characterization for each route. Because the model only uses these generic components, the software can be easily adopted on large scale for a diverse fleet. The designed software was implemented and validated.

BENEFITS

The practical benefits are twofold: Firstly, it allows for early flagging of critical state-of-charge deviations that could ruin the day-to-day planning and hence require adaptations in the operational planning. Secondly, it allows for continuous improvements in tactical line- and charge planning by creating transparency in the impact of load, driving style, seasonality, and other environmental factors on energy usage. This creates much more forward visibility and control over operations.

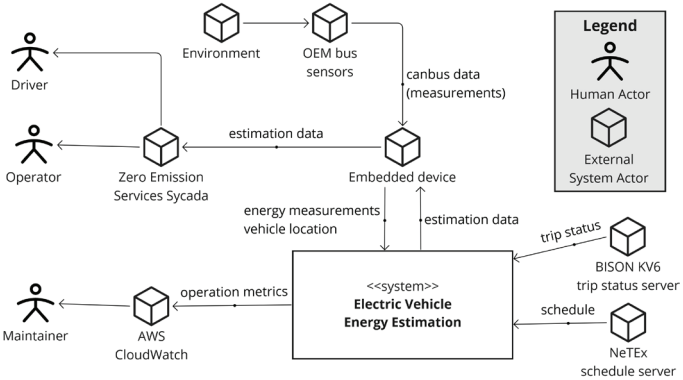
"With Destination Zero!, Sycada and TU/e aimed to develop a real-time energy consumption prediction model that can accurately forecast energy usage and battery state-of-charge at the end of a route, just shortly after a bus has commenced its journey. At Sycada, we are thrilled, and proud, that this project has led to tangible, demonstrated results.
The practical usability of the EVEE model is twofold: Firstly, it allows for early flagging of critical SoC deviations that could ruin the current day-to-day planning and hence require adaptations in the operational planning. Secondly, it allows for continuous improvements in tactical line- and charge planning by creating transparency in the impact of load, driving style, seasonality, and other environmental factors on energy usage. This creates much more forward visibility and control over operations than is available now.
EVEE hence provides another very important piece in the puzzle for the transformation towards zero emission transportation in Europe. Thank you, TU/e, for your guidance and support, and indeed to Berend, for a successful and rewarding cooperation."

Kristian K. Winge, MBA
CEO
Sycada

BEREND VAN DEN BERG, MSc EngD

Energy Consumption Prediction for Battery Electric Buses

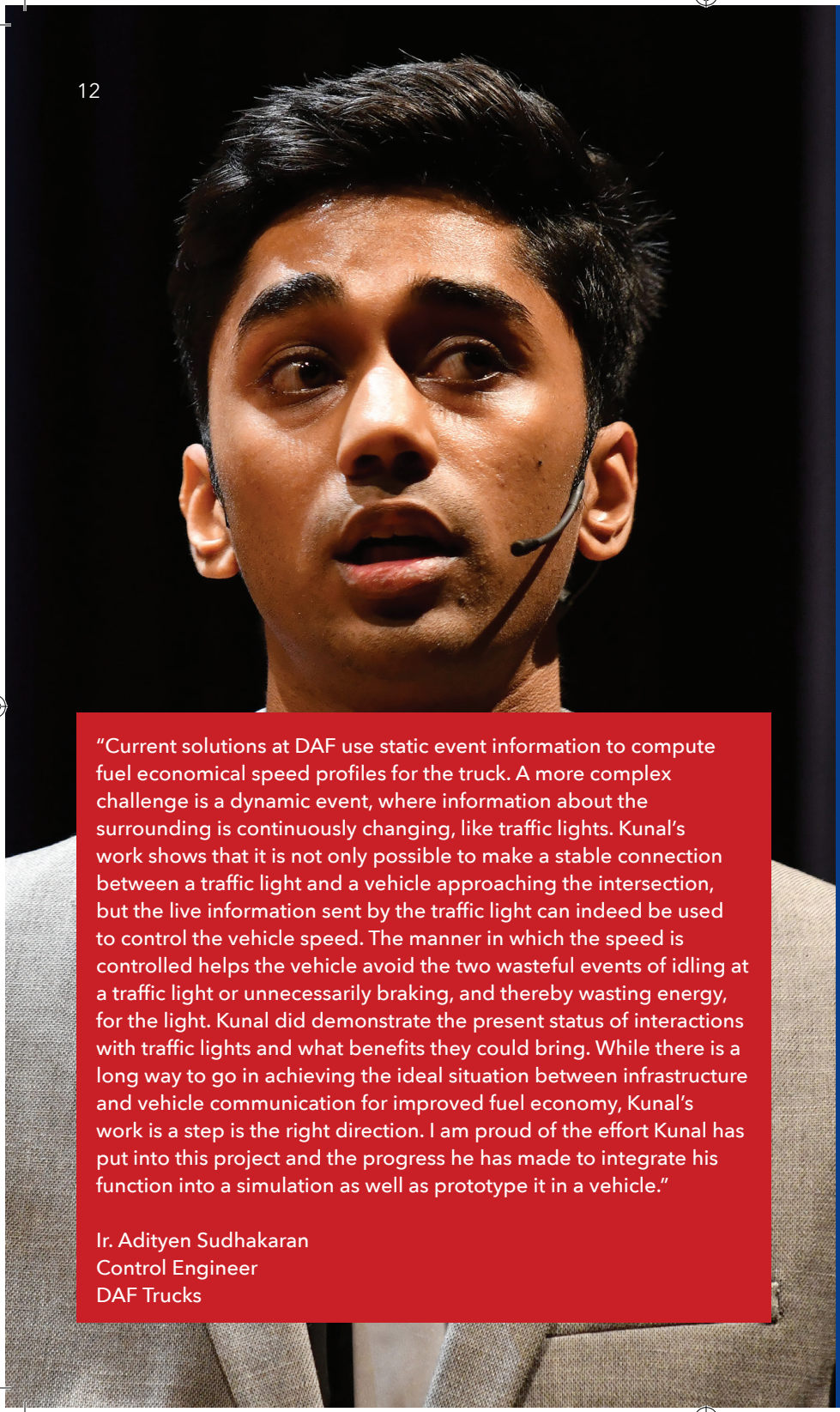
DESIGN, IMPLEMENTATION, AND VALIDATION OF A CLOUD-BASED SOFTWARE



The global aim of realizing zero-emission transportation involves transitioning from conventional fossil fuels to electric energy. This transition exposes fleet operators to increased uncertainty in their operation due to reduced range of the vehicles, decreasing range due to battery aging, and lack of a reliable energy consumption forecast. This uncertainty increases the overall costs of the transition through additional investments and operational expenses. Practically, these investments include a buffer in the fleet size to cope with the uncertainty. The operational expenses include costs for extra maintenance and dealing with operational disturbances such as fallout due to excessive energy consumption.

Sycada's Cloud Your Bus system aims to accelerate the transition to zero emission transportation, by providing insight into the real-time operation of the fleet, allowing improvement of the operation and a decrease of the involved costs and risks. This insight is realized by equipping the buses with a device sending operation data to an online platform, which operators use to improve their operation.

Project Destination Zero continued this work, extending CYB with an Electric Vehicle Energy Estimation (EVEE) system, that can forecast the trip energy consumption for battery electric buses, at any point throughout the trip. To realize this, a prior developed prototype was evaluated, as well as a newly developed model based on Machine Learning. The designed software was realized using the best performing method and deployed as a cloud service.



"Current solutions at DAF use static event information to compute fuel economical speed profiles for the truck. A more complex challenge is a dynamic event, where information about the surrounding is continuously changing, like traffic lights. Kunal's work shows that it is not only possible to make a stable connection between a traffic light and a vehicle approaching the intersection, but the live information sent by the traffic light can indeed be used to control the vehicle speed. The manner in which the speed is controlled helps the vehicle avoid the two wasteful events of idling at a traffic light or unnecessarily braking, and thereby wasting energy, for the light. Kunal did demonstrate the present status of interactions with traffic lights and what benefits they could bring. While there is a long way to go in achieving the ideal situation between infrastructure and vehicle communication for improved fuel economy, Kunal's work is a step is the right direction. I am proud of the effort Kunal has put into this project and the progress he has made to integrate his function into a simulation as well as prototype it in a vehicle."

Ir. Adityen Sudhakaran
Control Engineer
DAF Trucks

CHALLENGES

The designed system is the first at DAF to make use of dynamic V2X information for vehicle speed control. Since the performance of such a system depends on the quality of external information, it was a challenge to design a system that works with unpredictable dynamic information. The integration and testing of such a system in the prototype truck was a major challenge.

RESULTS

A system was developed that can communicate with smart traffic lights to understand their intentions and translate this into an optimal velocity profile, that reduces idling and harsh braking at traffic intersections. Routes with real-world traffic light data were simulated to show the benefits. A proof-of-concept was tested on a prototype truck and recommendations were made to realize such a system on a production level.

BENEFITS

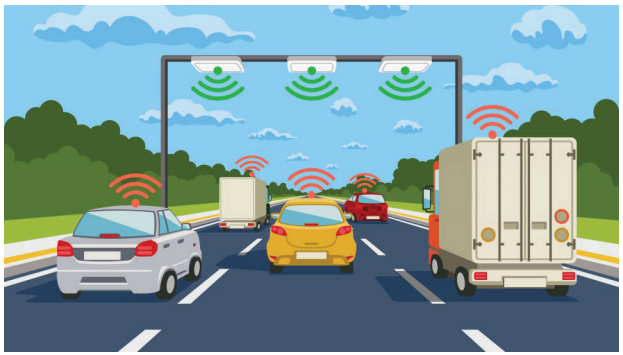
Information from smart traffic lights was seen to be the most relevant source of dynamic V2X data for CO_2 reduction. Simulations of the designed system show significant reduction in CO_2 emissions in comparison to a benchmark truck without the knowledge of traffic light intentions. This solution is a step in the right direction towards utilization of information from the environment to control the truck in a more fuel-efficient manner.

KUNAL IYER, MSc EngD

CO_2 Reduction Potential Using Dynamic V2X Data

Improvements to the fuel economy of a vehicle has always been an important development in the automotive industry, but it stands at a critical junction, now more than ever. With ever changing climates, it is necessary to explore all avenues towards a greener and more sustainable future. Medium and heavy trucks contribute to about 22% of global CO_2 emissions. The Longrun V2X project, which DAF is a major part of, is one such avenue which drives an advancement in the vehicle to help reduce the emissions of a long-haul truck application.

Currently, DAF utilizes static V2X data in their ADAS to improve fuel economy. The goal of this project was to develop a system that makes use of dynamic V2X information, like the intention of smart traffic lights. The complete design process was explored, right from concept phase, system design, simulating use-cases and finally testing the system on a prototype truck. Such optimization of driving behaviour using information from the environment shows significant potential to reduce CO_2 emissions in order to reach the new emission targets set by EU legislation.



CHALLENGES

The main challenge of the project was to understand the process, the product and frame the requirements for the project. Also to transfer the design artifacts that are produced into a SSOT seemed to be another challenge that was overcome by the use of MBSE.

RESULTS

Delivered a framework using MBSE consisting of a modeling language, method and tool which were SysMl, SYSMOD and IBM Rhapsody respectively. Using this framework, a successful transfer of the process in the Functional safety team was performed and the stakeholders are willing on implementing this framework within their design process.

BENEFITS

It will improve the understandability of complex interrelations, the quality, and the speed at which a project can react to change. MBSE has proven to reduce cost and can cope with design change, fast and is less prone to errors.

"This project is a start for Punch Powertrain to move towards system modelling tools to enable better traceability and have single source of truth for our design documents. The focus of the project was to develop a framework for the safety architecture for our DT2 transmission using MBSE. The learnings from this project will be used to scale deployment of the proposed framework of SysML, SYSMOD and IBM Rhapsody (or a similar tool) for integration in our process. This will help us improve productivity and quality while reducing risk during system development.
Yash developed a framework and described how we at Punch Powertrain can apply MBSE using the proposed framework and have a single source of truth from requirements till the physical architecture during system development. In the "Functional Safety team" at Punch Powertrain, we are proud of the results that Yash obtained. I would like to take this opportunity to express our sincere gratitude to Yash and his colleagues at the Eindhoven University of Technology for their contribution to the success of this endeavor."

Ravishankar Rugge, MSc
Functional Safety Manager
Punch Powertrain

YASH KHETAN, MSc EngD

Using MBSE to Improve Traceability and Form a Single Source of Truth for Systems Design

Currently, Punch Powertrain designs and manufactures transmissions for the automotive sector, the Electric Dual Clutch Transmission (eDCT) is one of them. While designing such complex systems a basic concept design change can take weeks to ripple through various departments, often requiring manual updating of models, which is both slow and error prone. This can be a major hindrance to the creation of optimal, cost-effective designs. Component-level software tools have traditionally been unable to provide the over-arching system level design needed within modern integrated approaches. Many manufacturers recognize that this critical issue needs to be addressed.

Traceability is an essential piece of puzzle particularly in engineering compliance to formally identify the provenance, motivation, and relations between engineering artifacts. It is a key method to counter the growing complexity of product development. Traceability is mandatory for complying with all the standard safety processes such as functional safety for road vehicles, ISO 26262. It improves the understandability of complex interrelations and thus, the quality and the speed at which a project can react to change.

The goal of this project was to define a framework using Model Based Systems Engineering (MBSE) which will help improve the traceability and have a single source of truth (SSOT) while designing systems and manage the complexity better for Punch Powertrain. Using the already designed eDCT transmission of Punch Powertrain the proposed framework will be used to reverse engineer the tasks to display the possibility of a better traceability and a SSOT for different artifacts generated during system design.

"Gijs' objective was developing a Matlab (Simulink) based modular air path model which should be able to simulate pressures, temperatures and mass flows and run real-time on the ecu. The air path model should be fitted using mostly existing steady-state and transient data and the provided hardware specifications. The model should be applicable both for simulating the air path for software development and calibration purposes and be used on the ecu for model based control strategies.
With the work of Gijs, important steps have been made towards achieving such an air path model and towards achieving model based control."

Ir. Joost Basten
Control Engineer System Function Design
DAF Trucks

CHALLENGES

Current approaches at DAF do not meet the required simulation capabilities for model based control design of the engine air path. The challenge at hand for this project was to develop a generic software tool to create predictive dynamic models of various DAF engines. A well-considered trade-off between model accuracy and simulation speed had to be made for meeting the desired model performance.

RESULTS

The developed *Engine Modeling Tool* is employed for modeling three DAF engines: MX11, MX13/1 and MX13/2. The specific engine parameters of these engines are identified which subsequently results in three models that meet the desired prediction accuracies. Moreover, the computational load of the models have the potential to be employed onboard the engine in a model based control setting.

BENEFITS

Important steps have been made towards model based control of the engine air path for DAF Trucks. The *Engine Modeling Tool* can be employed in the various engine configurations for fast and accurate identification of air path models. Subsequently, the models can be tested for model based control design. In the next steps, the model structures can be expanded to describe actuator dynamics and emission predictions.

GIJS LINSKENS, MSc EngD

Towards Model Based Control of a Heavy-Duty Diesel Engine Air Path with the Engine Modeling Toolbox

Diesel engine development for heavy-duty trucks faces challenges in meeting legislated pollutant emissions levels, such as nitrogen oxides and particulate matter, whilst preserving torque demands and fuel economy targets. The onboard engine control unit employs active control methods to monitor and regulate the combustion process in the engine. Sensor data-based control can suffer from inaccurate, delayed, or missing information. Therefore, model based control strategies offer a solution by actuating engine subsystems by means of dynamic engine behavior predictions.

Development of mean-value engine air path models which are suitable for the above mentioned control strategy is the main topic of this project, which is carried out in collaboration with DAF Trucks N.V. Accurately modeling the air path behavior, with fast simulation capabilities can be a time consuming effort. Hence, an automated software based tool to create applicable air path models for engine control is the main design objective of this project.

Identifying engine specific parameters correctly is essential for accurately predicting the engine flows, pressures, and temperatures. An automatic procedure is implemented in the tool to identify the parameters of component dependent submodels. After identification, the submodels are merged into a single air path model, ready for simulation. The procedure is tested for three DAF engines with satisfactory results in terms of simulation speed and accuracy.

CHALLENGES

The major challenge in this project was the high complexity of the stakeholders' expectations that made the design requirements difficult to reach. It was required to perform a feasibility analysis to prove that the combination of the expectations is not realistic. Moreover, the way of working of the stakeholders was in such a way that they changed requirements and constraints along the way.

RESULTS

There were many negotiation moments with internal and external stakeholders. The results of feasibility analyses on dynamics and control were provided to the stakeholders and convinced them that the current needs are difficult to reach and provide them with options for extending the requirements. In the end, the performance expectations were adapted that helped defining realistic requirements. Moreover, realizing the concept and moving forward in the design process was initiated.

BENEFITS

The team gained overviews about possibilities in the mechatronics design and have a better understanding of the solutions to reach their aims in a realistic way. The following steps in the mechanic design can be easier taken now that the requirements are clear and feasible. The accuracy budget is extended, and tough measurement situations are avoided. This project paved the way for the next designers for the measurement tool.

"Maryam used the CAFCR framework to understand expectations from key stakeholders. She used this information to make concept designs. These concept designs are then simulated to check feasibility of the tool, and the results are used to challenge the stakeholder expectations, and design constraints. Moving forward, these results are considered when designing the tool. The team would like to express our thanks to Maryam for her role in this project, and for her contribution towards the design of this tool which would be used for the study of the paintings, and hence the preservation of the legacy of Van Gogh."

Ir. Rohan Lakhotia
Researcher
ASML Research

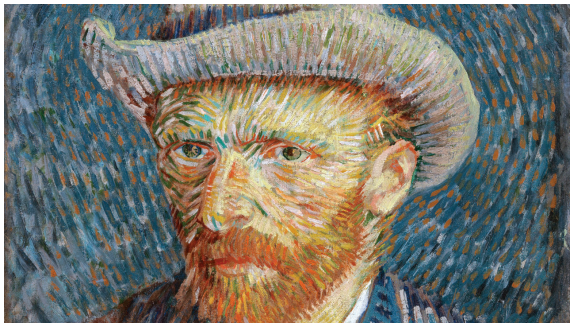
MARYAM MASHAYEKHI, MSc EngD

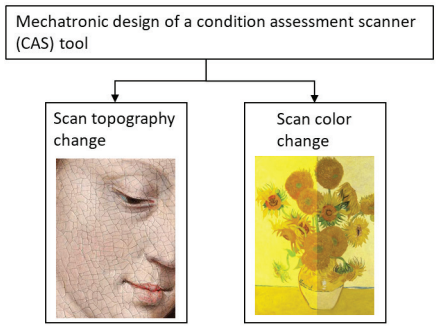
Design and Feasibility Analyses of a Condition Assessment Scanner Tool for Van Gogh's Paintings

Van Gogh was a great Dutch painter. He has left a valuable heritage behind, and he is famous as father of modern art. His paintings are from more than 100 years ago, therefore they are going through degradation and some changes such as change of color and formation of cracks are happening to them. Although Van Gogh Museum is trying to conserve the paintings as good as possible, aging of the materials is unavoidable. Therefore, Van Gogh Museum has started a consortium with ASML, Cultural Heritage Agency of the Netherlands, and University of Amsterdam with the goal of preserving Van Gogh's legacy by using science and technology.

ASML aims at developing a tool that can scan different aspects of the paintings. To be able to measure the changes in the paintings over time, and understand the change mechanisms, they expect the measurement tool to have accurate results. This project started with initiating the design process of the scanning tool and help problem definition.

In this project, the stakeholders' expectations were collected and used for the concept designs. The concepts were then simulated to check the feasibility of the defined requirements, and the results were used to challenge the stakeholders' expectations, and design constraints. The project is finalized by definition of realistic requirements and initiation of component realization for the tool.





"Lars investigated the needs of the museum professionals and translated them into technical requirements. One of the highest ranking items, a visualization tool for the simultaneous examination of technical images and pigment maps obtained for paintings in the collection was developed by Lars. It was received with great enthusiasm by the Van Gogh Museum conservators, scientists and curators and will become a very valuable tool to explore and understand the paintings and Van Gogh's process. We want to thank Lars for his great contribution to the VGM – ASML Partnership in Science and for bringing both partners a step closer to creating a digital twin for our works of art."

Ir. Martijn Wubbolts, Principal CAE Architect, ASML
Ana Martins, PhD, Conservation Scientist, Van Gogh Museum

CHALLENGES

The challenge in envisioning a digital twin for paintings was ensuring all the user needs were cohesively mapped as to provide a unified and accessible understanding of what a digital twin means for the consortium. In actually creating a solution – a prototype image viewer – the underlying challenge was maintaining communication and expectations between stakeholders across the hemispheres of cultural heritage and engineering.

RESULTS

The vision of the consortium's digital twin spans five areas: accessing, visualizing, and integrating data; digital condition reporting and inventorying; virtual (un)aging and pigment exploration; monitoring and predicting condition and environmental impact; and educating the public on the life, work, and impact of Van Gogh. The image viewer – an installable prototype distributed to the consortium for testing – is accompanied by a registered imaging stack of *Small Pear Tree in Blossom*.

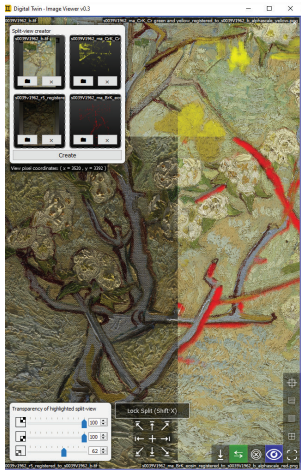
BENEFITS

Future work in the consortium will use the vision and its cataloging of needs to help steer digital twin efforts as well as supplement related efforts in the consortium, including the condition assessment tool and digitization of the Van Gogh Museum's information and knowledge. The viewer prototype provides a tangible and useful tool for users, therewith enabling both short-term feature feedback and long-term prioritization of future digital twin tools.

LARS VINCENT MAXFIELD, MSc EngD

Towards a Digital Twin for Van Gogh's Paintings

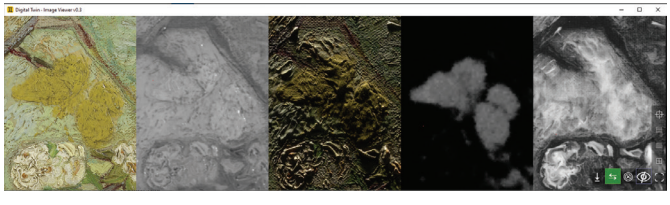
DEFINING A VISION WHICH MEETS THE NEEDS OF USERS IN CULTURAL HERITAGE; REALIZING A PROTOTYPE VIEWER FOR COMPARING AND INTEGRATING MULTI-MODE IMAGES



From 2019–2024, ASML has committed itself to the Van Gogh Museum as Partner in Science in which it contributes to the Museum both financially and by enabling educational and research activities. The consortium conducting a subset of these research activities consists of teams from the Van Gogh Museum, ASML, the University of Amsterdam, and the Cultural Heritage Agency of the Netherlands. Their unifying goal is to explore and preserve the legacy of Van Gogh using research and technology.

Digital twins – software comprising models and services to represent and manipulate original systems – are one such technology the consortium is investigating. Their intent is to create a digital twin for paintings, beginning with a pilot study for Van Gogh's *Small Pear Tree in Blossom*.

Jointly funded by ASML and Materials innovation institute (M2i), this project assisted the pilot study by establishing a high-level view of the system (a vision) and realizing a prototype thereof (an image viewer). The project involved interviewing conservators, conservation scientists, researchers, collection managers, and historians to catalog the needs of cultural heritage users and ultimately envision a system meeting those needs. This vision includes the access and combination of all knowledge for a given painting, as well as the description and prediction of how it behaves using sensors and simulations of the painting and its environment. To realize a prioritized subset of user needs, the project resulted in the prototyping and internal distribution of an image viewer which enables users to compare and integrate multiple imaging modes.



Credits: Van Gogh Museum, Amsterdam (Vincent van Gogh Foundation)

CHALLENGES

The feasibility study formed a three-way collaboration between the technical university Eindhoven (TU/e), Bosch Transmission Technology and Tribus Specials. Managing the information and requirements from multiple stakeholders during the Corona period formed one of the most challenging aspects of this study.

RESULTS

Two powertrain models were developed, 1-speed vs CVT, to compare them on an efficiency level. Additionally, a TCO formulation was set-up to be able to compare the systems on a total cost level. The pushbelt-CVT shows a good potential in terms of reaching performance requirements, increasing powertrain efficiency and reducing TCO, despite the need for the regular servicing thereof.

BENEFITS

The CVT's potential to reduce efficiency and cost was showcased within this feasibility study. Several unique selling points have been highlighted. The project was able to provide insight and quantify benefits as well as drawbacks of the CVT as compared to the 1-speed driveline. Several recommendations were proposed to improve belt durability for such a use-case.

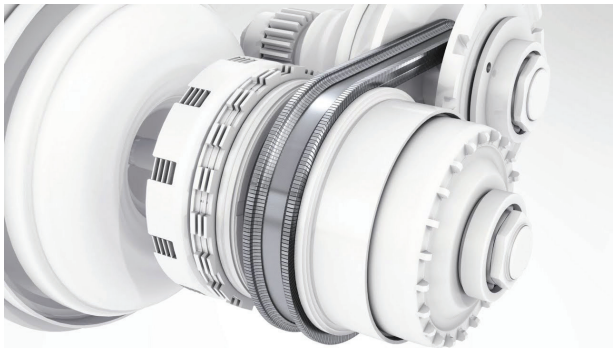
"Markos has started to work with us at Bosch Transmission Technology 2 years ago. His Bosch journey started in an EngD Team Project, where he and his team members developed an analytical scaling tool for electrical traction drives in an incredible short period of 2 months. In the final project, we looked together for a new application area of our current product CVT pushbelt, the electric midi-busses. He achieved in-depth results and relationships he got between different design aspects and performance requirements. Another achievement Markos had realized was *"Successfully balancing information and communication flow from 2 different industrial companies and a technical university in the time of Corona"*."

Dr.ir. Esin Ilhan Caarls
Electrical System Engineer, Bosch Transmission Technology
Assistant Professor, Department of Electrical Engineering, TU/e

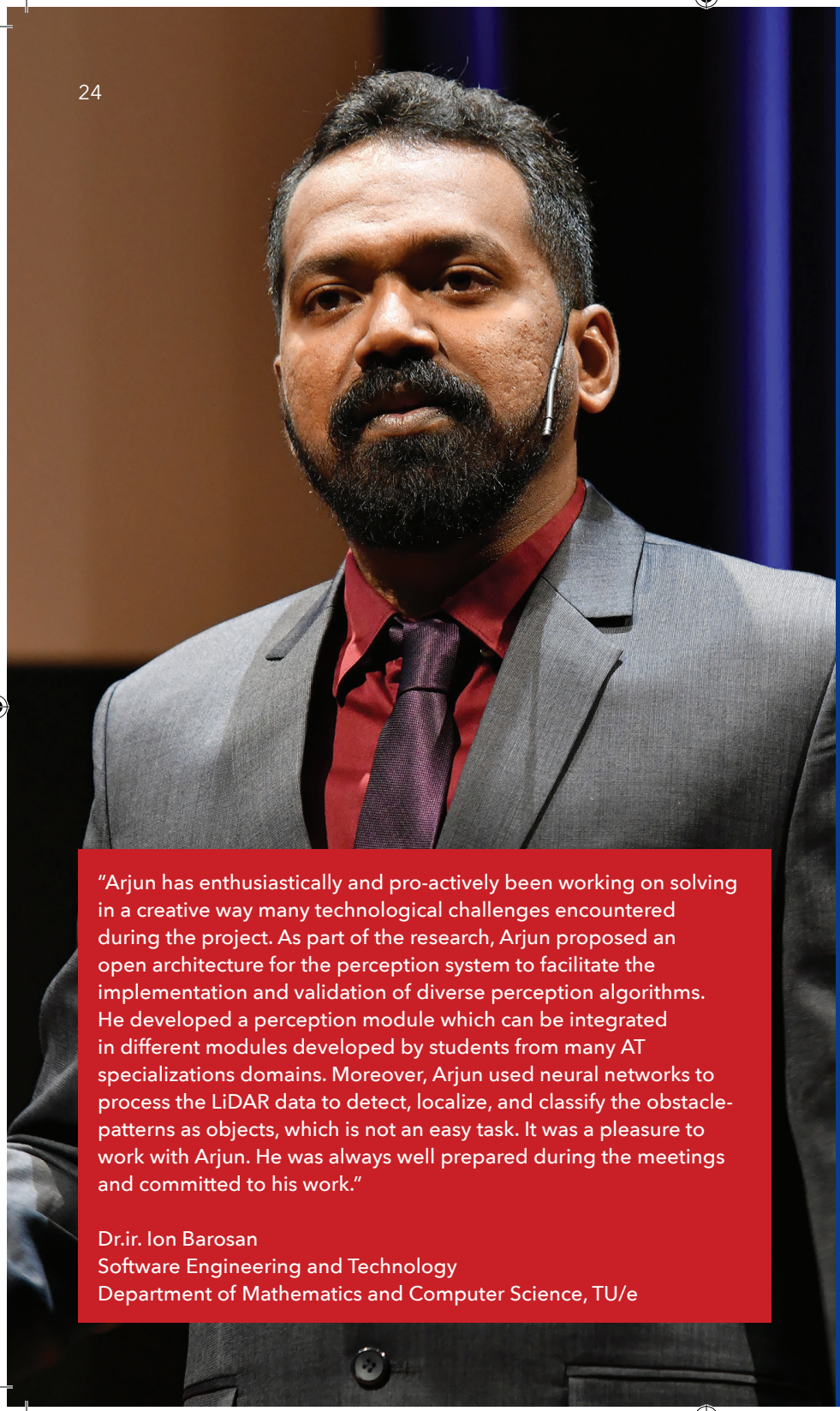
MARKOS PAPADIMITRIOU, MSc EngD

Feasibility Study of an Electric CVT-Powered Midi Bus

The automotive world has been striving to reduce fuel consumption in Internal Combustion Engine (ICE) vehicles to meet the stringent emission regulations. As for ICE vehicles, a strive for ever more efficient drivelines also persists for EVs. Continuously Variable Transmissions (CVTs) can further contribute towards more efficient drivelines. Bosch has been able to successfully improve efficiency within the passenger vehicle segment. A new segment, however, which can be of interest to the pushbelt-CVT is the medium-sized electric city bus, which forms a bridge between the passenger vehicle and the heavy-duty segment.



This feasibility study sets out to explore the possibility of employing a CVT within an electric city bus, while highlighting its advantages and disadvantages. Using the current 1-speed system as a baseline, the new driveline with pushbelt-CVT is developed and compared. The application of the CVT in the medium-sized (electric) city bus segment has the potential to improve system efficiency by considerably reducing the losses of the electric motor over the driving cycle. Moreover, the downsized components that are enabled by the CVT, provide several benefits: (i) reduced overall system weight which complements the net efficiency gain, (ii) extended range on a single battery charge, (iii) increased payload to boost revenue. On the other hand, operating costs are higher for the pushbelt-CVT based on current pushbelt product technology that has been developed for (ICE) passenger cars. This is due to the necessary CVT-servicing instances for pushbelt replacement to achieve the reference lifetime of the bus.



"Arjun has enthusiastically and pro-actively been working on solving in a creative way many technological challenges encountered during the project. As part of the research, Arjun proposed an open architecture for the perception system to facilitate the implementation and validation of diverse perception algorithms. He developed a perception module which can be integrated in different modules developed by students from many AT specializations domains. Moreover, Arjun used neural networks to process the LiDAR data to detect, localize, and classify the obstacle-patterns as objects, which is not an easy task. It was a pleasure to work with Arjun. He was always well prepared during the meetings and committed to his work."

Dr.ir. Ion Barosan
Software Engineering and Technology
Department of Mathematics and Computer Science, TU/e

CHALLENGES

The main challenge is to develop a perception system architecture that incorporates different possible configurations of sensors as part of vehicles and infrastructures. The architecture must also allow perception concepts of various developers to be implemented and validated as part of research. The other challenge is to devise and define the essential abstractions of environment perception to achieve automation.

RESULTS

A perception system has been designed for a distribution center. This has been developed and implemented as a software package, and validated at the TruckLab environment. The developed perception system can effectively capture and interpret the dynamic environment at different abstraction levels such as obstacle detection and localization, object detection localization and classification. Furthermore, a learning module has been developed to help any developer familiarize with the TruckLab environment and its implementation framework, so that one can implement and analyze their concepts at the TruckLab.

BENEFITS

TruckLab can use the developed perception system to interpret obstacles and objects in the environment. This interpreted information shall be used for path-planning and control of vehicles to achieve automation in the TruckLab environment. In addition, the developed architecture of the perception system can be used for interpreting the environment of other two-dimensional controlled spaces that are not subjected to public-road safety regulations. Students and other TruckLab developers can use the developed learning module to implement and analyze their concepts at the TruckLab.

ARJUN PRADEEP KUMAR, MSc EngD

Software Design of a Perception System Applied to the TruckLab Environment

A perception system is a vital part of autonomous vehicles to capture the dynamic surrounding environment. Perception system can perform better when the system incorporates multiple sensors capturing the environment from complementary views. Automated driving can be achieved more easily in controlled private spaces not subjected to public road safety regulations. TruckLab is a research laboratory, which is a part of the TU/e Automotive Lab, with a focus on the accelerated development of autonomous trucks in controlled spaces, particularly for the distribution center's external area. This project focuses on the development of a perception system for a controlled environment, which is applied to the TruckLab environment. This project proposes an open architecture for the perception system to incorporate various combinations of vehicle and infrastructure perception. This facilitates the implementation and validation of diverse perception algorithms. The project focuses on developing the most suitable configuration of perception system for the TruckLab environment. Further, the project continues into the development and implementation of the proposed perception system. It is demonstrated that the developed perception system can effectively capture and interpret the dynamic surrounding environment at different abstraction levels.

CHALLENGES

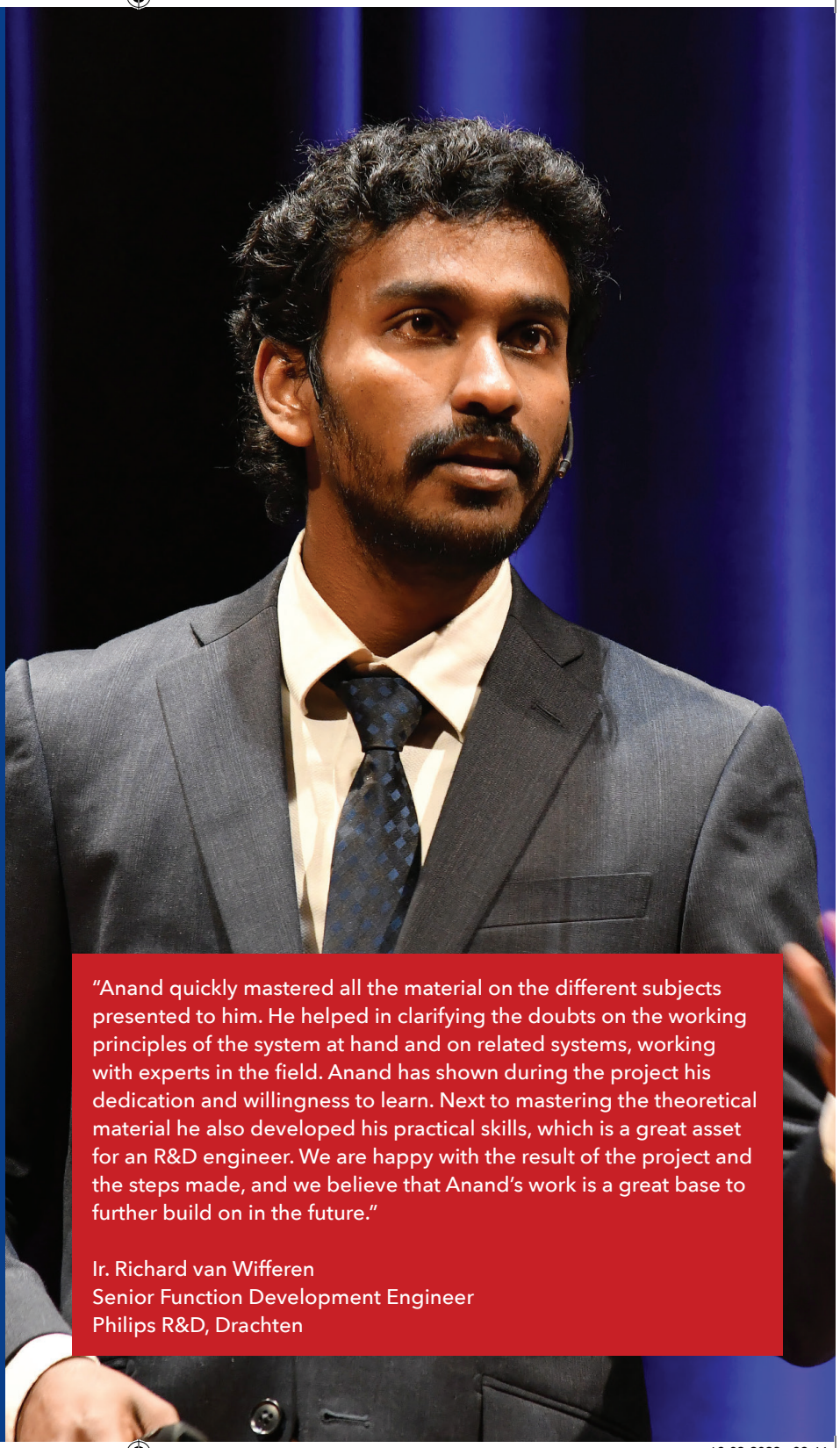
Some of the initial challenges were quick mastering of the theoretical aspects of DC motor models and collaborative works with experts to derive the measurement principles. Furthermore, a well-designed hardware and software implementation that could achieve the required levels of measurement accuracy was an important challenge dealt in this project. Finally realizing the modularity and scalability in the designed system was also a challenging aspect of the project.

RESULTS

Design and implementation of a verified measurement system to characterize the drivetrain modules was achieved. The measurement system was developed by integrating various electronic instruments and automation controller based on Python. The complete system design following a V model approach also resulted in a well-documented requirements elicited from the stakeholders, market study of relevant sub-systems products and relevant organizational decisions.

BENEFITS

The realized measurement system enables to perform accurate and automated measurements of drivetrain characteristics of modules in grooming appliances developed by Philips like shavers, trimmers, and epilators. The system helps in making data driven decisions and optimizations on the module level of these appliances. This in turn contributes to the vision of achieving higher performance at lower costs.

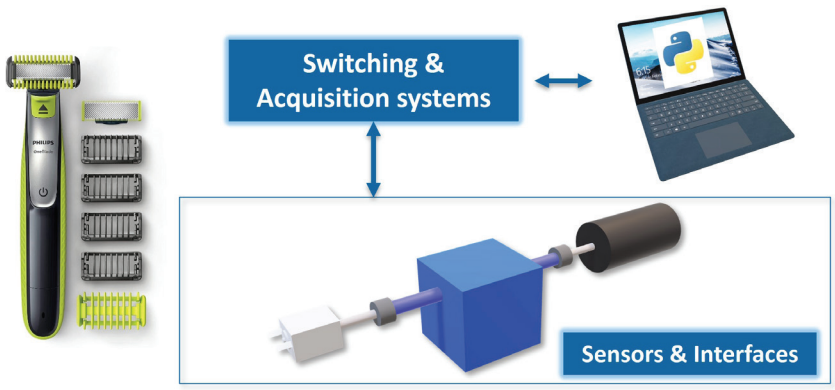


"Anand quickly mastered all the material on the different subjects presented to him. He helped in clarifying the doubts on the working principles of the system at hand and on related systems, working with experts in the field. Anand has shown during the project his dedication and willingness to learn. Next to mastering the theoretical material he also developed his practical skills, which is a great asset for an R&D engineer. We are happy with the result of the project and the steps made, and we believe that Anand's work is a great base to further build on in the future."

Ir. Richard van Wifferen
Senior Function Development Engineer
Philips R&D, Drachten

ANAND VAZHAYIL SURENDRAN, MTech EngD

Semi-Automatic Measurement System for Drivetrain Characterizations: Design and implementation



Measurement systems are vital part of any verification framework in relation to product development. Semi or fully automated and reliable measurement systems helps to improve the quality of the verification framework as well as the lead-time in the product development process.

Philips R&D at Drachten focuses on the innovative product development of hair removal appliances like shavers, trimmers, and epilators. Performance, product lead time and cost are some critical factors that give edge over the competition in the consumer market industry. Performance and cost of the shaver products is highly dependent on the torque-speed characteristics of the product drivetrain. Hence, accurate and reliable measurements of drivetrain characteristics is important to make informed tradeoffs on cost and performance.

The goal of this EngD project was to design and build a new measurement system for the drivetrain modules like motors, gears, seal cups and cutting elements. This project investigated alternatives for the high-level system architecture, like Benchtop systems and PXI based systems. This project also investigated the design and integration of various hardware systems like Power supply units, Voltage-current-speed measurement systems, DC load controller, Speed controller and Relay switching systems. This project also involved developing a software controller based on Python to automate the electronic instruments for the measurement process.

"Haoyu's assignment involves the optimization and quantitative verification of an existing experimental setup for free-fall and thermophoresis verification in a vacuum. The optimized setup shows a satisfactory performance with errors less than 5% in a wide region of interest that met all the important customer requirements. At the same time, his verification results also have strong research value. What is impressing in Haoyu is his balance between flexible and rigorous planning, quick adaptation to the ever changing requirements. When he was informed that he needed to transfer the setup to another site, he changed his experimental plan and managed to efficiently complete all the experiments before the transfer. Another impressive moment about Haoyu is his ability to learn new things. Besides improving the setup from engineering perspective, he was actively learning the topic in depth and doing experimental research, as a way to validate the system performance. Haoyu showed his quality as a good engineer and experimentalist with high potential through his assignment. We highly appreciate his work."

Dr. Dmitri Shestakov
Senior Function Analyst, VDL Enabling Technologies Group

CHALLENGES

The particle dynamics are very unpredictable in the vacuum environment. Most of the involved physics such as flow, pressure and temperature are hard to measure and visualize. This leads to the difficulty even in optimization of the system.

RESULTS

The optimized performances of the four modules satisfy 90% specification requirements. The integrated setup has a good accuracy, where the velocity error is limited below 5% in the wide range of interest. The theoretical values of the higher-order parameters were well traced by the results derived from the measured velocities. In addition, the setup presented excellent reproducibility over the entire range of interest for thermophoresis research.

BENEFITS

The setup now can be used for quantitative measurements with high accuracy. Further experiments could involve various gases and non-spherical particles, which could provide deeper insights into particle dynamics theory in vacuum. In addition, this setup can be used as an auxiliary device to assist the research on other physics.

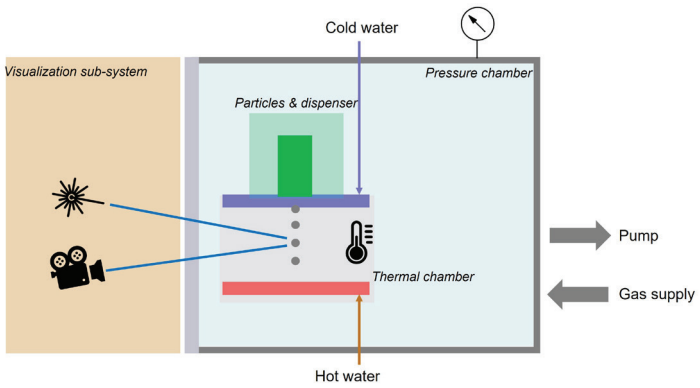
HAOYU ZHU, MSc EngD

Setup Optimization and Experimental Verification for Accurate Transport Measurement of Microparticles

It is established that the demand for contamination control in the semiconductor industry is increasing. The contaminants in the micro-scale and nano-scale generated in the chip production process could fall on the clean wafer surfaces, damage the devices and decrease the yield of the production. To mitigate this issue, thermophoresis is put forward as a promising solution, where a thermophoretic force applied to the contaminant is created by a temperature gradient, which can create a “seal” around the clean surface and protect it.

Nevertheless, the theory of thermophoresis in rarefied gas is not mature, which makes it difficult to use thermophoresis technology to control the contamination in real industry. To understand the behaviour of particles under the influence of the dominant forces in the thermophoresis environment, a thermophoresis experimental setup has been designed and tested in the past years at VDL Enabling Technology Group (VDL ETG). The system verification showed that the prototype is a proof of concept that could qualitatively present the influence of thermophoresis in the vacuum.

The purpose of this project was to optimize the existing prototype, so that it had the performance to meet the requirements of quantitative experiments for the thermophoresis application. The optimization was implemented from the aspects of four modules: visualization subsystem, pressure chamber, thermal chamber, and particle dispenser. After the optimization, the integrated performance of the setup was verified for the free-fall and thermophoresis application by comparing the measurement data with the theoretical results in a wide pressure range of interest.



CREDITS

Edited by: R. Meijer and P.J.M. van Hoof-Rompen, Automotive Systems Design program, Eindhoven University of Technology

Text: EngD graduates of generation 2020-2022 of the program Automotive Systems Design, including the track Mechatronic Systems Design

Photography: Rien Meulman

Production: R. Meijer and P.J.M. van Hoof-Rompen, Eindhoven University of Technology

Design: Grefo Prepress

Printing: De Digitale Drukker

Alireza Moayyedi, MSc EngD & Mahmoud Abdelhady, MEng EngD; Project Buurauto-Noom - Design and Implementation of an Infrastructure-Independent Automated Valet Parking System into a Toyota Prius ■ **Aneesh Ashok Kumar, MSc EngD;** Material Composition Analyzer for Waste Streams in Sorting Applications ■ **Abhishek Balakrishna Bhat, MSc EngD;** Assessment and Preliminary Vehicle-Level Architecture Design of an SAE Level 4 Rated Vehicle Platform ■ **Berend van den Berg, MSc EngD;** Energy Consumption Prediction for Battery Electric Buses - Design, Implementation, and Validation of a Cloud-Based Software ■ **Kunal Iyer, MSc EngD;** CO_2 Reduction Potential Using Dynamic V2X Data ■ **Yash Khetan, MSc EngD;** Using MBSE to Improve Traceability and Form a Single Source of Truth for Systems Design ■ **Gijs Linskens, MSc EngD;** Towards Model Based Control of a Heavy-Duty Diesel Engine Air Path with the Engine Modeling Toolbox ■ **Maryam Mashayekhi, MSc EngD;** Design and Feasibility Analyses of a Condition Assessment Scanner Tool for Van Gogh's Paintings ■ **Lars Vincent Maxfield, MSc EngD;** Towards a Digital Twin for Van Gogh's Paintings - Defining a vision which meets the needs of users in cultural heritage; realizing a prototype viewer for comparing and integrating multi-mode images ■ **Markos Papadimitriou, MSc EngD;** Feasibility Study of an Electric CVT-Powered Midi Bus ■ **Arjun Pradeep Kumar, MSc EngD;** Software Design of a Perception System Applied to the TruckLab Environment ■ **Anand Vazhayil Surendran, MTech EngD;** Semi-Automatic Measurement System for Drivetrain Characterizations: Design and implementation ■ **Haoyu Zhu, MSc EngD;** Setup Optimization and Experimental Verification for Accurate Transport Measurement of Microparticles