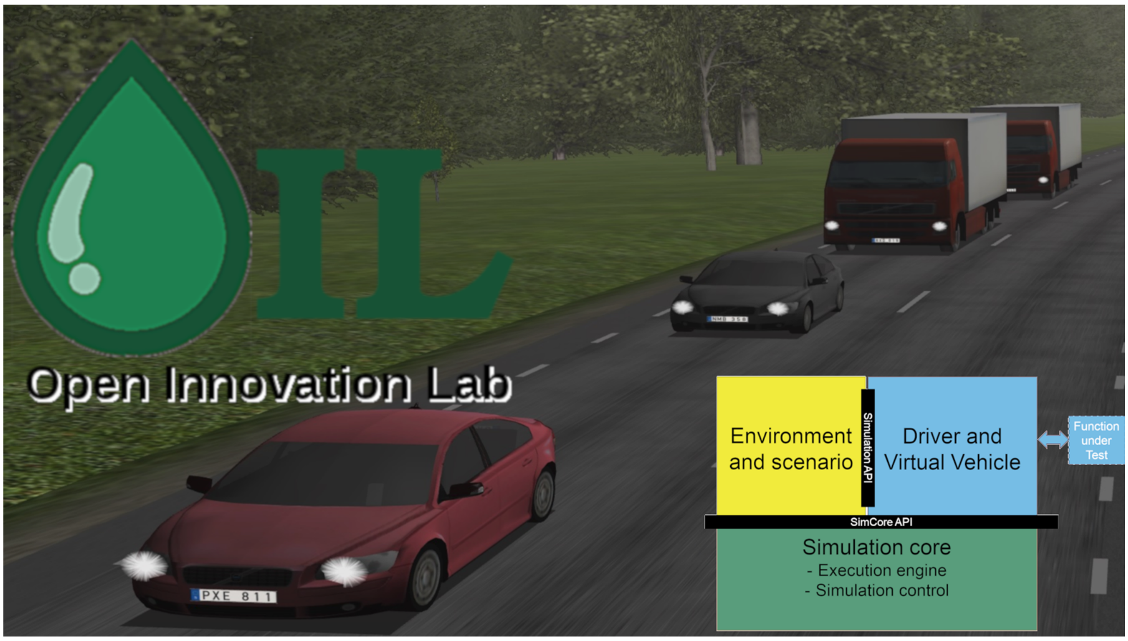
Open Innovation Lab

Public report



Project within FFI – Elektronik, mjukvara och kommunikation (Dnr 2016-05497)

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Content

FFI in short

FFI is a partnership between the Swedish government and automotive industry for joint funding of research, innovation and development concentrating on Climate & Environment and Safety. FFI has R&D activities worth approx. €100 million per year, of which about €40 is governmental funding.

Currently there are five collaboration programs: Electronics, Software and Communication, Energy and Environment, Traffic Safety and Automated Vehicles, Sustainable Production, Efficient and Connected Transport systems.

For more information: www.vinnova.se/ffi

1. Summary

The automotive industry is in a transitional phase. New and increasingly sophisticated active safety and driver support functions are being deployed at an increasing rate, and are step by step getting closer to fully autonomous driving. Such functionality is to a large extent realized by software—a big change in itself for the automotive industry, traditionally centred on mechanical and electrical engineering. This also means that software engineers can be added to the crowd of automotive innovators and developers. However, for software engineers to be able to quickly create, test and demonstrate functionality—from prototypes to production software—they need accessible and cheap development environments that facilitate collaboration between the vehicle manufacturers and third party software developers. Today, such environments are typically specialized and proprietary with expensive licenses, and often incompatible with each other, leading to lock-in and difficulties in exchanging artifacts between environments—effectively a barrier for open innovation.

The goal of the project Open Innovation Lab (OIL)[1] was to develop and demonstrate tools to facilitate open automotive software innovation. The project, which ran between April 2017 and March 2019, was divided in two sub-projects.

Sub-project 1, *Simulator platform and tool-chain*, aimed at developing an open license-free purely software based simulation platform and tool-chain for supporting development, test, and demonstration of automotive software components, with a strong focus on standards that facilitate interoperability.

Sub-project 2, *VCC Infotainment Proof-of-concept*, aimed at demonstrating open automotive innovation by engaging university students to develop applications for the infotainment head-unit.

[1] https://www.vinnova.se/p/oppet-innovationslabb/

2. Sammanfattning på svenska

Fordonsindustrin genomgår just nu en stor förändring med alltmer kapabla säkerhets- och förarstödssystem, och som steg för steg närmar sig fullt autonom körning. Sådan funktionalitet realiseras till stor del av mjukvara—en stor förändring i sig för fordonsindustrin, som traditionellt är en mekanik- och senare elektronikfokuserad ingenjörsdisciplin. Detta betyder också att mjukvaruingenjörer i större utsträckning kan ansluta sig till gruppen utvecklare av fordonsfunktioner, men utan att vara lika beroende av fysisk tillgång till fordon och/eller fordonskomponenter—en möjliggörare för öppen innovation. Men för att nå dit behövs lättillgängliga utvecklingsmiljöer för att snabbt kunna ta fram prototyper att testa och demonstrera. Idag är typiskt sådana miljöer specialiserade och kommersiella. Dessutom är sådana miljöer ofta inkompatibla med varandra vilket leder till inlåsning, och därmed svårigheter att utbyta komponenter mellan miljöer som en konsekvens—en barriär för öppen innovation.

Målen med projektet Öppet Innovationslabb (OIL) var att utveckla och demonstrera en helt mjukvarubaserad simuleringsplattform för att stötta öppen mjukvaruinnovation för fordonsindustrin. Projektet som löpte mellan april 2017 och mars 2019 genomfördes i två delprojekt.

I **Delprojekt 1**, *Simulatorplattform och verktygskedja*, utvecklades en öppen helt mjukvarubaserad licensfri simuleringsplattform och verktygskedja med syftet att stötta utveckling, provning och demonstration av fordonsmjukvara med fokus på standarder för att möjliggöra interoperabilitet.

Delprojektet bygger vidare på resultaten från projektet Second Road fas 2[2] delprojekt 5, i vilket målet var att etablera ett öppet innovationslabb genom att utveckla och tillgängliggöra en simulatormiljö med en modell- och hardware-in-the-loop-simulator byggd på industriledande simulatorhårdvara. Som del av resultaten från projektet kom VICTA Lab[3] till, vilket tillgängliggör och underhåller simulatormiljön.

OIL-projektet utökar VICTA Lab med en helt mjukvarubaserad simulatorplattform. I delprojekt 1 togs en generell simulatorplattform fram som dokumenterades och instansierades i tre konkreta simulatorer. Instansieringarna tjänade som demonstratorer för att validera plattformen och visa på dess användbarhet, och byggdes med hjälp av existerande öppna komponenter, samt fordonsmodeller från Volvobolagen. Simulatorerna implementerades för att utveckla och demonstrera två enkla tredjepartsfunktioner med var sitt trafikscenario—en kolonnkörningsfunktion och en nödbromsfunktion. För nödbromsfunktionen byggdes två olika simulatorkonfigurationer som nyttjade samma

[2] https://www.vinnova.se/p/second-road-fas-2/
[3] https://vehicle.lindholmen.se/node/40273

trafikscenario. Trafikscenariot definierades i och exekverades av komponenter byggda i FFI-projektet Simuleringsscenarier[4].

Plattformsdokumentationen innehåller beskrivning av bakgrund, syfte och behov, arkitekturella mönster, en inventering av existerade verktyg och komponenter, samt dokumentation av simulatorinstanserna. Simulatorinstanserna tillsammans med steg-för-steg-guider finns tillgängliga för nedladdning[5].

Resultaten från projektet är i korthet:

- Plattformsdokumentation[6]
- Websida med exempelsimulatorer byggda på plattformen[7]

Delprojekt 2, *VCC Infotainment Proof-of-concept*, demonstrerade öppen innovation genom att universitetsstudenter, som del av en kurs, utvecklade infotainment-applikationer tillsammans med Volvo Personvagnar (VCC) där Android Automotive[8] utgjorde plattformen för öppen innovation.

Som resultat i delprojektet togs en Android Automotive-miljö fram på vilken 67 studenter i 11 grupper från Högskoleingenjörsprogrammet på Chalmers Tekniska Högskola utvecklade fordonsapplikationer utan att behöva tillgång till en fysisk bil. Som del av projektet utvecklades även en signalgenerator (dvs en rudimentär simulering av fordonet) som kopplades till Android Automotive-miljön. Denna generator tillät studenterna att, i form av en textfil, definiera ett körfall som förser applikationen med indata för testning.

Efter genomförd kurs presenterade studenterna sina applikationer vid en tillställning på utvecklaravdelningen för infotainmentapplikationer på VCC.

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[4] https://www.vinnova.se/p/simuleringsscenarier/
[5] http://openinnovationlab.se/open-innovation-lab-project
[6] https://www.dropbox.com/s/yko4km20epg796o/OIL_Platform_Documentation_v1.0_2019-04-23.pdf?dl=0
[7] http://openinnovationlab.se/open-innovation-lab-project
[8] https://source.android.com/devices/automotive

3. Background

Expectations on the automotive industry of tomorrow are soaring. Connectivity and self-driving capabilities paired with novel propulsion techniques require extreme measures in software and electronics development. These demands can only be met with novel processes, methods and tools. Software oriented companies provide inspiration in terms of agile methodologies and continuous deployment concepts. These, combined with state of the art modelling and simulation based technologies, allow the automotive industry to meet the challenges of the future.

As the amount of software in vehicles increases, it is reasonable to assume it will directly influence competition within the industry. In the same way that crowd funding and the open source concept strive on collaboration, so will the automotive OEMs and Tier1s reach out for collaborative innovation and development. This will allow companies to benefit from a far larger community than their conventional employee base. Hence vehicle manufacturers are increasingly recognizing open innovation and third party development as sources of creativity and new ideas.

Already in 2013, Volvo Cars arranged their Open Innovation Challenge Active Safety, to encourage and collect novel, creative and innovative ideas for active safety features. The interest was great and attracted a lot of engaged companies (e.g. engineering service suppliers) and engineers. The winning team (from Semcon) proposed a feature called Pro-Active Wipers (PAW). This purely software-based "add-on" to target vehicles from VCC was developed as a concept and prototyped using simulation software. The prototype was then used to demonstrate and promote the concept. Participation in the competition required the teams to be external to VCC, which implied no access to VCC-specific vehicle models, software and such. This turned out to be a challenge of predominantly time consuming character, as all vehicle models, driving data, etc had to be manually generated or created. Furthermore, the Innovation Challenge made clear that collaboration and sharing of certain information would reduce the time and effort to create prototypes or demonstrators and boost the potential for innovation.

Within the VICTA community[9], this insight led to the initiation of two pre-studies in 2014.Their aim was to investigate the possibility of a range of suitable platforms, as part of the planned VICTA Lab[10], supporting open innovation for third party developers. In the VICTA Lab Pre-Study a stand-alone desktop simulator (MIL) called DeskSim was proposed and the requirements defined. The subsequent VICTA Lab Desksim project further detailed the specification of DeskSim and proposed three different and realistic solutions for it. None of the proposed solutions entirely fulfilled the requirements—e.g. non-commercial license, or had limited functionality or usability. As a result of the FFI project Second Road F2 (sub-project 5), VCC and partners developed a MIL/HIL simulator as an open test bed for research and innovation around vehicle ICT for VICTA Lab. However, this was based on commercial tools and proprietary vehicle models.

[9] https://vehicle.lindholmen.se/
[10] https://vehicle.lindholmen.se/node/40273

The Open Innovation Lab (OIL) project takes the next step to explore the potential of simulation-based testing methods when used to support open innovation and third party development. This was achieved by investigating and proposing a common—and to the extent possible—non-commercial platform and tool-chain for collaboration around different simulators focused on supporting open innovation. This is envisioned to lower the threshold for a third party developer to experiment with automotive software functions by providing a common simulator platform. Such a platform will make it easier to share OEM tools, e.g. vehicle models among others, significantly reducing the effort a function developer would currently need to spend on preparing a suitable test environment. In addition, with verified realistic vehicle and scenario models, fewer unfounded assumptions need to be made regarding sensors, features, actuators, etc., ideally resulting in demonstrators of increased relevance and higher quality.

4. Sub-project 1—Simulation Platform and Tool-chain

Purpose, research questions and method

The main purpose with sub-project 1 was to develop, document, and demonstrate an open simulation platform and its respective configuration tool-chain. Both should be non-commercial and purely software based with the purpose of supporting development, test, and demonstration of automotive software components. To facilitate interoperability, scalability, and maintenance, both tools should have a strong focus on standards.

Sub-project 1 continues the work done in FFI project Second Road fas 2[11] sub-project 5, in which the aim was to establish an open innovation lab with a model- and hardware-in-the-loop simulator environment. The results included the establishment of VICTA Lab[12], which maintains and makes the simulator available.

The main research questions addressed in this project were:

- How can a generic simulator architecture be designed to facilitate interoperability and promote reuse of simulator components?
- How can such an architecture be instantiated to concrete simulators using open and license free tools?
- How can such simulator instantiations support a third party software developer in creating, testing and demonstrating automotive software components?

To address these questions, a design thinking[13] approach was taken where researchers and practitioners collaborate and iteratively define goals, implement prototypes, reflect, and refine the goals for the next iteration. Concretely, sub-project 1 began by defining the desired outcomes which were documented in a report[14]. In the remainder of the project, the simulator platform was defined, documented and tested in small increments.

Objective

Sub-project 1 built on other FFI projects and aimed at extending VICTA lab to better support open innovation and third-party development of vehicle software and services. VICTA lab is a part of Vehicle ICT Arena (VICTA), which provides an open environment for innovation and maintenance of competence in vehicle ICT that helps to secure the Swedish competitiveness in sustainable and safe mobility. VICTA currently

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[11] https://www.vinnova.se/p/second-road-fas-2/
[12] https://vehicle.lindholmen.se/node/40273
[13] C. Swann, "Action Research and the Practice of Design," Design Issues, vol. 18, no. 1, pp. 49–61, 2002.
[14] https://www.dropbox.com/s/a2fmaypxaledars/OIL_WP1_Final_Report_v1.0.pdf?dl=0

has around 45 partners of different types: SMEs, research institutes, universities, service providers, established suppliers to the automotive industry, and automotive companies.

Besides supporting third-party development, a complementary goal of the project was to collaborate and share simulation artefacts between existing simulation platforms such as VCC SPAS, Volvo Adapt, VTI ViP, (see project report[15]) and the MIL/HIL simulator at VICTA lab. Close collaboration with neighbouring arenas and centres of competence creates a strong ecosystem around the Swedish automotive industry and strengthens its competitiveness.

The specific objectives of sub-project 1 were to:

1. Describe the simulated system (and its environment) with variability and abstraction support suitable for a third party user;
2. Develop a non-proprietary simulation engine;
3. Set up a common repository with version handling and containing models, scenario descriptions demo cases, field data, etc. that can be shared (in formats protecting sensitive IP);
4. Set up a Developer zone with user access to the repository, containing information and tutorials supporting a third party user to select the relevant models and configurations for a specific purpose;
5. Implement at least two proof-of-concept simulators supporting third party involvement for cars and heavy vehicles.

Results and deliverables

In sub-project 1 a simulator platform architecture was developed and documented. The platform was instantiated with three different configurations using existing open tools from the project partners, and two proof-of-concept third-party functions were developed and integrated into virtual representations of a car and a truck.

Specifically, to meet **objective 1** a platform report[16] elaborating on the simulation platform including the simulated system and its environment. **Objective 2** was met by contributing to and utilizing the simulation engine Adapt developed by AB Volvo, and also by contributing to an open source simulation engine developed by HiQ. The former was used as the main simulation engine in the sub-project while the latter was tested and verified to work. For **objective 3**, the tools available in VICTA Lab will be utilized, and the results from the sub-project will be integrated as part of future work (see chapter 7). For **objective 4**, a public website[17] has been created containing a summary of the project together with documentation and other downloadable material produced as part of the

[15] https://www.dropbox.com/s/yko4km20epg796o/OIL_Platform_Documentation_v1.0_2019-04-23.pdf?dl=0
[16] https://www.dropbox.com/s/yko4km20epg796o/OIL_Platform_Documentation_v1.0_2019-04-23.pdf?dl=0
[17] http://openinnovationlab.se/open-innovation-lab-project

sub-project. Finally, **objective 5** was met by instantiating the simulator platform to support development of two proof-of-concept third party functions.

To summarize, the concrete results from the sub-project are:

- Platform documentation[18]
- Website with PoC simulators available[19]

In addition, the sub-project has contributed to the following relevant results:

AB Volvo has during the OIL project established an open consortium managing the Adapt simulation engine. The consortium is open for membership application and is a means to share the technology without compromising its integrity through changes. Furthermore, during the course of the OIL project, VCC has become a member of the Adapt Consortium and part owner of the Adapt simulation engine, and internal initiatives have begun at VCC to adopt Adapt, initially complementing the tools used today.

ArTOP and EATOP are two Eclipse-based platforms for AUTOSAR and EAST-ADL editing, respectively. During the project, plugins for a combined Artop/EATOP platform have been used and refined. The tool environment allows a user to define system architectures with behaviour (based on functional mockup unit technology), parameters and variability. After variability resolution simulation artifacts for the Adapt platform can be generated.

Sub-project 1 has contributed to the development of the HiQ open source simulation engine. Furthermore, the sub-project utilized the results from and contributed to defining the requirements for the FFI-project Simulation Scenarios[20].

In the final phase of the project, one of the PoC simulators were integrated into a combined simulation platform with Adapt and the VTI SimIV simulator demonstrating the interoperability of the tools, as defined in the objectives.

In summary, sub-project 1 has delivered results according to the objectives set in the application.

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[18] https://www.dropbox.com/s/yko4km20epg796o/OIL_Platform_Documentation_v1.0_2019-04-23.pdf?dl=0
[19] http://openinnovationlab.se/open-innovation-lab-project
[20] https://www.vinnova.se/p/simuleringsscenarier/

5. Sub-project 2—VCC Infotainment PoC

Purpose, research questions and method

The purpose of sub-project 2, *VCC Infotainment Proof-of-concept*, was to demonstrate open automotive innovation by engaging university students to develop applications for the infotainment head-unit (IHU) in a Volvo car. The students represent the extreme end of third party developers in that they have no previous experience of automotive software development and no access to expensive tools or licensed technologies.

The IHU is a suitable environment to test and demonstrate the potentials of open innovation as vehicle manufacturers have lately been implementing these on top of standard and (in various ways) open platforms, such as Apple Carplay, GENIVI, Android Auto and Android Automotive.

The planned approach was to create a virtual development environment representative to the platform available in a Volvo car in which the students could work. During the course, the students had weekly meetings with representatives from Volvo Car Corporation (VCC) to show work in progress and validate their ideas.

Objective

The specific objectives of sub-project 2 were to:

1. Extend the MIL/HIL simulator in VICTA lab with support for third party development of infotainment apps;
2. Demonstrate how open innovation can work in an automotive context, by involving students as third-party developers.

Concretely, the goal was to develop at least five infotainment applications that should be demonstrated in real cars. This was achieved by using the tools and platforms existing in VICTA lab.

However, these objectives changed during the project. Initially, the plan was for VCC to use the GENIVI platform for their future IHU implementations. These plans changed as, between submitting the project proposal and the start of the project, VCC decided to change track and instead work with an IHU based on the upcoming Android Automotive platform[21]. This required sub-project 2 to re-plan efforts to develop an Android Automotive system image compatible with the Android Studio development environment, and a simple vehicle simulator able to provide the Android system image with vehicle data. This required considerably more effort than anticipated, which led to not meeting objective 1 as well as a nine month delay in the project progress, which in turn meant that there were no vehicles available for in-car testing of the applications.

[21] https://source.android.com/devices/automotive

Results and deliverables

For sub-project 2, an Android Automotive image compatible with Android Studio was developed. The image was constructed such that the students would be able to develop their applications without the need to access a real car. Instead a signal generator (essentially a very rudimentary simulated car) was connected to the Android vehicle integration layer. The students could then edit a simple text file specifying a test case in the form of timing and values of signals that the vehicle would send to the application. This allowed students flexibility in defining their test-cases and at the same time providing a familiar and open development environment.

Due to circumstances explained above, **objective 1** was not met. With a grant from Västra Götalandsregionen[22], this work is planned to be done in the near future.

Objective 2 was met by organising a university course where students developed 11 IHU applications for a Volvo Car. The students each spent approximately 150 working hours in a total of eleven teams of 6-7 students over 5 calendar weeks to develop their applications. The sub-project was concluded with a half-day workshop at the infotainment department at Volvo Cars were the students presented their applications to industry practitioners.

[22] Grant from Västra Götalandsregionen (Dnr RUN 2018-00710)

6. Dissemination and publications

In addition to the dissemination activities described below, the OIL project and the tools developed and refined within the project has been demonstrated at internal seminars at the Volvo companies.

Dissemination

How are the project results planned to be used and disseminated?	Mark with X	Comment
Increase knowledge in the field	X	The project results have been made available through VICTA Lab and a website. Also available is extensive documentation of the platform and its environment.
Be passed on to other advanced technological development projects	X	Proof-of-concept simulators which demonstrate implementation of 3rd party software functions have been made available. In addition, the activities in the project has contributed to VCC joining and becoming part owners of the Adapt consortium, and to VCC adopting the simulation engine as complement/alternative to the proprietary engines used today
Be passed on to product development projects		
Introduced on the market		
Used in investigations / regulatory / licensing / political decisions		

The following dissemination activities were done as part of the project:

- Presented the project at Vehicle Electronics and Connected Services (VECS)[23] 2018 with the title ”Open Innovation Lab—Simulation Based Test Methods as Support for Open Innovation and Third Party Software Development”;
- Organised a seminar within sub-project 2 where the students presented their application at the infotainment department at Volvo Cars, October 24 2018;
- Presence at the Lindholmen Innovation Bazaar 2018[24] exhibition sessions, demonstrating the results from sub-project 2;
- Presented preliminary results from sub-project 1 at the Simulation Scenarios[25] final seminar February 21 2019;
- Organized an open final project seminar[26] with about 40 participants at Lindholmen Science Park, March 26 2019;
- Presented project technologies at the ModProd Conference 2018[27]
- Presented project technologies at Smart Variant CON 2018[28]

Collaborations

FFI project Simulation Scenarios

A close collaboration with the FFI project Simulation Scenarios[29] resulted concretely in the ability to:

1. Utilize the OpenSCENARIO format for specifying test scenarios executed by the environment simulator
2. Utilize the OpenSCENARIO interpreter implemented in the ViP software
3. Utilize the environment simulator ESMini

This allowed the OIL project to use the environment simulator with little effort and focus on the vehicle simulator and simulation engine components which were the main objectives in the project.

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[23] https://insightevents.se/vehicle-electronics-connected-services/
[24] https://vehicle.lindholmen.se/event/vehicle-ict-arena-innovation-bazaar-0
[25] https://www.vinnova.se/p/simuleringsscenarier/
[26] https://sites.google.com/view/open-innovation-lab-seminar/home
[27] https://www.openmodelica.org/events/modprod/modprod-2018
[28] https://www.tacton.com/events/smart-variant-con-2018/
[29] https://www.vinnova.se/p/simuleringsscenarier/

Publications

Master Thesis

Title:	Virtual vehicle modelling architecture with centralized control,
Authors:	Mario Majdandzic, Pooja Sousthanamath
Place:	Chalmers University of Technology
https://www.chalmers.se/en/departments/e2/calendar/Pages/Masterpresentation-Mario-Majdandzic.aspx	
Title:	*Virtual Integration and Simulation of Autonomous Systems*
Authors:	Ashok Krishna, Palaniappa Sambanthan
Place:	Chalmers University of Technology *(to appear)*

Scientific publications

Title:	Towards an Open Automotive Software Innovation Lab
Authors:	Mellegård, Reichenberg (RISE), Lönn (ABV), Gupta, Bhat (VCC), Piegsa, Masaracchia, Sousthanamath (Semcon), Augusto (VTI)
Place:	ELIV 2019 (in submission)
Title:	Integration and Simulation Technologies supporting Needs of Emerging Vehicle Functionality and Development Processes
Authors:	Lönn (ABV)
Place:	ELIV 2019 (in submission)

7. Conclusions and future research

The goals of the Open Innovation Lab project were a) to demonstrate the potential of open automotive software innovation, b) to demonstrate the viability of open automotive software innovation, and to c) to develop and document a generic desktop-based simulator platform for supporting development, test and demonstration of automotive software functionality.

Sub-project 2 demonstrated open innovation by engaging university students to develop infotainment applications for a Volvo car, and in collaboration with VCC. The course was appreciated by both the students and staff at VCC, and provided both challenges and lessons learned. Configuration of the Android platform to improve usability from a perspective of a third-party developer, proved to be a challenge. Firstly, because the Android Automotive platform is still in development and may not yet be mature enough for this purpose. Secondly, estimating the signals (and respective properties) that a vehicle would make available is not an easy task, and is nothing short of guesswork. The second issue could easily be solved by providing a complete simulator as described in sub-project 1, leaving the vehicle signal simulation to the OEM. Then, a developer could drive or script a driving cycle and let the vehicle simulator provide the signals to the infotainment application through the Android Automotive operating system.

To facilitate open innovation the OEM has to be prepared to support third party developers with appropriate technologies. From the experiences of the student collaboration it became evident that the change of IHU platform had an effect on the resources available for testing and demonstrating open innovation. In this particular case the limited possibilities for realistic simulation and lack of test vehicles meant that the applications could only be tested and demonstrated as stand-alone applications but not their integration with the rest of the vehicle systems. Open innovation also requires in-depth automotive knowledge to assess possible value propositions. This was managed by the weekly meetings between the student teams and the VCC representatives.

While open innovation can facilitate fast development of novel services and products, it is not for free – the OEMs need to supply the outside with both tools and technologies as well as assessment of emerging prototypes to steer innovation in a valuable direction.

Sub-project 1 developed and documented a simulator platform architecture. The platform was instantiated with three different configurations using existing open tools from the project partners, and two proof-of-concept third-party functions were developed and integrated into virtual representations of a car and a truck.

The platform is flexible with respect to configuring a simulator for the purpose of developing, testing and demonstrating a software function by a third-party. However, the simulator instantiations results show that there are still challenges that need to be addressed particularly when considering the interfaces.

Firstly, the interface between the environment and the vehicle simulator needs standardizing to allow decoupling the environment and vehicle simulators, specifically the EnvironmentAPI, VehicleDynamicsAPI and SensorAPI (see the platform report[30]). These interfaces are crucial in order to decouple the simulated vehicle from the environment, and bolstering reusability of the models which comprise the complete vehicle. The interfaces are non-trivial as they need to provide the vehicle with enough information about the environment to simulate sensors. The sensors—the vehicles perception of its surroundings—are key components when developing and testing active safety and driver support functions. A candidate interface, Open Simulation Interface (OSI)[31], is in development and is planned to become part of the ASAM[32] portfolio of standards together with OpenDRIVE, OpenCRG and OpenSCENARIO. Another relevant initiative is the Open Fusion Platform[33] which aims to define a sensor fusion platform with open interfaces specifically for autonomous vehicle functions.

Secondly, to support a third party developer, a standard set of interfaces towards the vehicle (see the VehicleAPI in the platform report[34]) would be valuable. While this interface would probably be specific to the vehicle deployed in the vehicle simulator, a basic/minimum set of interfaces with common naming conventions would provide a third party developer with a more uniform way of interacting with vehicles. Similar initiatives but with more specific application areas include: the FMS standard (Fleet Management Standard)[35] which provides a manufacturer independent way of accessing certain kinds of on-board data for use with fleet management systems; and ITxPT[36] which aims to enable interoperability between IT systems in Public Transport by providing standard interfaces for on-board, over-the-air and back-office IT systems. No such initiative for generic access to vehicle on-board data, for the purpose of facilitating open automotive software innovation, exists to the best of our knowledge.

Considering the vehicle models, there is great effort in developing virtual vehicle representations (a.k.a digital twins). As to achieving interoperability between simulation models, the FMU standard provides the means to co-simulate models from different sources. However, developing and maintaining the contents of these components presents great challenge. While a tempting prospect would be to develop a complete and correct representation of the entire vehicle, it would not be feasible due to the sheer complexity and to the computational power that would be required to execute them. Instead the typical approach is to, based on the specific purpose the models are to serve, select only the subset of functionality that is required and choose or create models of the behaviour at the required fidelity. This typically results in many model component variants for the same vehicle functions, and where it is often not obvious what components are compatible or when. As a consequence, to support open innovation the vehicle

[30] https://www.dropbox.com/s/yko4km20epg796o/OIL_Platform_Documentation_v1.0_2019-04-23.pdf?dl=0
[31] https://github.com/OpenSimulationInterface
[32] https://www.asam.net/
[33] http://www.ofp-projekt.de/ofp-project/en/index.html
[34] https://www.dropbox.com/s/yko4km20epg796o/OIL_Platform_Documentation_v1.0_2019-04-23.pdf?dl=0
[35] http://www.fms-standard.com/
[36] https://itxpt.org/

manufacturer would need to provide custom-made virtual vehicles on demand, which is not feasible. Instead, there is a need to better organize the model components in a way to make them more easily combinable. Although a master thesis on the subject was written as part of the project, no such tried and tested approach exists today, to the best of our knowledge.

Looking forward, a generic vehicle simulator platform provides interesting opportunities beyond supporting open development of software functionality for a specific vehicle—seamless distribution of simulator components. Virtual vehicle representation will likely—due to OEM IPR—remain a restricted resource. With standard interfaces in place an OEM could allow restricted remote access to instances of a virtual vehicle (e.g. running on a trusted data centre). This solves the issue with distributing copies of the software and allows interesting simulation use-cases. For testing—and maybe even certifying highly autonomous functions—there will be a need to evaluate behaviour when vehicles from multiple OEMs interact in the same traffic situation, or with models of human drivers. It is conceivable that a governing body sets up a number of key scenarios in which an OEM must demonstrate proper function. Initial feasibility tests using tools from the open innovation lab project have been done in a previous study[37].

There are several on-going projects related to OIL. The EMISYS[38] project addresses enhanced simulation of FMU components and at examining FMUs as production software containers. Its aim is to improve integrated modelling of complete vehicles which can contribute to more efficient construction of virtual vehicles. The goal of the TrAF-Cloud project[39] is to examine and build prototypes of a new on-board software architecture for trucks that allow safe and secure integration with cloud functionality. The architecture is envisioned to be deployed partly on-board and off-board, abstraction layers with APIs will be defined, some of which would be open to third parties.

Widening the perspective, the SIMnVIS pre-study aims to define project(s) that establishes a generic traffic and transport simulation and visualization platform. The purposes of such a platform would include investigating various interventions such as infrastructure investments, mobility services, and their impact on e.g. traffic flow, emissions, or land use. The aims of the SIMnVIS project is similar to OIL in aiming to identify standard components and interfaces that improve reusability of components, reducing the effort needed to set up a simulator. In such simulators the behaviour of individual vehicles is typically abstracted (simple agent-based behaviour or as flow models). With standard interfaces able to provide a virtual vehicle with input (Environment API), enables inclusion of models of the actual vehicle.

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[37] Aramrattana, Andersson, Burden, Reichenberg, and Mellegård, *Testing Cooperative Intelligent Transport Systems in Driving Simulators*, presented at the 17th Driving Simulation & Virtual Reality Conference & Exhibition (DSC) 2018

[38] https://www.vinnova.se/p/emisys/

[39] https://www.vinnova.se/p/lastbilsarkitektur-for-funktionalitet-i-molnet-traf-cloud/

As a next step, the results from the OIL and Simulation Scenarios project[40] will be adapted to and made available in VICTA Lab[41].

[40] https://www.vinnova.se/p/simuleringsscenarier/
[41] Grant from Västra Götalandsregionen (Dnr RUN 2018-00710)

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