MuCCA

Multi-Car Collision Avoidance Report

Using connectivity and autonomy to minimise the damage in high-speed, multi-vehicle traffic accidents.

INTRODUCTION

In early 2020, a consortium of experts from across industry and academia came together to realise their vision of vehicles communicating and working together to avoid collisions. The success of this Multi-Car Collision Avoidance (MuCCA) project demonstrated the feasibility of a cutting-edge active safety system that would help prevent multi-car collisions on motorways.

As well as being much more likely to result in a fatality, accidents that involve multiple vehicles – especially those that occur on motorways – also cause significant disruption to the road network.

When things go wrong on a motorway, the traffic density in adjacent lanes, coupled with limited time for other drivers to react, makes it a particularly challenging environment in which to mitigate risk – and in which risk can escalate dangerously quickly dependent on the severity of the incident.
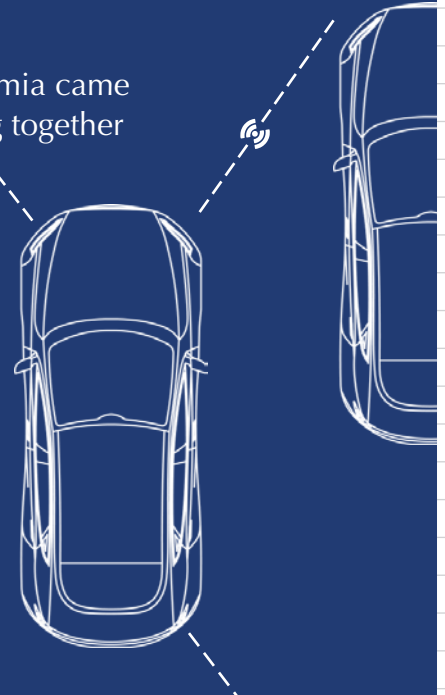
Whilst the theoretical safety benefits of autonomous vehicles are regularly discussed, it's clear that a single autonomous vehicle working in isolation would be unable to deliver the kind of additional benefits made possible when multiple vehicles work together as a group – as now demonstrated by the MuCCA system of:

- cutting-edge algorithms
- combined connectivity and autonomy
- coordinated behaviour between vehicles – rather than just single vehicles 'looking out for themselves'
- state-of-the-art connectivity
- human driver modelling enabling it to account for unconnected vehicles.

PROJECT OVERVIEW

In 2016 the Centre for Connected and Autonomous Vehicles (CCAV) and Innovate UK, under the banner of their Connected and Autonomous Vehicles 2 competition, put out a call for 'technical solutions for connected and autonomous vehicle features that provide real-world benefits to users'. The MuCCA consortium – formed of six partners working across industry, academia, and innovation in Mobility, Smart Cities and the Built Environment – successfully responded to that call.

The project proposed by MuCCA to develop and demonstrate an active, automated safety system that utilised connectivity to minimise high-speed, multi-vehicle collisions – one of the most difficult challenges for automated vehicles – pushed the boundaries of connected and automated vehicle thinking.

With a budget of £4.6 million jointly funded by government and industrial partners, work started in summer 2017 and ran for two-and-a-half years and culminated in a demonstration of multiple real vehicles working together autonomously to avoid collisions, as well as successfully negotiating multiple scenarios both on the test track and many more in virtual simulation. The project proved that the MuCCA system was capable, flexible and scalable.

BUDGET OF **£4.6 million**
JOINTLY FUNDED BY GOVERNMENT AND INDUSTRIAL PARTNERS
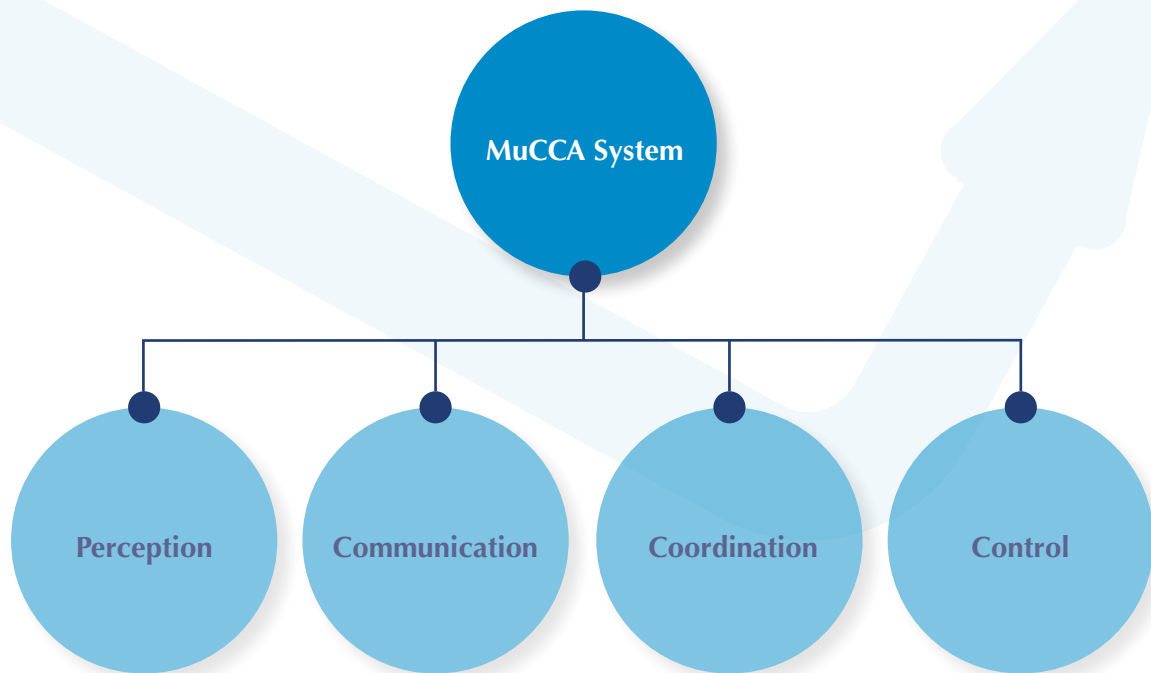
PROJECT PARTNERS AND ROLES

The consortium – led by Applus IDIADA UK working collaboratively with partners from different fields of expertise – delivered a proof-of-concept demonstration in a representative motorway environment of a ground-breaking system that was only made possible through collaboration.
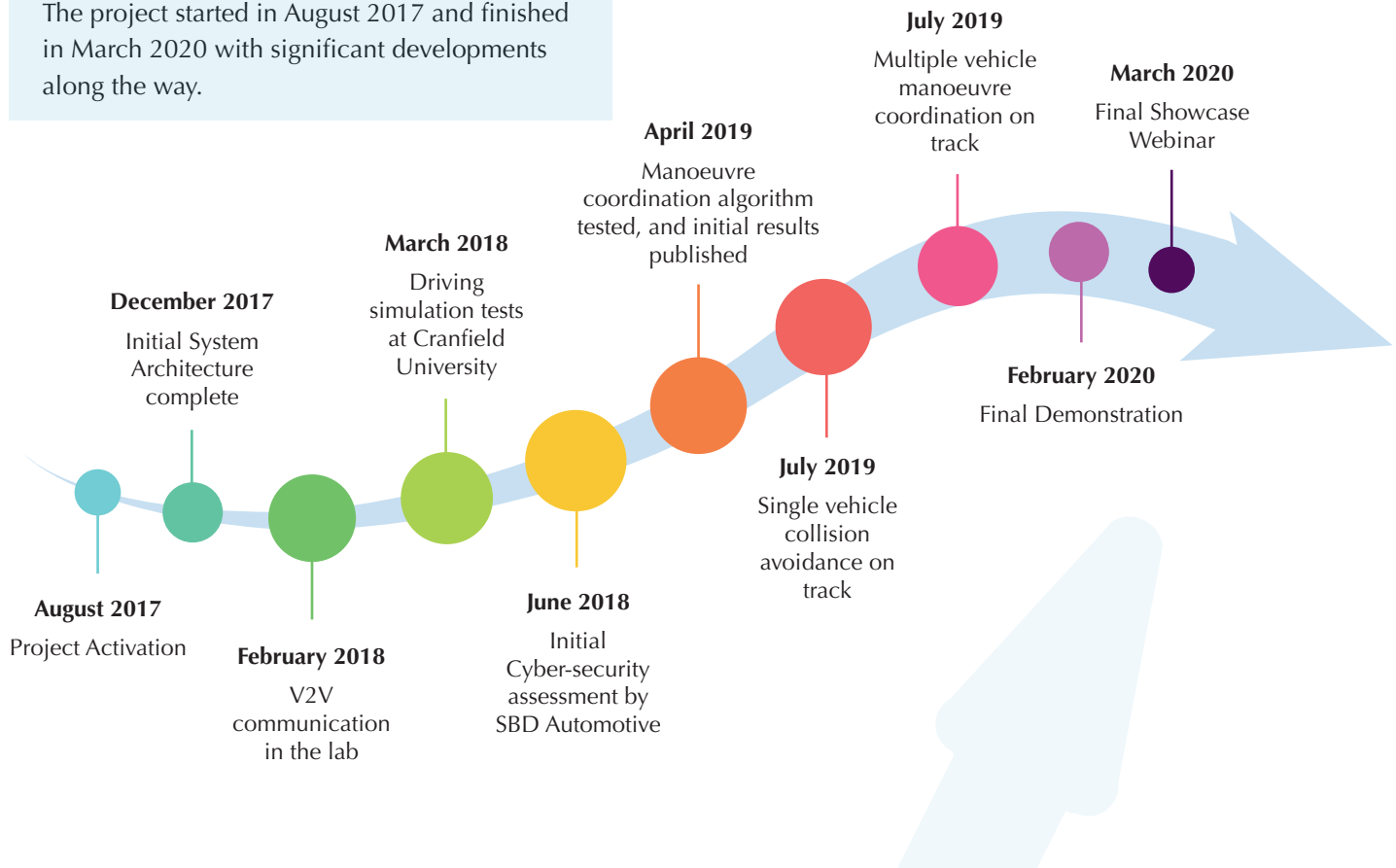
The MuCCA partners are:

- **Applus IDIADA UK –** project technical lead, developed the MuCCA system hardware and software, integrated partners' sub-systems into the MuCCA system and then the vehicles, and undertook the virtual and track testing.

- **Cranfield University –** developed coordinated path planning algorithms, a human driver model, and improved vehicle dynamics models.

- **Cosworth Electronics –** applied data-logging expertise to an automated driving system and developed sensing capability for MuCCA.

- **Westfield Sportscars –** supplied vehicles capable of drive-by-wire and managed the trials.

- **Connected Places Catapult –** considered human factors and regulatory requirements, undertook Systems Engineering for the MuCCA system and managed dissemination for the project.

- **SBD Automotive –** undertook initial cyber-security analysis of the proposed MuCCA system to inform later developments.

PROJECT TIMELINE

The project started in August 2017 and finished in March 2020 with significant developments along the way.

July 2019
Multiple vehicle manoeuvre coordination on track

March 2020
Final Showcase Webinar

April 2019
Manoeuvre coordination algorithm tested, and initial results published

March 2018
Driving simulation tests at Cranfield University

December 2017
Initial System Architecture complete

February 2020
Final Demonstration

August 2017
Project Activation

July 2019
Single vehicle collision avoidance on track

February 2018
V2V communication in the lab

June 2018
Initial Cyber-security assessment by SBD Automotive

CONNECTIVITY

The long-envisioned concept of connected vehicles communicating with each other and their surrounding infrastructure is fast becoming a reality – with potential safety benefits being a significant motivating factor – and MuCCA takes a significant leap beyond that which has so far been delivered.

The MuCCA system uses connectivity for two key functions:

- **Sharing information about the surrounding environment** – while vehicle sensor technology is improving all the time, there are still limitations in range, and objects frequently obstruct line of sight. Sharing sensor information between vehicles, known as 'Collective Perception', can help overcome some of these limitations. MuCCA uses state of the art messaging implemented by Applus IDIADA UK to exchange perception information.

- **Coordinating manoeuvres of MuCCA vehicles** – the MuCCA system extends the concept of Manoeuvre Coordination through a decentralised approach to collaborative collision avoidance. Each vehicle shares their next planned trajectory along with a hypothetical trajectory they would take if other vehicles could accommodate it. This information, sent in a single message, then informs decisions made by other vehicles.

These key functions were developed using Applus IDIADA UK's IDAPT hardware units in the lab and simulation before being deployed in the vehicle, and were ultimately demonstrated at Bruntingthorpe proving ground in 2019.
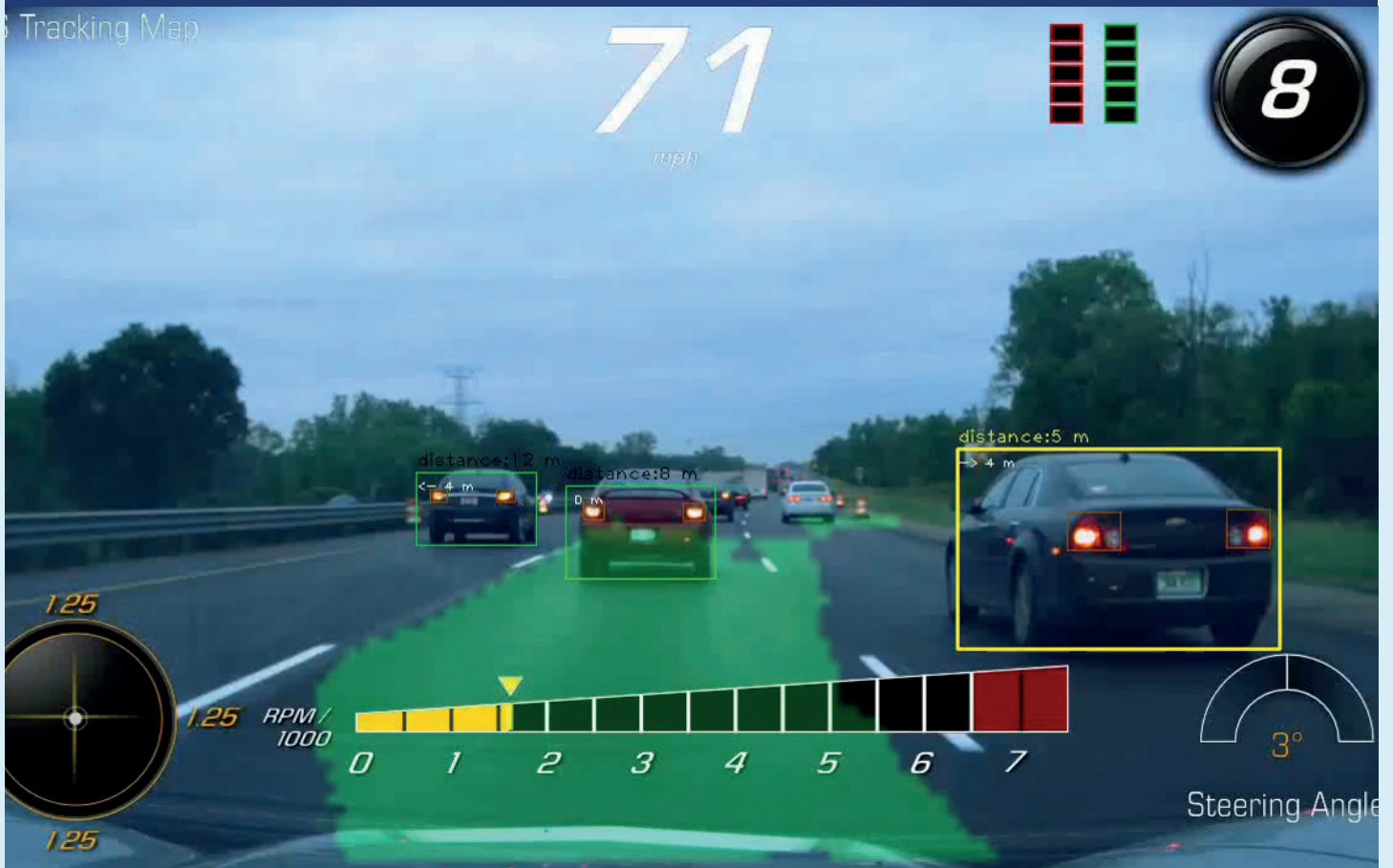
PERCEPTION

The Collective Perception enabled by MuCCA relies on individual vehicles perceiving their environment. To achieve this a combination of sensors were used in the lab and on the test track. Cosworth Electronics undertook detailed research into appropriate computer vision algorithms, and developed camera and lidar-based perception systems to detect other vehicles using state-of-the-art machine-learning.

For the scene-understanding task the perception system used a single-stage object-detection algorithm, where the base neural network architecture that is used for feature extraction is specifically enhanced to enable better detection of smaller objects. The MuCCA vehicles could then share this perception information via vehicle-to-vehicle communication.

The Collective Perception enabled by MuCCA builds on individual vehicles perceiving their environment.

COORDINATION

Connectivity gave the MuCCA system a richer view of each vehicle's surroundings and plans, but to build on this MuCCA developed cutting-edge algorithms for vehicle coordination.

Each MuCCA vehicle shared both its immediate planned trajectory as well as its preferred trajectory. Every vehicle then accounted for both trajectories broadcast by each of the other vehicles. This enabled them all to accommodate other vehicles' preferred trajectories when safe to do so, whilst at the same time ensuring they all kept clear of each others' immediate planned paths. In this way cooperative behaviour emerges, without any one vehicle ever being in charge, and without any vehicle putting itself at risk. This is similar (but generalised to any manoeuvre and with any number of nearby vehicles) to how a human driver might use an indicator signal to indicate to other drivers a desire to make a specific manoeuvre, whilst another driver might then respond by flashing their headlights as a gesture to indicate 'go ahead'.

The result of this group communication is an intelligent, shared response to the emerging scenario that continually iterates as the situation continues to develop:

- **There is no script or library of tactics** – instead, the cars establish a good solution amongst themselves, in real-time.

- **The planning is not based on specific lane changes –** just as a human driver would, each vehicle considers the whole road width as free space for emergency collision avoidance, with just a weak preference to settle into a traffic lane once the danger has passed.

This concept is illustrated in the diagram on the next page with the vehicle on the right blocked by an obstacle in its lane, and desiring to move into the centre lane vehicle's path. This desire can be knowingly accommodated by the centre lane vehicle, with both vehicles then working in unison to change lanes and thereby avoiding the obstacle.
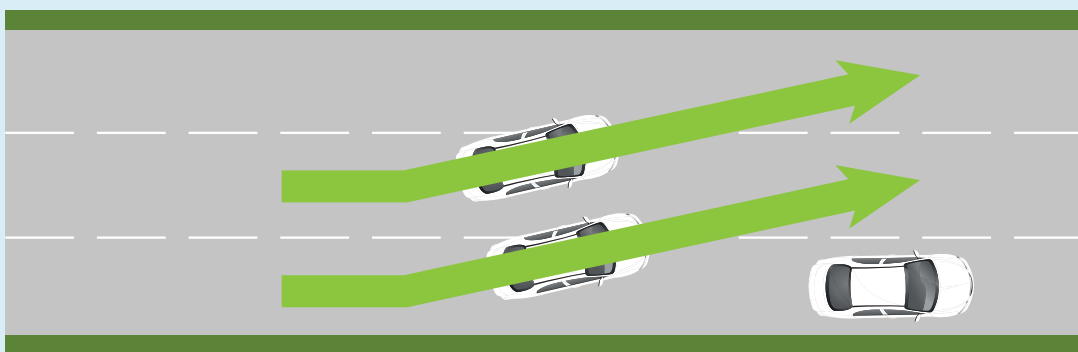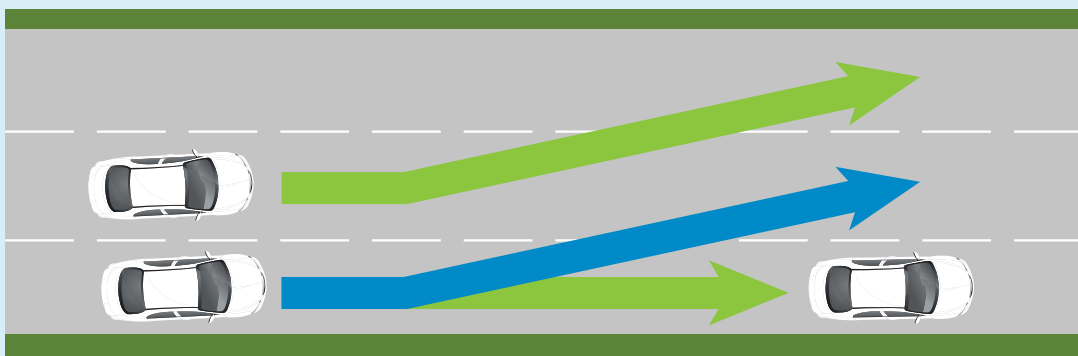
This approach produces an ever-evolving group solution that doesn't rely on a "leader". In fact, assigning a leader prior to considering trajectories, as well as being a significant overhead, limits the group's ability to respond to scenarios dynamically. This non-hierarchical group structure also means that the MuCCA system is both readily scalable and very flexible as more vehicles can be added to the group without having to 're-train' lead vehicles to recognise and accommodate them.

Whilst the obvious ultimate goal would be for all vehicles to be MuCCA-enabled, there would of course be a significant transition period where whilst some vehicles are connected to the system, many others won't be. As such MuCCA does also consider non-MuCCA vehicles in the local environment.

In order to handle these situations, predictions need to be made about what other vehicles will do and a human driver model was developed by Cranfield University to do just this. Consisting of a machine-learning algorithm trained on a combination of simulation and real-world data, this model predicts what human drivers are most likely to do in any given situation, and this data can then be used to guide MuCCA in its trajectory planning.

To test these elements together, Applus IDIADA UK developed a virtual environment using Prescan, an automotive simulation software developed by Siemens. This virtual environment was based on the Bruntingthorpe test track and Prescan ran the MuCCA software 'in-the-loop" on the real MuCCA hardware. This was as close to real track-testing as possible and was critical to testing the software safely. This virtual testing also allowed more complex scenario testing than would have been possible on the track, including demonstrating five MuCCA vehicles coordinating in real-time.

CONTROL

Connectivity and coordination can only produce results if the MuCCA system has control of each vehicle. This entailed controlling the vehicle steering, throttle and brakes from an external system, in this case the IDIADA ADAS Platform Tool (IDAPT). Highlighting the flexibility of IDAPT and the MuCCA system, production vehicles were used in the project with removal and reinstallation of the additional equipment taking minutes
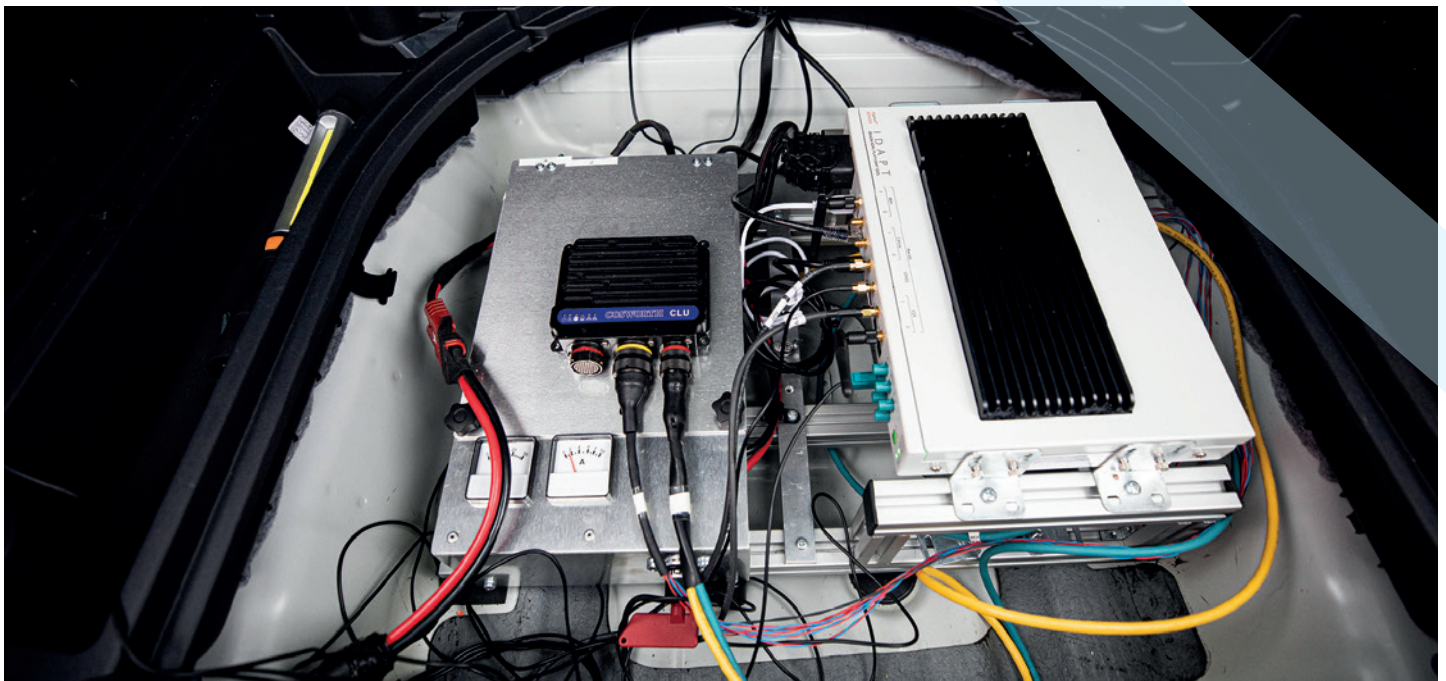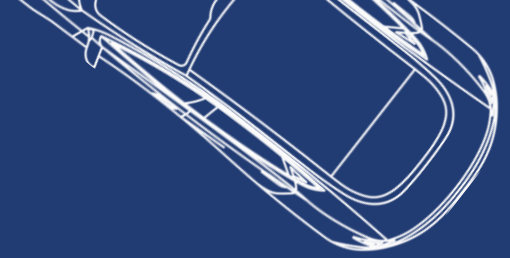
SAFETY

The track testing took place at Bruntingthorpe Proving Ground during 2019. The trial management was led by Westfield Sportscars whose experience of low-speed autonomous vehicle trials positioned them to lead development of the consortium's safety case for track testing and build their experience of higher-speed testing using conventional road vehicles. Informed by the latest industry best practice, the safety case considered amongst other things:

- the operational environment
- the maturity of the vehicle and systems
- the ability of safety drivers to intervene safely.

The professional safety-drivers from Westfield ensured the ultimate mitigation and the trials were then designed with speeds and separations dictated by reaction times and calculations.

DRIVERS

While safety-drivers were critical for track testing, a future MuCCA system will not be able to rely on safety drivers. This highlights a key research topic for autonomous vehicles: the interaction between human and machine. In the case of a MuCCA system this interaction is novel as takeover could be initiated by the system, as opposed to conventional automated driving systems where the driver passes control to the system. The focus of the MuCCA project was on the proof of concept demonstration, however the human-machine interaction was explored in virtual reality by Connected Places Catapult. Different prototype human-machine interfaces can be tested in a virtual vehicle as real MuCCA scenarios are replayed for participants to experience.

DEMONSTRATION

The MuCCA final demonstration took place in February 2020 at Bruntingthorpe Proving Ground. With two vehicles communicating in their starting positions, the safety-drivers then brought the vehicles up to speed and engaged the MuCCA systems. From then the vehicles were automated and worked together to manoeuvre around a stationary vehicle in lane one. After successfully manoeuvring around the first obstacle, a second stationary vehicle was met in the middle lane. The vehicles continued to work together successfully to manoeuvre around this new situation before the safety-drivers retook control at the end of the scenario.

Slight variations in the positions and speeds of the vehicles resulted in different manoeuvres showing that the two MuCCA systems were working together live to best manoeuvre around a new situation. For example, the vehicles may manoeuvre around the second obstacle in the same lane one in front of the other as opposed to taking different lanes. This really highlighted the power of the algorithms developed in the MuCCA project and, along with the virtual test runs, demonstrated the potential of the MuCCA system in more complex scenarios.

MARKETING

The MuCCA project truly pushed the boundaries of current technology and it is therefore critical now for the consortium to share their findings with as many people as possible.

To that end, the consortium has already started conversations with industry and academia at international conferences, events and through journal publications.

MuCCA has already attended:

- **Intelligent Transport Systems (ITS) World Congress 2018** – Copenhagen, Denmark. Applus IDIADA presented the MuCCA project.
- **ITS World Congress 2019** – Singapore.
- **Cenex Low Carbon Vehicle conference (LCV)** and **Connected Automated Mobility (CAM) Event 2019** – Millbrook, UK. Applus IDIADA presented the MuCCA project and displayed MuCCA vehicles.
- **IEEE Intelligent Transportation Systems Conference (ITSC) 2019** – Auckland, New Zealand. Cranfield University presented the MuCCA project.
- **IEEE International Conference on Connected Vehicles & Expo (ICCVE) 2019** – Graz, Austria. Cranfield University presented the MuCCA project.
- **MOVE 2020** – London, UK. Applus IDIADA presented the MuCCA project.

News of MuCCA's success has also been shared with the general public via social media, a project website *mucca-project.co.uk*, a final showcase event for the project and a video of the demonstration.

CONCLUSION

The MuCCA project has compellingly shown what is possible when connectivity and autonomy combine to deliver a potentially life-saving active safety system. It has also demonstrated how a consortium partnership can work closely together to access the mutual benefits of collaborative research and development, where the whole is greater than the sum of its parts.

MuCCA

Project Partners

Applus⊕
IDIADA

Cranfield
University

COSWORTH

WESTFIELD

caTAPULT
Connected Places

SBD

Project funded by

Centre for Connected
& Autonomous Vehicles

UK
RI
Innovate
UK