



**THE
COMMAND
HUB**





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INSTANT
REMOTE-ACCESS
TO AUTONOMOUS
VEHICLES



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Complete control of an autonomous vehicle is paramount when it comes to their safe operation and introduction to public roads. In order to achieve this, systems must be implemented beyond the base level of trust given to autonomous driving software, which whilst may reach a level of 100% of autonomy, still requires the expertise and oversight of a trained operator utilising a Command Hub.

The Command Hub functions as a robust, remote monitoring and building that allows for complete oversight over an autonomous vehicle such as Kar-Go (and eventually fleet,) with the ability to monitor key operational metrics whilst possessing the ability to take full control of the vehicle and

remotely operate it if required. All of this possible from a remote location, or 'Hub.'

Safety is an integral component when operating an autonomous vehicle and whilst it is currently a requirement for a safety driver to be present in the vehicle, the ultimate aim is to reach a level of autonomy and safe practice where an autonomous vehicle no longer requires a safety driver. It is at this stage, and even whilst a safety driver is required, that there is a further fundamental requirement for a high-level resource such as the Command Hub, that allows for the safe monitoring of an autonomous vehicle and the ability to take complete control at a moment's notice.



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WHAT

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What is the Command Hub?

The Command Hub is a building with system and that allows remote access to an autonomous vehicle such as Kar-go. Through the interface, an autonomous vehicle, its software and performance can be monitored and interacted with, along with diagnostics for exploring potential problems and faults. All of this completed by a dedicated and trained Command Hub overseer and team.

The building features multiple super computers with near instantaneous access to the Kar-go, our autonomous delivery vehicle. This allows an added level of safety and control over and above all measures taken in the Kar-go safety case and accompanying risk registers

The Command Hub allows staff to supplement the safety driver, monitor the fleet and if required, to act as a back-up remote driver, engineer and software developer. This system covers a wide range of safety parameters by being accessible both during the live real-time operation of an autonomous vehicle and also while the vehicle is stationary, allowing for a dynamic level of interaction.



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WHY

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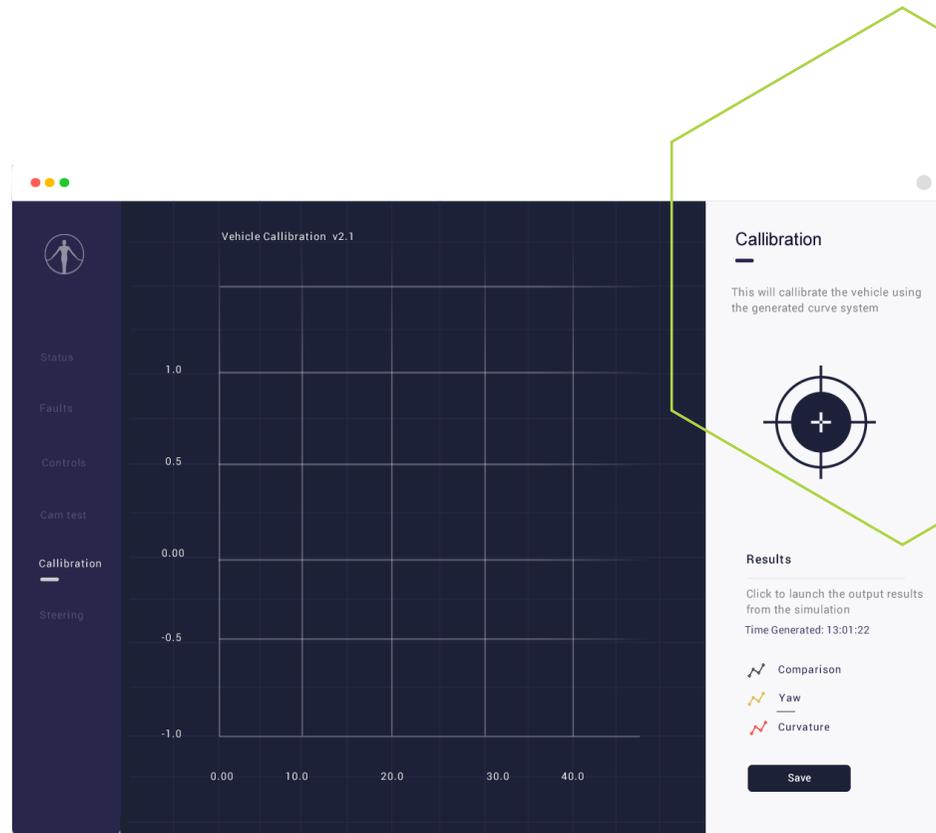


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Why is the Command Hub important?

Assurance of safety cannot be understated when it comes to putting autonomous vehicles on the road. Even though autonomous vehicles can be developed and trained to become the perfect drivers, they are still subject to many of the same risks as every other road user. Whilst the importance of a Command Hub exists at every stage of autonomous driving, there will also be a stage where there is no longer a safety driver to respond to any



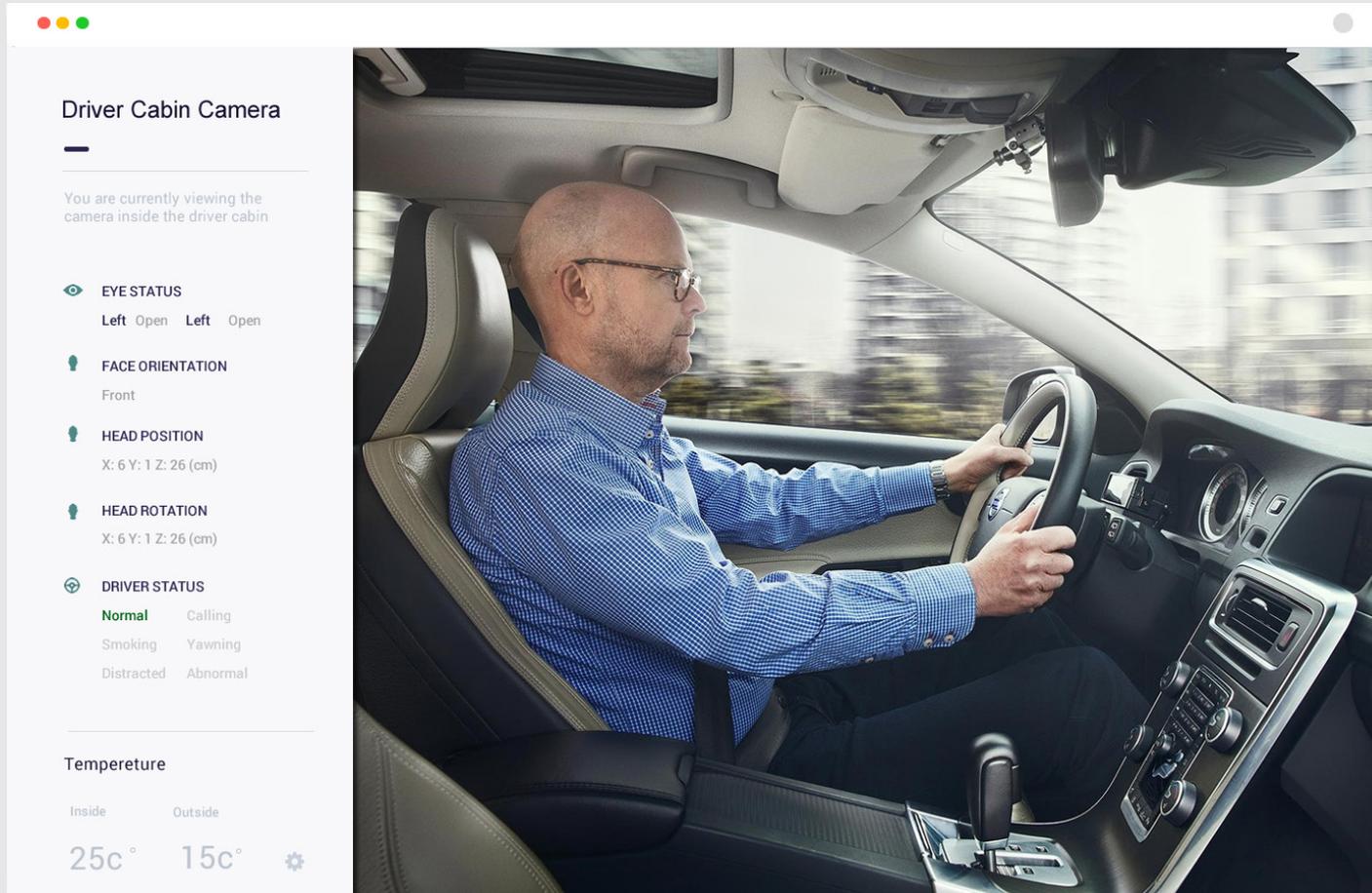
faults or problems from inside the vehicle itself, and a Command Hub is of the utmost importance to ensure that the autonomous vehicle is functioning as intended and is navigating its set route without deviation. All of which is being done safely and remotely by trained operators who are prepared to intervene if required.

The importance of the Command Hub is not just apparent in the ability for a trained operator to monitor the navigation and performance of the vehicle through a real-



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The screenshot displays a user interface for a driver cabin camera. On the left, a sidebar contains the following information:

- Driver Cabin Camera**
- You are currently viewing the camera inside the driver cabin
- EYE STATUS**: Left Open, Left Open
- FACE ORIENTATION**: Front
- HEAD POSITION**: X: 6 Y: 1 Z: 26 (cm)
- HEAD ROTATION**: X: 6 Y: 1 Z: 26 (cm)
- DRIVER STATUS**:
 - Normal** (highlighted in green)
 - Calling
 - Smoking
 - Yawning
 - Distracted
 - Abnormal
- Temperature**:
 - Inside: 25c°
 - Outside: 15c°
 - Settings gear icon

The main area of the interface shows a live video feed of a driver from a side-rear perspective. The driver is a man with glasses wearing a blue checkered shirt, sitting in a leather car seat and driving. The background shows a blurred city street, indicating the car is in motion.

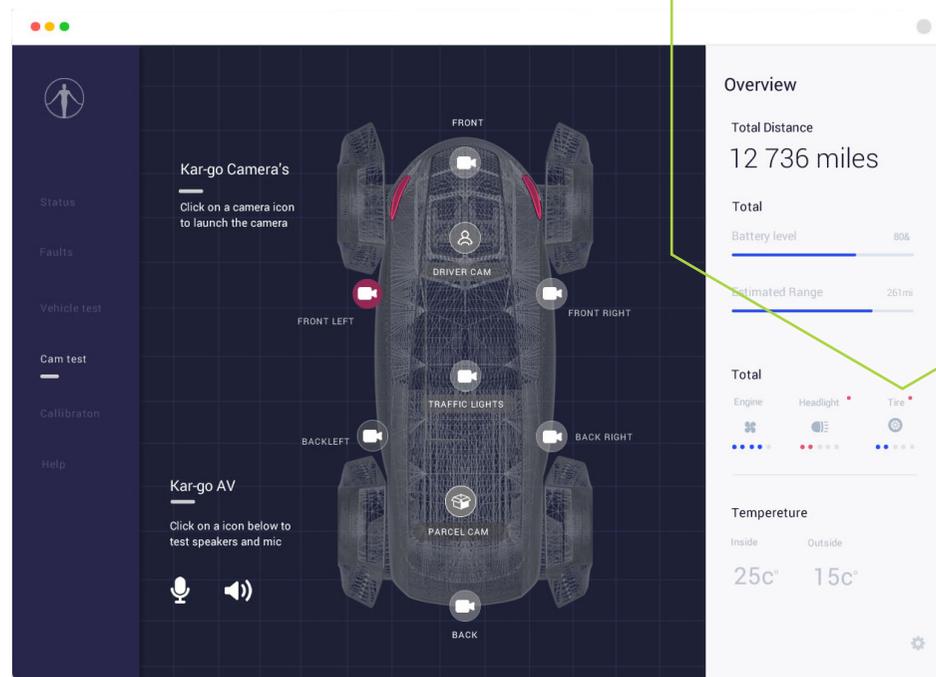


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time live connection to its many cameras, software and hardware. But, the Command Hub is also a deep, robust and all-encompassing tool that allows for insight into the performance and status of the vehicle on a high-level, that goes far beyond the intuition of even the most seasoned drivers.

Layers of safety that the Command Hub ensures cannot be overlooked, given that this safety is intrinsically linked to its overall importance. Whilst the Command Hub does provide safe coverage of all aspects of the vehicle with the



ability to interact and respond in real-time, its importance as a safety orientated diagnostics tool is further evidence of its necessity. Diagnostics provided by the Command Hub allow for troubleshooting and identification of problems and faults in real-time, also providing developer and terminal access if required. In the short term, this provides a dynamic level of response during vehicle operation and in the long-term, means that information, data and evidence collected through this tool, can be used to further shape safe practices associated with the autonomous vehicle.

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HOW



How does the Command Hub work?

The Command Hub once activated, is a front-end interface that provides access to several in-built software suites that cover every aspect of the vehicle as well as supplementary suites that can access autonomous training and driving tools such as simulators and previously stored drive footage. Access to this interface is secure and with the correct training and authorisations, a user or team can access this from either a control centre, allowing them to view multiple software

Having the ability to monitor the performance, logistics and status of the vehicle in real-time from a remote position enables levels of safety imperative to the operations of autonomous vehicles, this applies to not just one vehicle, can be expanded to an entire fleet.

suites on separate screens, all at once, or alternatively from a laptop if they are potentially on the move or are required to do something separate to operations in the control centre.

In order to safely monitor the operations of an autonomous vehicle, several of the vehicle's operations must be monitored thoroughly all at once, hence the Command Hub is designed with fluid functionality in mind to allow for multiple functions to be observed and interacted with all at once and in real-time.

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The screenshot displays the 'THE COMMAND HUB' interface. On the left is a dark sidebar with navigation options: Status, **Faults**, Vehicle test, Cam Test, Callibration, and Help. The main area features a wireframe car model with several status indicators: SAFETY MODE (OFF), IGNITION (OFF), CAN ERROR (CHK), SYSTEM VOLTAGE (12.4v), and STEERING ANGLE (0deg). A 'Developer Mode' section provides instructions on how to edit settings and includes a 'Terminal' button. On the right, a 'Faults' panel shows the date 'Tuesday 11 August 2020' and a note: 'To edit or adjust any setting please use developer mode in terminal'. Below this is a list of system components with their status: Encoder (checked), Drive PID (crossed), Turn PID (crossed), Mode Enable (checked), Date Time (crossed), Acceleration (checked), CAN Status (crossed), Relay Status (crossed), Steering Motor (checked), Drive Status (checked), and Limiter (checked). At the bottom right, a 'Battery level' indicator shows 80%.

System Time 13:22



How Features of the Command Hub Provide Safe and Complete Control

The Command Hub provides a complete and extensive level of control over the vehicle through a variety of functions that are accessible and interactable with. Control is a critical asset when deploying an autonomous vehicle on the road and as such, the following list of Command Hub functions detail both what they do and their relevance to safety;

- **Vehicle Diagnosis** This is a platform that provides

An operator is given complete access to Kar-Go and its functionalities. Remotely, we can check vehicles position, its estimated time of arrival, position access the perception and detection modules that the vehicle is running.

a complete overview of the vehicle and its internal hardware. Allowing remote operators to send commands to the vehicle in order to do things such as turning the vehicle lights on and off, or to lock and unlock the vehicle. From an engineering standpoint, this provides an added level of safety as it allows for the performance of the vehicle to be monitored in real-time, providing a diagnostics overview that can allow for engineers to identify hardware faults and issues remotely and subsequently develop solutions to them,

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**ABSOLUTE CONTROL
MEANS ABSOLUTE
SAFETY**

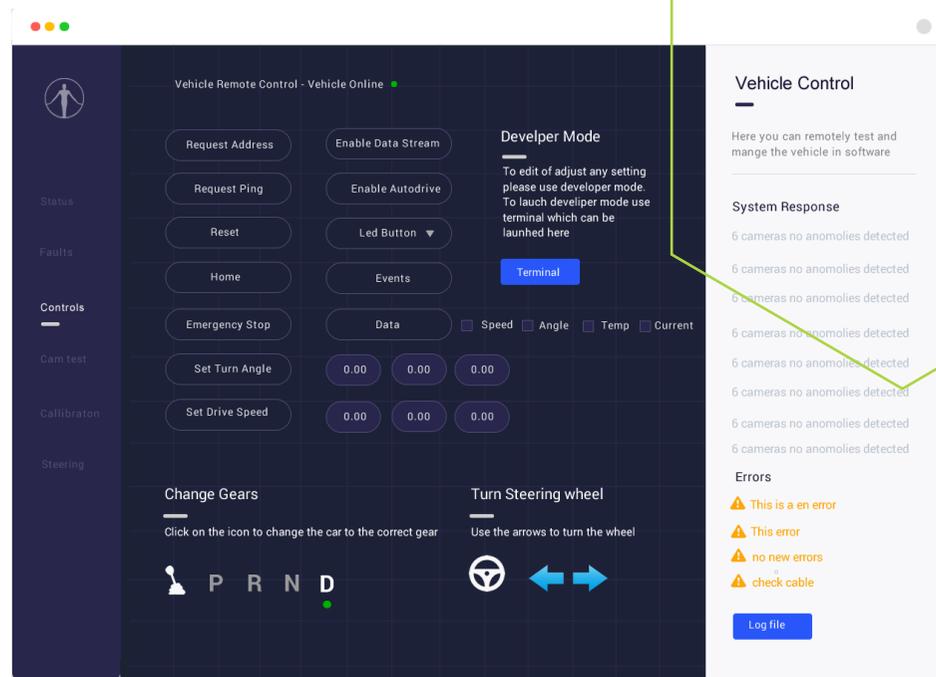


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all from the Command Hub itself.

- **Fault Tracking** The monitoring, tracking, mapping and logging of faults is a critical tool when running any form of software. This is only amplified when applied to an autonomous vehicle in live operation. The fault tracking tool allows remote operators to receive identification of faults and review their logs from the Command Hub, with access to mapping and status indicators as well as remote access to the terminal from



a dedicated fault menu for use by a train Command Hub operator.

- **Change Logs and User Access** The system keeps track of all changes and edits made to any aspect of the software via detailed logs, noting the time and user ID with which these were initiated. Moreover access to individual parts of the command hub is granted on a need-to basis. This prevents unauthorized changes that may affect live vehicle operation or cause faults that are detected later.

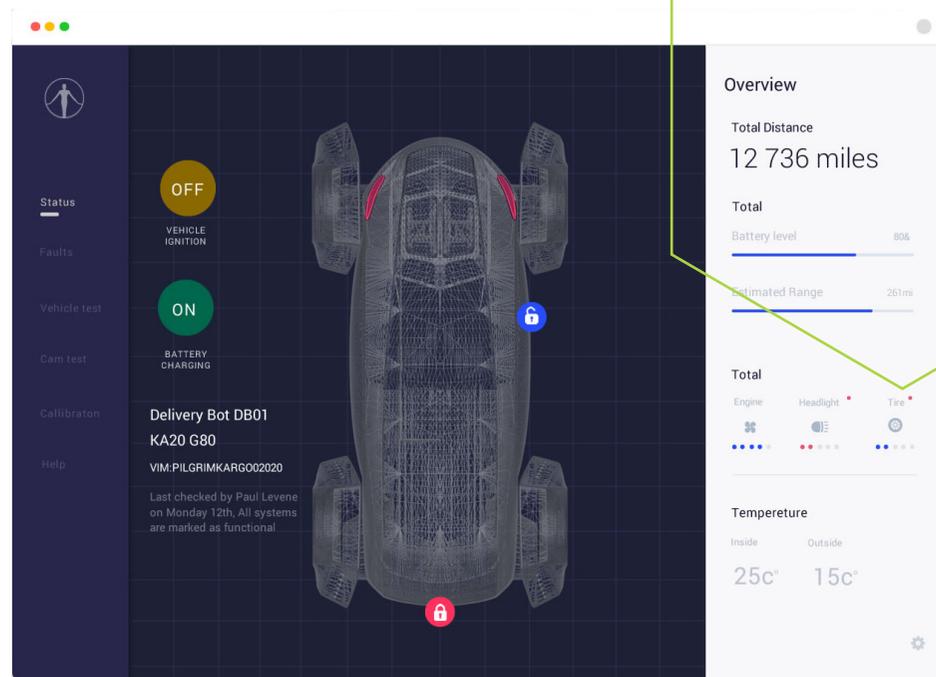


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- **Camera Test Function**

This provides a Command Hub operator access to the vehicles on-board cameras remotely. Allowing for them to make in depth adjustments to camera angles and coverage whilst also enabling an ability to record beyond the already present recording functions of the autonomous vehicles. The level of calibration provided through this adds a layer of safety in ensuring that the cameras, one of the most important aspects of an autonomous vehicle, function correctly and are at the



appropriate angles so that the autonomous software modules can operate safely and as intended.

- **Vehicle Controls**

This is where navigational control of the vehicle can be enabled remotely. Giving the Command Hub operator a level of safety and control over the vehicle that enables them to essentially pilot the vehicle when required, whether as a result of a fault or a risk. Key aspects of this function include the ability to make gear changes and turn the steering wheel, whilst

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What would you like to do ?

| | | | |
|--|---|---|---|
|  Annotate Data cadalogger.cpp |  Vehicle Diag. cadalogger.cpp |  Launch Evosim cadalogger.cpp |  Control Centre ControlCentre.cpp |
|  Logs & Graphs graphrunner.cpp |  Console cadalogger.cpp |  Test a module cadalogger.cpp |  Live Camera cadalogger.cpp |
|  Footage Archive graphrunner.cpp |  cadalogger.cpp |  Route Manager cadalogger.cpp |  Kar-go Config cadalogger.cpp |
|  Carla Simulator cadalogger.cpp |  Sys Interface cadalogger.cpp | | |

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Kar-go System Software v 2.1



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logging vehicle trajectories in real-time. Regardless of any intervention, all information is logged which can be later utilised in further training and implementation of changes to the autonomous driving software.

- **Vehicle Calibration**

A further logging tool to vehicle controls, this provides recordings and logging of steering wheel angles with an overlay that provides a timestamped graph that is live updated to provide in depth coverage of the vehicle and steering wheel



trajectory. This information is of importance in influencing any required intervention potentially needed regarding Vehicle Controls.

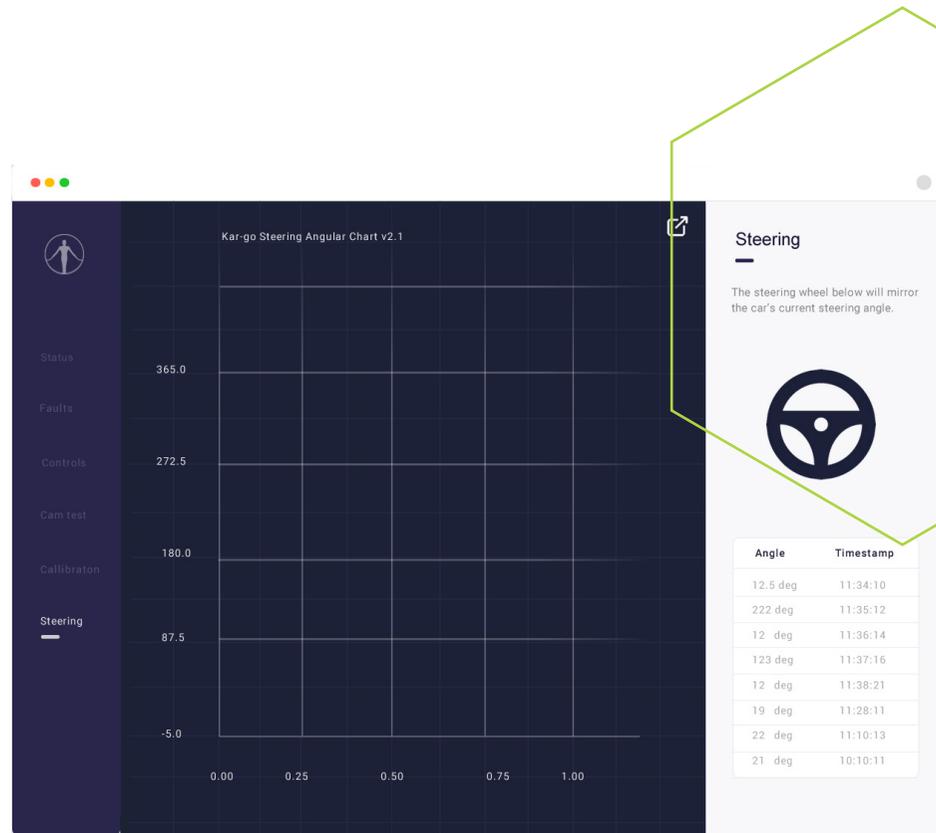
- **Route Manager** This provides on a live, updated map in real-time, information on the route the vehicle is taking to its destination. It further details where the vehicle is and the expected duration of the journey. The Route Manager tool provides insight into the navigation of the autonomous vehicle and allows for the accurate monitoring of the vehicle's

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position and its relevance to the predetermined route it is required to take.

- **Control Centre** This is the primary tool for monitoring the operations of the autonomous vehicle. Providing a complete overview of all of the vehicles cameras as well as access to the visualisations provided by the autonomous software modules that are running as the vehicle drives autonomously. From the Control Centre overview, a Command Hub operator can switch views, monitor which neural networks are



running, having access to the audio based modules to gain insight into what the vehicle is hearing as well as have direct contact with the safety driver present in the vehicle. The real-time detections that can be viewed with the Control Centre tool are logged and can be tracked remotely during its use.





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