

HYPERMOTIVE

2021 ADS-DV USER MANUAL

VERSION A

JUNE 2021

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GLOSSARY OF TERMS

Term	Definition
ADS-DV	Autonomous Driving System – Dedicated Vehicle
AIMS	AI Master Switch
AMI	Autonomous Mission Indicator
ASMS	Autonomous System Master Switch
ASSI	Autonomous System Status Indicator
CAN	Controller Area Network
EBS	Emergency Braking System
LVMS	Low Voltage Master Switch
MPP	Multi-Purpose Port
RES	Remote Emergency Stop
SDC	Shutdown Circuit
SOC	State of Charge
TSAL	Tractive System Active Light
TSMS	Tractive System Master Switch
VCU	Vehicle Control Unit

DOCUMENT CHANGE HISTORY

Revision	Date	Summary	Issued by
A	29 June 2021	First issue	S. Chubbock

1. INTRODUCTION

This user manual provides details of the procedures that should be followed to operate the ADS-DV safely in both manual and autonomous driving modes, and when charging the traction battery.

A list of the equipment supplied with the ADS-DV is given, along with procedures for removing the upper bodywork, discharging the hydraulic braking system, and a few hints on troubleshooting some typical issues that may be encountered.

2. SUPPLIED EQUIPMENT

The following equipment is supplied for operating the ADS-DV:

2.1. MASTER SWITCH KEYS



Figure 1: Master switch key

Three keys are provided for the master switches on the right-hand side of the ADS-DV.

2.2. GROSSFUNK REMOTE E-STOP SYSTEM



Figure 2: GrossFunk RES transmitter

The GrossFunk remote E-stop system consists of a remote transmitter (supplied with 2 batteries and a battery charger) and a receiver unit that is fitted to the ADS-DV.

The NiMH batteries for the remote transmitter provide about 4 hours of operation. When the battery needs to be swapped, the red LED in the E-stop button will start to flash and the transmitter will emit a beeping sound. To swap the battery, turn off the transmitter and open the flap on its underside (secured with Velcro). Lift the battery retaining flap and slide the battery out. It is recommended to charge the battery when not in use to minimise vehicle downtime during testing and at events.



Figure 3: GrossFunk transmitter battery compartment



Figure 4: Insertion/removal of GrossFunk transmitter battery

2.3. AUTONOMOUS DRIVING MPP DONGLE



Figure 5: Autonomous driving MPP dongle

This dongle must be plugged into the MPP at the rear of the ADS-DV to enable autonomous operation.

2.4. JOYSTICK AND UMBILICAL CABLE:



Figure 6: Joystick and umbilical cable

The joystick allows the steering to be actuated when moving the ADS-DV using the pushbar, and to control the steering and drive motors in umbilical mode for low-speed vehicle manoeuvring. When connecting the joystick to the MPP on the vehicle, ensure that the yellow cable connector is attached to the joystick, and the red connector is inserted into the MPP socket.

2.5. CAN DIAGNOSTICS HARNESS



Figure 7: CAN diagnostics MPP harness

This harness plugs into the MPP vehicle connector and allows the CAN data to be interrogated for software communications checking and vehicle diagnostics. A second vehicle-side MPP connector on the harness allows the autonomous driving dongle, umbilical joystick cable and battery charger comms cable to be connected as usual.

2.6. TRACTION BATTERY CHARGER

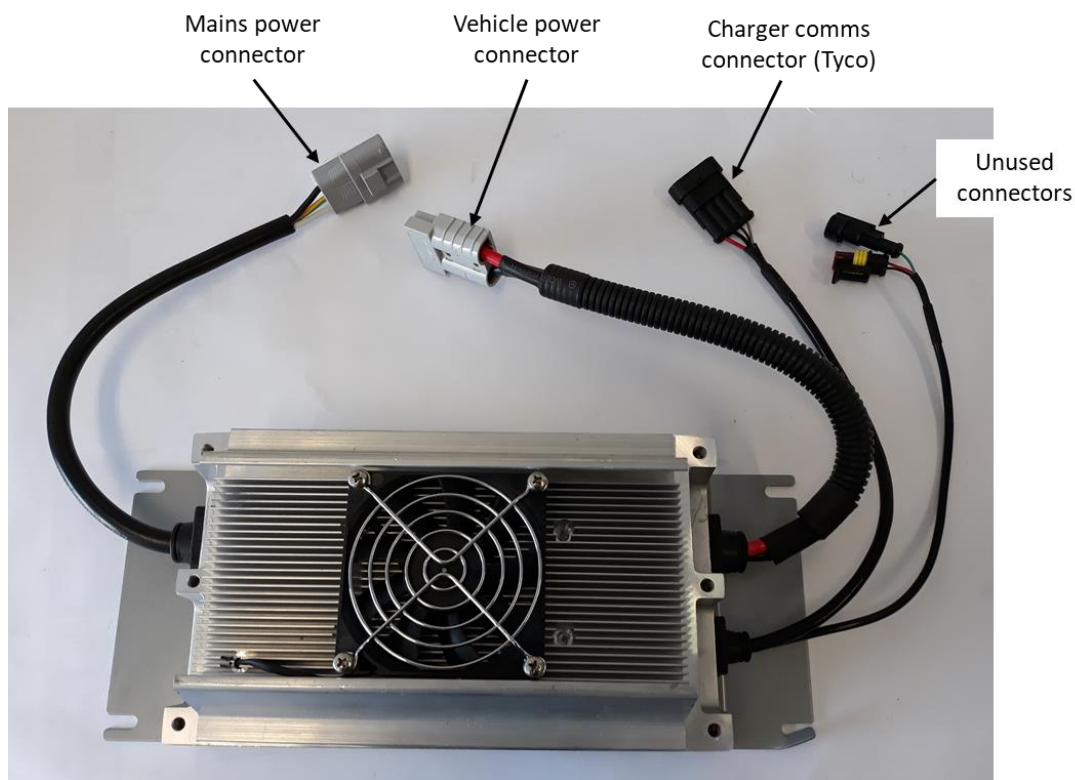


Figure 8: Battery charger

A TC Charger HK-J-H66-40 battery charger is provided with the vehicle for charging the traction battery. See section 9 for details of how to charge the ADS-DV.

The battery charger comes with three sets of cables:

- Two power cables: a mains power cable with a UK 3-pin mains plug, and a charger-vehicle power cable with an Amphenol ELP02A04 connector that mates with the vehicle charging connector.
- A communications cable that connects the Tyco 4-way charger connector to the MPP on the vehicle.

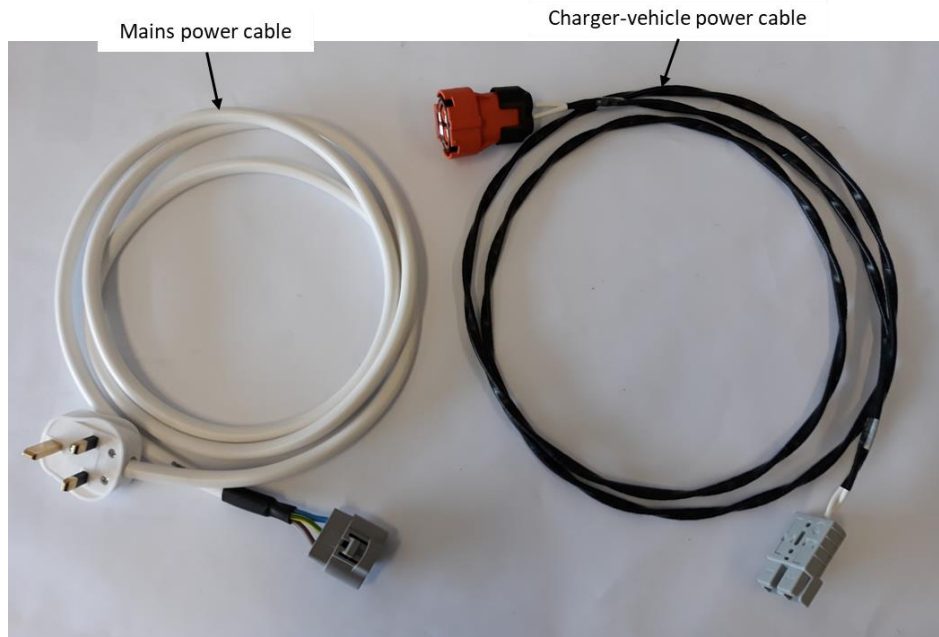


Figure 9: Battery charger power cables



Figure 10: Battery charger communications cable

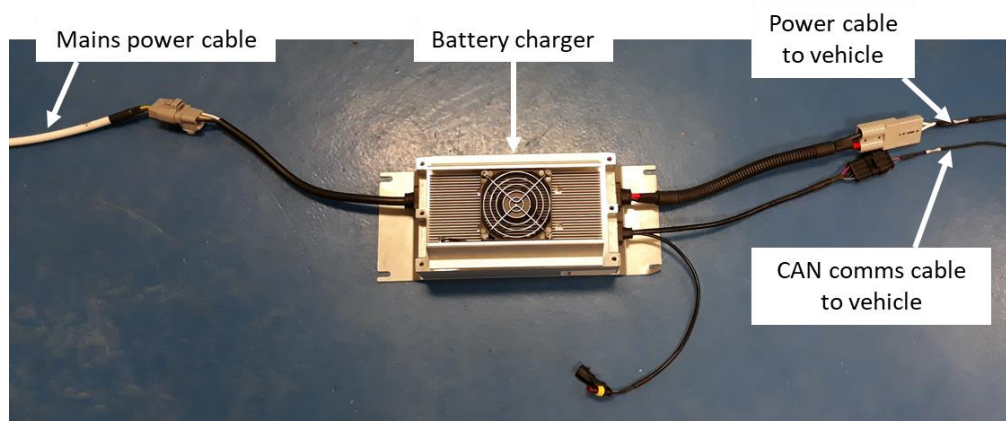


Figure 11: Battery charger cable connections

3. CONTROLS AND USER INTERFACES

3.1. MASTER SWITCHES

Three rotary master switches are located on the right-hand side of the ADS-DV to provide power to various systems on the vehicle and initiate certain state changes in the Vehicle Control Unit (VCU) software.

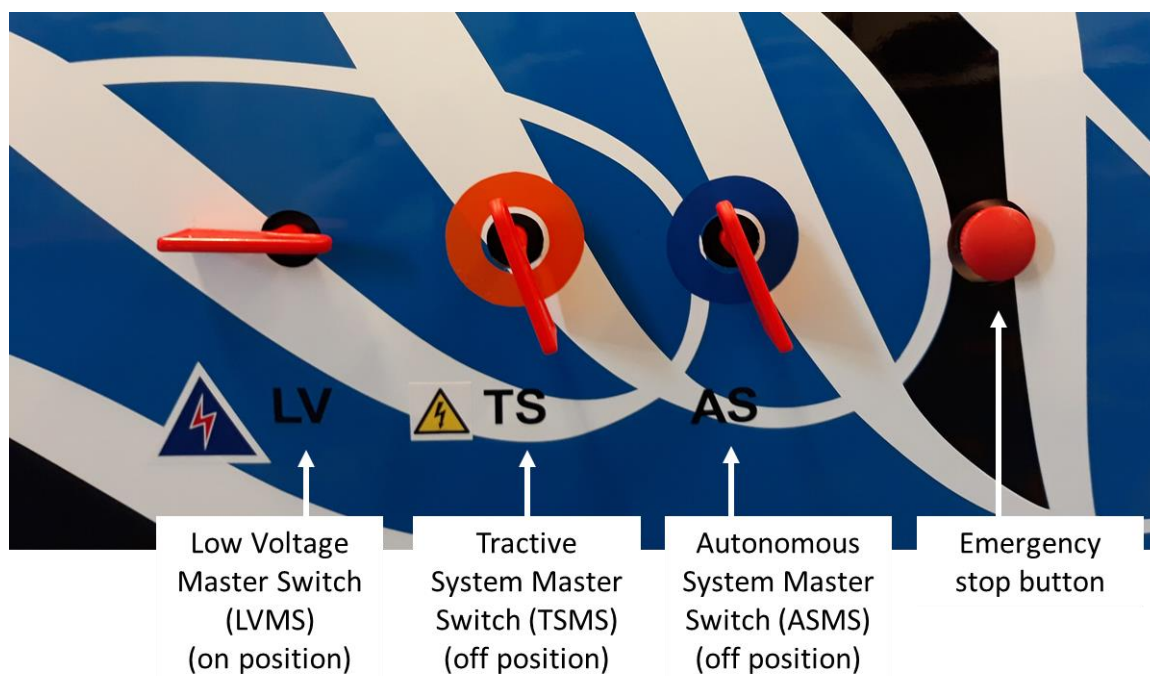


Figure 12: External master switches

The AI Master Switch (AIMS) is located at the rear of the vehicle and provides power to the AI systems.

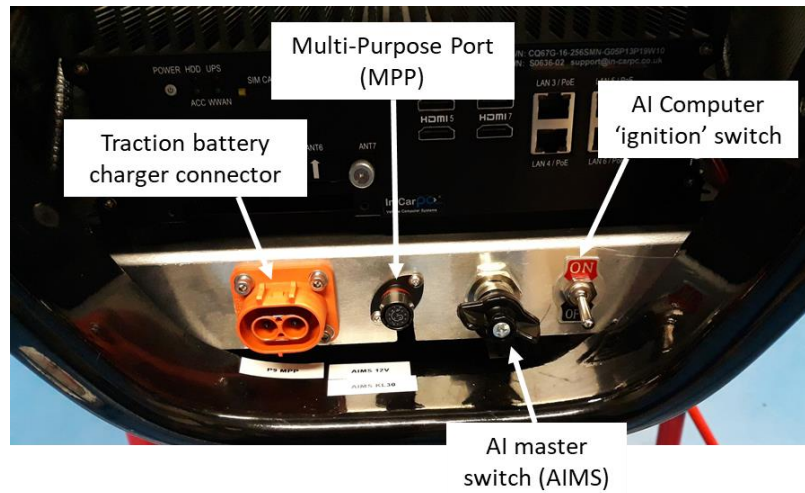


Figure 13: Rear interface panel connections and switches

3.2. INDICATORS

Two LED indicators are mounted on top of the ADS-DV bodywork:

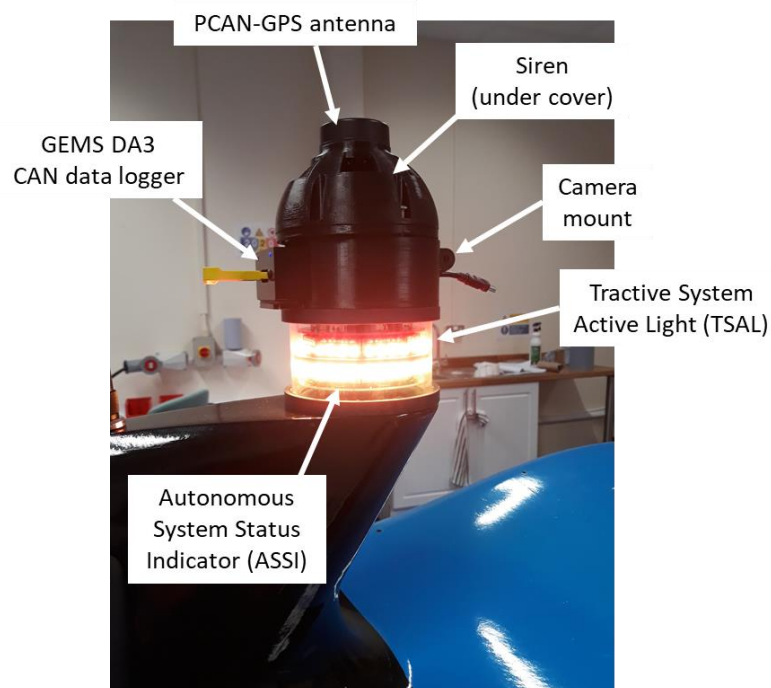


Figure 14: LED indicators and top bodywork

TSAL = Tractive System Active Light

This indicator shows the status of the electric drivetrain:

LED colour	Meaning
Green	Drive motors are disabled
Red (flashing)	Drive motors are enabled, and the vehicle is capable of moving under its own power

ASSI = Autonomous System Status Indicator

This LED array indicates the active state of the autonomous driving state machine when the vehicle is conducting an autonomous mission (see section 7.3 for more details):

LED colour	State	Meaning
Off	AS_OFF	Drivetrain is disabled and no mission is selected
Yellow (continuous)	AS_READY	Mission selected and awaiting 'Go' signal
Yellow (flashing)	AS_DRIVING	Vehicle is carrying out the selected driving mission
Blue (continuous)	AS_FINISHED	Autonomous mission has been completed
Blue (flashing)	EMERGENCY_BRAKE	Emergency braking system has been deployed

3.3. TOUCHSCREEN DISPLAY

A 4.3" touchscreen mounted on the right-hand side of the ADS-DV provides key information about the vehicle over four pages:

Main page: functions as the Autonomous Mission Indicator (AMI) in autonomous driving operation. Features a drop-down list to select an autonomous mission, and shows the active mission and VCU state.

Vehicle diagnostic data page: shows the voltage for the traction battery and auxiliary 12V battery, the state of the powertrain contactors, and status flags for the main vehicle fault conditions.

Traction battery data page: shows key data about the 48V traction battery, which are particularly useful when the battery is being charged.

Braking system data page: shows the status of the hydraulic braking ECU and the normalised pressure in the front and rear brake circuits. Also contains buttons to control a brake pressure discharge (see section 10).

Use the left and right arrows at the bottom of the screen to navigate between the data pages (see figures 15-18).

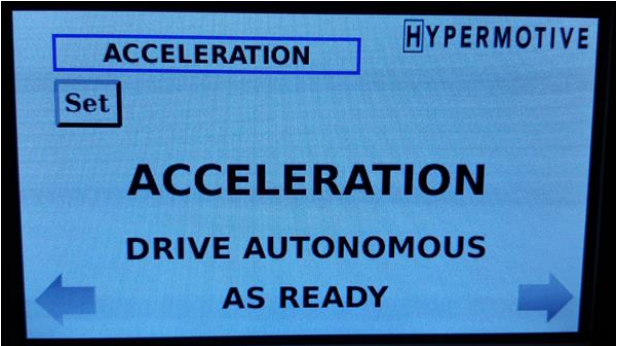


Figure 15: Main AMI screen page

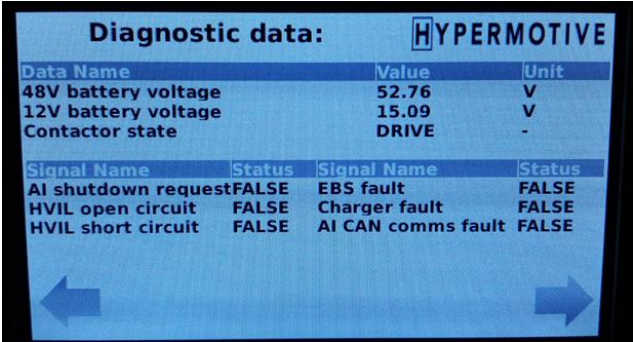


Figure 16: Vehicle diagnostic data page

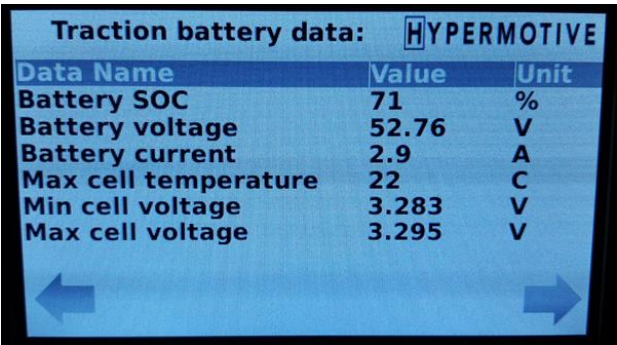


Figure 17: Traction battery data page

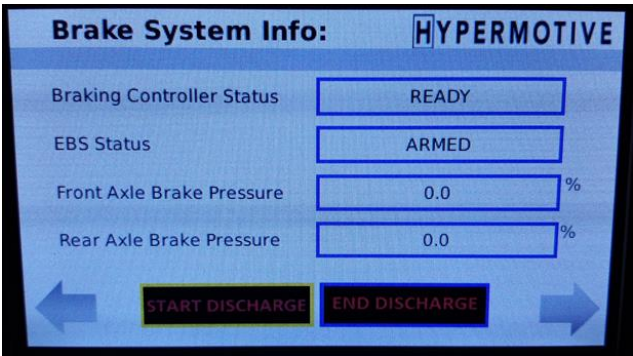


Figure 18: Braking system data page

4. PUSHBAR OPERATION

For low-speed manoeuvring of the ADS-DV with the drivetrain deactivated, the pushbar operation mode should be used to allow the ADS-DV to be pushed by team personnel, with the umbilical joystick being used for steering. This operation mode is intended for moving the ADS-DV at Formula Student events outside of the 'hot' event areas, e.g. in the paddock area.

4.1. EQUIPMENT

- Master switch keys (×3)
- GrossFunk remote E-stop transmitter
- Pushbar
- Joystick and umbilical cable

4.2. PROCEDURE

NOTE: Always stand behind the ADS-DV when operating it in the pushbar mode. Hold the joystick controller so that the umbilical cable connector is pointing away from you.

1. Insert keys into the three external master switches on the right-hand side of the vehicle.
2. Insert the pushbar into the spigot on the rear chassis bulkhead. Take care to avoid damaging the AI equipment installed in the rear of the car, and ensure that the pushbar is securely attached.
3. With all master switches turned off, connect the umbilical controller cable into the MPP socket on the rear interface panel. Ensure that the umbilical cable is securely connected to the handheld joystick, and that the AI systems are powered off (AIMS is off).
4. Ensure that the GrossFunk RES transmitter is turned on by resetting the E-stop button (red LED in the button is illuminated). Check that the two emergency stop buttons on the vehicle have been reset.
5. Turn on the ASMS, TSMS and LVMS, in that order. The TSAL on top of the vehicle will illuminate green.
6. The VCU will execute its start-up procedure and then "PUSHBAR MODE" will be indicated on the AMI.
7. Push the ADS-DV using the pushbar, and move the joystick left/right to actuate the steering.
8. When you have finished moving the vehicle, turn off the ASMS and TSMS to initiate a vehicle shutdown. The brakes will be applied to stop the vehicle moving, and the "SHUTDOWN ACTIONS" state will be displayed on the AMI.
9. When the VCU enters the "SHUTDOWN OFF" state, turn off the LVMS switch to power down the vehicle.
10. Turn off the GrossFunk remote E-stop transmitter by pressing its E-stop button. The LED in the E-stop button will turn off.

To initiate a vehicle emergency stop, press the E-stop button on the GrossFunk remote E-stop transmitter. This will apply the emergency brakes and bring the vehicle to a halt.

5. UMBILICAL DRIVING

The ADS-DV can be moved at low speeds using the joystick controller connected to the MPP by an umbilical cable. This mode is intended for use within a 'hot' event area at Formula Student events to allow the ADS-DV to be staged in preparation for autonomous driving, and to be recovered to a safe position if the vehicle stops on course.

It is recommended that at least 2 people are in attendance when operating the ADS-DV in the umbilical driving mode: one to operate the joystick controller, and a second person to wear the GrossFunk remote E-stop transmitter. **NEVER** walk directly in front of the ADS-DV in this operating mode.

5.1. EQUIPMENT

- Master switch keys (×3)
- GrossFunk remote E-stop transmitter
- Joystick and umbilical cable

5.2. PROCEDURE

In this operation mode the joystick buttons are used to provide a "dead man's handle" safety measure, meaning that the ADS-DV can only be driven and/or steered when both buttons are held down. Releasing the buttons when driving will cause the vehicle to come to a halt.

NOTE: Always walk behind the ADS-DV when operating it in the umbilical driving mode. Hold the joystick controller so that the connector on the umbilical cable is pointing away from you.

1. Insert keys into the three external master switches on the right-hand side of the vehicle.
2. With all master switches turned off, connect the umbilical controller cable into the MPP socket in the rear bodywork cavity. Ensure that the umbilical cable is securely connected to the handheld joystick, and that the AI systems are powered off (AIMS is off).
3. Ensure that the GrossFunk RES transmitter is turned on by resetting the E-stop button (red LED in the button is illuminated). Check that the two emergency stop buttons on the vehicle have been reset.
4. Turn on the ASMS, TSMS and LVMS, in that order. The TSAL on top of the vehicle will illuminate green initially.
5. The VCU will execute its start-up procedure and enter the "PUSHBAR MODE" state, which will be indicated on the touchscreen.

6. With the vehicle stationary, hold down both joystick buttons for 5 seconds, after which the ASSI will flash blue. The VCU will enter the “POWERTRAIN ENABLE” state that will close the drive motor contactors.
7. When the vehicle is ready for umbilical operation, the TSAL will flash red and the active state on the AMI will be “DRIVE MANUAL”.
8. To enable the driving mode, hold down the joystick buttons. Push the joystick forward to accelerate the vehicle, and left/right to actuate the steering.
9. At the end of driving, release the joystick buttons to bring the ADS-DV to a halt. Turn off the ASMS and TSMS to initiate a vehicle shutdown. The drive motor contactors will then open and the TSAL will turn green again. Turning off the ASMS will apply the EBS, preventing the ADS-DV from moving.
10. When the VCU enters the “SHUTDOWN OFF” state, turn off the LVMS switch to power down the vehicle.
11. Turn off the GrossFunk remote E-stop transmitter by pressing its E-stop button.

To initiate an emergency stop in umbilical driving, press the E-stop button on the GrossFunk remote E-stop transmitter. The siren will sound for 15 seconds.

6. AUTONOMOUS DRIVING

This section describes the procedure for running autonomous driving missions with the ADS-DV.

6.1. EQUIPMENT

- Master switch keys (×3)
- GrossFunk remote E-stop transmitter
- Autonomous driving MPP dongle

6.2. PROCEDURE

1. With all master switches turned off, insert the autonomous driving MPP dongle (figure 3) into the Multi-Purpose Port (MPP) at the rear of the vehicle.



Figure 19: Autonomous driving MPP dongle

2. Ensure that the GrossFunk RES transmitter is turned on by resetting the E-stop button (red LED in the button is illuminated). Check that both E-stop buttons on the vehicle have been reset.
3. Turn on the AI Master Switch (AIMS) on the rear panel to provide power to the autonomous systems.
4. Turn on the ASMS, TSMS and the 12V master switch (LVMS) on the right-hand side of the vehicle, in that order. The TSAL on top of the vehicle will illuminate green and the EBS will be released.

5. When the Vehicle Control Unit (VCU) receives CAN data from the AI Computer, it will transition to the 'DRIVE AUTONOMOUS' state and the TSAL will flash red to indicate that the tractive system is activated.
6. Select an autonomous mission on the display screen by pressing on the blue rectangle labelled 'NOT SELECTED' to open a list of available missions. Select the desired mission and press the 'Set' button – the text on the AMI will change to the selected mission.
7. When the AI system confirms that a mission has been selected, the VCU will enter the 'AS_READY' state, which will be indicated on the AMI and the ASSI will turn yellow. The vehicle will remain in this state for at least 5 seconds, after which the blue ASSI will illuminate for 1 second.
8. Send the remote 'Go' signal from the GrossFunk RES transmitter by moving the toggle switch (K2) to the on position. The ASSI LED will flash yellow, the "Ready to drive" siren will sound for 3 seconds, and the vehicle will then execute the selected autonomous mission. The siren will continue to sound intermittently until the vehicle has started to move.
9. Once the vehicle has come to rest and the AI Computer confirms that the mission has been completed using the MISSION_STATUS CAN signal, the VCU will move to the AS_FINISHED state, indicated by the ASSI turning blue.
10. Turn off the ASMS to return to the AS_OFF state, where the ASSI will turn off.
11. To initiate the vehicle shutdown procedure, turn off the TSMS. The AMI will show that the VCU has entered the "SHUTDOWN ACTION" state.
 - To start a new autonomous mission, turn the ASMS back on repeat steps 6-10.
12. Once the vehicle has entered the "SHUTDOWN OFF" state, turn the LVMS off to power down the vehicle.
13. Power down the autonomous systems and turn off the AIMS at the rear of the vehicle.
14. Turn off the GrossFunk remote E-stop transmitter by pressing its E-stop button.

If a fault is detected or an emergency stop is initiated while driving:

- The autonomous driving state machine will move to the EMERGENCY_BRAKE state to bring the vehicle to a halt. The ASSI will flash blue and the siren will sound for 15 seconds. The TSAL will turn green as the drive motor contactors will be opened to de-energise the traction system,
- When the siren stops, turn off the ASMS,
- Turn off the TSMS to initiate a vehicle shutdown,
- Turn off the LVMS when the "SHUTDOWN OFF" state is displayed on the screen,
- If you do not intend to restart the ADS-DV, power down the autonomous systems and turn off the AIMS at the rear of the vehicle. Otherwise, restart the vehicle.

The vehicle power cycle must be completed when an E-stop is carried out to clear the fault in the VCU.

NOTE: When running the ADS-DV for long periods, periodically check the 12V system voltage (highlighted in figure 5) on the Diagnostics page of the AMI (press the right arrow from the main

screen). Normal operating voltage range is 13.5-15.0V, and if the voltage drops below 13.0V the ADS-DV should be power cycled – there is no need to turn off the AI computer when power cycling the car as long as the LVMS is not turned off for more than 5 minutes.

Repeatedly power cycling the car will gradually cause the 12V battery to be discharged, so if the voltage drops allow the vehicle to run for a few minutes to allow the VCU to recharge the 12V battery.

6.3. AUTONOMOUS DRIVING STATE MACHINE

Figure 19 shows the autonomous driving state machine that has been implemented in the VCU software.

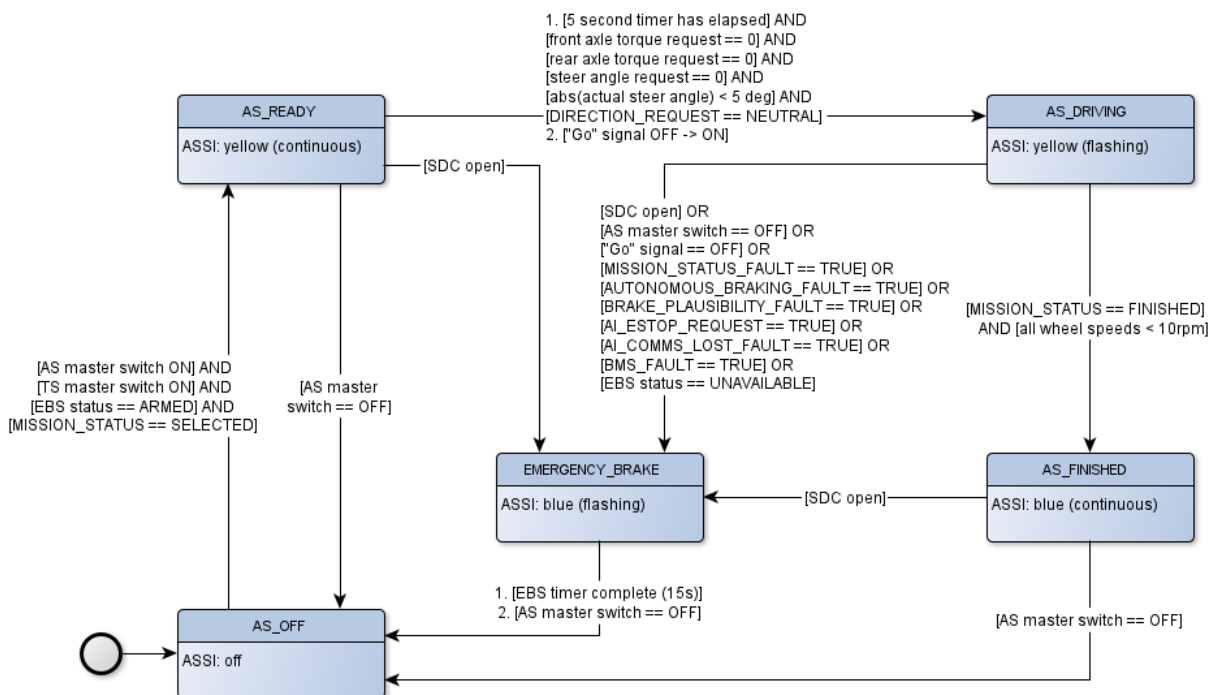


Figure 20: Autonomous driving state machine

7. AUXILIARY STATE

A dedicated operating state has been created to allow the AI Computer to be programmed without the vehicle being in a condition that would allow it to drive, and all vehicle systems are powered from the traction battery via the in-built DC/DC converter. The procedure below assumes that the computer is not transmitting CAN data to the VCU.

7.1. EQUIPMENT

- Master switch key (×1)
- GrossFunk remote E-stop transmitter
- Autonomous driving MPP dongle

7.2. PROCEDURE

1. Insert the key into the LVMS.
2. Connect the autonomous driving dongle to the MPP at the rear of the vehicle.
3. Ensure that the GrossFunk RES transmitter is turned on by resetting the E-stop button (red LED in the button is illuminated). Check that the two emergency stop buttons on the vehicle have been reset.
4. Turn on the LVMS. After completing the startup procedure, the vehicle will enter the "AUXILIARY" state and programming of the AI computer can commence.
5. To shut the vehicle down, press any of the emergency stop buttons either on the vehicle or the GrossFunk RES transmitter.
6. When the vehicle has entered the "SHUTDOWN OFF" state, turn off the LVMS.
7. Turn off the GrossFunk remote E-stop transmitter by pressing its E-stop button.

8. BATTERY CHARGING

The charging port for the traction battery is located on the rear switch panel next to the MPP. An offboard battery charger is supplied with the ADS-DV for charging the traction battery. It is advised to charge the traction battery when the minimum cell voltage drops below 3.1 V – do not operate the vehicle with a battery SOC value of less than 20%.

8.1. EQUIPMENT

- Master switch key (×1)
- GrossFunk remote E-stop transmitter
- TC Charger offboard battery charger and cables

8.2. PROCEDURE

1. Insert the key into the LVMS.
2. Position the battery charger on the floor close to the rear of the ADS-DV. The charger must be positioned with the cooling fan orientated as shown in figure 8 to provide cooling to the charger during operation. Do **NOT** cover the cooling fan during charging.
3. Plug the battery charger into a mains power supply. Do not use an extension cable.
4. Connect the orange battery charging connector into the charging socket next to the MPP at the rear of the vehicle. Insert the charging communications cable dongle into the MPP.
5. Ensure that the GrossFunk RES transmitter is turned on by resetting the E-stop button and checking that the red LED in the button is on. Check that the two emergency stop buttons on either side of the vehicle have been reset.
6. Turn on the LVMS only. The Tractive System Active Light (TSAL) on top of the vehicle will illuminate green.
7. The VCU will automatically start charging the traction battery. 'CHARGE' will be displayed on the AMI.
8. At the end of charging, press any of the emergency stop buttons on the vehicle or the GrossFunk remote E-stop transmitter to initiate a vehicle shutdown.
9. Turn off the LVMS when the vehicle state is shown as "SHUTDOWN OFF". Turn off the mains power supply to the charger.
10. Turn off the GrossFunk remote E-stop transmitter by pressing its E-stop button.
11. Remove the charger CAN comms connector from the MPP.
12. Remove the charger connector from the charging socket on the vehicle by sliding the red tab down and gently pulling down on the connector body.
13. Disconnect the charger power supply cable from the mains.

If the BMS detects a fault during charging, it will isolate the traction battery and cut power to all vehicle systems. The 'SHUTDOWN OFF' state will be displayed on the main page of the touch screen

display, at which point the LVMS must be turned off. The ADS-DV should not be left unattended while it is charging.

The traction battery is fully charged when the maximum cell voltage displayed on the battery data page of the AMI reaches 3.55V, although the charging procedure will continue to balance the cell voltages across the pack. Charging will be stopped automatically by the BMS once cell balancing has completed.

9. REMOVING THE TOP BODYWORK

When removing the top bodywork of the ADS-DV, it is important that the cables from the enclosure containing the Grossfunk RES receiver and PCAN-GPS to the harness in the top bodywork are disconnected.

The length of these cables allows the top bodywork to be lifted up and for two cable connectors to be unplugged:

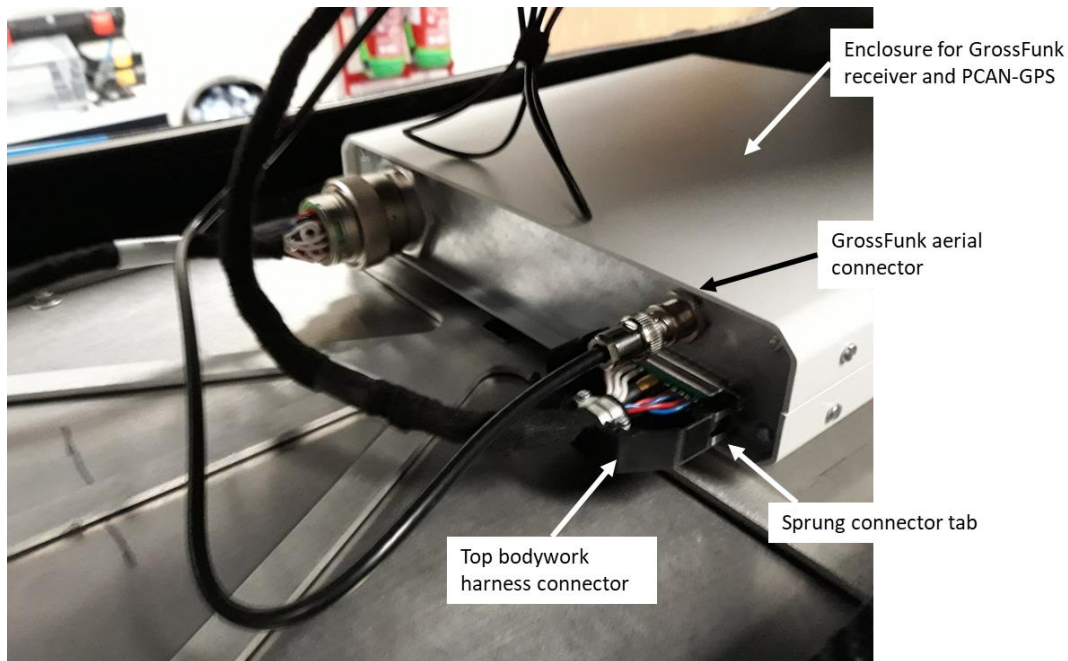


Figure 21: Grossfunk enclosure cable connections

Before removing the bodywork, undo the two connectors on the left-hand side of the vehicle:

- Grossfunk aerial connector: silver bayonet-type connector needs to be unscrewed ($\frac{1}{4}$ turn) and removed,
- CAN bus and PCAN-GPS aerial connector: black D-sub connector is removed by pressing the tabs on either side of the connector, and gently removing the connector.

When re-inserting the D-sub connector, press the two tabs on the connector and push until it clicks into place. Be sure to align the connector correctly to avoid damaging the PCAN-GPS aerial connector.

10. DISCHARGING THE HYDRAULIC BRAKES

When the ADS-DV is powered down, the brakes are automatically applied using the fluid stored in the system's hydraulic accumulators. To allow the ADS-DV to be manoeuvred when it is switched off, the braking system needs to be discharged prior to shutting down the vehicle using the following procedure.

A brake system discharge can only be initiated under the following conditions:

- In the PUSHBAR_MODE state,
- In the DRIVE_MANUAL state when the vehicle is in its idle condition (i.e. joystick buttons are released) and both the ASMS and TSMS are on,
- In the AS_OFF state during autonomous operation with both the ASMS and TSMS on.

Brake discharge procedure:

1. Navigate to the braking system data page on the touchscreen display,
2. Press the 'Start discharge' button at the bottom left of the screen. The brake discharge procedure is automatically initiated, and you will see the front and rear brake pressures change between 100% and 1-2% as the accumulators are discharged.
3. Wait for the pressures in the front and rear brake circuits to drop to 1-2%, which should take around a minute. Press the 'End discharge' button to finish the operation.
4. Initiate a vehicle shutdown by turning off the ASMS and TSMS. When the VCU state has changed to "SHUTDOWN OFF", turn off the LV master switch. It will now be possible to roll the ADS-DV.

The braking system will automatically recharge the accumulators the next time the vehicle is switched on.

11. TROUBLESHOOTING

Problem: The ADS-DV enters the “SHUTDOWN OFF” state immediately after powering on the vehicle.

Solution: The shutdown circuit on the vehicle is open. Check the following:

- the GrossFunk remote E-stop transmitter is on (red indicator LED is illuminated),
- none of the E-stop buttons on the ADS-DV have been activated,
- something has been inserted into the MPP (autonomous dongle, umbilical joystick cable, or charger communications cable).

If the problem persists, check the Diagnostics page on the touchscreen to see if any faults are active.

Problem: The autonomous state machine will not move from AS_READY to AS_DRIVING when the remote “Go” signal is triggered.

Solution: If the toggle switch for the “Go” signal was already in the on position, turn it off and back on again. The VCU software looks for a rising edge of the signal to activate the AS_DRIVING state.

If not, ensure that the front wheels are close to the straight-ahead position – the state transition will not occur if the measured steering angle is greater than 5°.

Also check that the DIRECTION_REQUEST in the AI2VCU_Status (510h) CAN message is set to NEUTRAL, the drive motor torque demands are set to zero, and the requested steering angle is zero.

Problem: The ADS-DV performed an emergency stop during an autonomous mission. How can I find out the cause?

Solution: Check the fault status bits in the VCU2AI_Status (520h) CAN message. Ensure that the GrossFunk remote E-stop transmitter is within 100m of the ADS-DV – if the receiver on the vehicle goes out of range it will perform an emergency stop. If the cause of the stoppage is still not clear and occurs repeatedly, contact Hypermotive for assistance.

Problem: The touchscreen display on the side of the ADS-DV does not turn on when the vehicle is powered up.

Solution: Check that the 20-way D-sub connector on the Grossfunk enclosure under the top bodywork is securely attached. The connector will click when it is correctly in place.