TORC

ROBOTIC BUILDING BLOCKS

ByWire XGV™ User Manual

Hybrid Escape Drive-by-Wire Platform

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1 ASSIGNMENT OF LIABILITY

WARNING: DO NOT OPERATE UNTIL USER MANUAL IS REVIEWED AND UNDERSTOOD. PRODUCT USE IS SUBJECT TO STRICT TERMS AND CONDITIONS. SEE CUSTOMER AGREEMENT FOR ADDITIONAL USE RESTRICTIONS. USE ONLY IN CONTROLLED, CLOSED ENVIRONMENT AND FOR RESEARCH AND DEVELOPMENT PURPOSES. OEM VEHICLE SYSTEMS MODIFIED TO SUPPORT COMPUTER CONTROL. NOT INTENDED OR SAFE FOR COMMERCIAL TRANSPORTATION, PASSENGER TRANSPORTATION, ENTERTAINMENT, OR OTHER NON-RESEARCH AND DEVELOPMENT PURPOSES. OPERATE ONLY WITH FUNCTIONING AND MANNED EMERGENCEY STOP SYSTEM. SHOULD ONE OR MORE MECHANICAL, ELECTRICAL, OR DATA SYSTEMS FAIL THE USER MIGHT NOT BE ABLE TO STOP OR CONTROL VEHICLE. OPERATING PRODUCT IN VIOLATION OF USER RESTRICTIONS COULD RESULT IN PRODUCT MALFUNCTION, PROPERTY DAMAGE, AND PERSONAL INJURY INCLUDING DEATH.

NOTICE: USER ASSUMES ALL RISKS ASSOCIATED WITH POSSESSION OR USE OF PRODUCT AND RELATED SYSTEMS. USER AGREES TO INDEMNIFY, DEFEND AND HOLD HARMLESS TORC FROM ANY DAMAGES ARISING OUT OF POSSESSION OR USE OF PRODUCT AND RELATED SYSTEMS. TORC IS NOT LIABLE FOR ANY DAMAGES OF ANY KIND.

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NOTICE: SEE CUSTOMER PURCHASE AGREEMENT AND END USER LICENSE AGREEMENT FOR ALL TERMS AND CONDITIONS APPLICABLE TO USE OF THE PRODUCT OR RELATED SOFTWARE.

2 TECHNICAL SUPPORT

For technical assistance and repairs, please use the following contact information:

Mailing Address	Email & Phone Support
TORC Product Support	support@torctech.com
2200 Kraft Dr, Ste 2050	www.torctech.com
Blacksburg, VA 24060	Phone: (540) 443-9262

All information contained in this manual is believed to be accurate at the time of printing, however, TORC Technologies, LLC reserves the right to make modifications to the specifications and operation of this product without obligation to notify any person or entity of such revision.

3 GENERAL SAFETY INFORMATION

The following symbols are used throughout the user manual to indicate a particularly hazardous condition.

WARNING: Indicates a hazardous condition that could result in serious injury or loss of life if not performed properly.

CAUTION: Indicates a hazardous condition or procedure that could result in damage to this product, or loss related to equipment malfunction.

NOTE: A note indicates information that may not be applicable regarding system safety but needs to be known for best system performance.

Read this manual before using the vehicle.
The ByWire XGV is a complex system requiring the user to be aware of several pieces of information to operate the vehicle safely. Make sure to read this manual in its entirety before attempting to operate the vehicle. Failure to follow the instructions and warnings contained in this manual could result in vehicle malfunction, property damage, and severe injury including death.

Always follow Ford's "Escape Modifiers Guide" when working on the vehicle.
The 330V power available on the Hybrid Ford Escape is extremely deadly if care is not taken when working within proximity to the system. **Always** follow Ford's recommendations within the "Escape Modifiers Guide" (available from Ford) when performing maintenance or modifications to the vehicle.

Do Not Operate With Suspected Failures.
If you suspect there is damage to the product, contact TORC Technologies to have it inspected before further use.

Do Not Modify Wiring Harnesses.
To avoid shock hazard and/or damage to the product, do not modify the wiring harnesses. Splicing into, or adding connectors to the harness may cause undesired operation or damage to the system, resulting in injury or loss of life.

Do Not use the ByWire XGV's existing Controller Area Network (CAN) buses for user communications.
Adding additional message traffic may interfere with existing traffic on the network buses. Interfering with these messages will cause undesirable operation and may cause system damage, injury, or loss of life.

Use Correct Fuse Ratings.
Replace fuses with only the recommended fuse ratings. Fuses that are not of the correct rating could cause undesired operation or damage to the system, resulting in injury or loss of life.

Do Not try to Physically Overpower the Actuators on the ByWire XGV.
The actuators used on the ByWire XGV are high power actuators that not designed to be overpowered by human force. Keep clear of the steering wheel and brake pedal during actuation as injury may occur.

The Steering and Braking Actuators may enter a Reduced Power Mode
The ByWire XGV was designed for normal driving conditions. Repeatedly sweeping the actuators across their full operating range may result in overheating and cause them to operate in a reduced power mode.

Do Not Operate on Public Roads.
Operating a vehicle that is under computer control in an uncontrolled environment is not safe. Operate this vehicle only in a place where outside influences can be controlled.

Do Not Operate in an Area with Unsuspecting Pedestrians.
It is the responsibility of the user to operate this vehicle in a safe area. Unsuspecting pedestrians are at great danger if within the operating area of an unmanned vehicle.

Do Not Drive in a Manner that will Cause a Vehicle Rollover.
Rollover prevention software has **NOT** been included in the ByWire XGV system. It is up to the user to send commands that fall within the vehicle's safe operating envelope. **As with any vehicle with a high center of gravity, the Ford Hybrid Escape is susceptible to rollover.**

Do Not Exceed the Load Capacity Limits of the Ford Hybrid Escape set by Ford.
The capacity limits as published by Ford are included in this manual for reference. Do not exceed these limits as this may cause undesirable and/or unsafe operation of the vehicle.

Do Not Exceed the Maximum Input Message Rate.
The XGV can accept input messages at a collective maximum rate of 50 Hz. Exceeding this rate will cause unsafe latency in the system, and may lead to equipment damage, injury or loss of life.

Do Not Activate the ByWire XGV System while the Vehicle is in Motion
The ByWire XGV performs multiple brake system checks upon startup of the system. If the activation key is turned to the "1" position while the vehicle is in motion it could cause unintended extreme braking of the vehicle.

4 VERSION APPLICABILITY

This manual describes the functionality of version 1.3.2 of the XGV Controller firmware. If your ByWire XGV has a different version of the firmware, portions of this document may not apply to your vehicle.

The version number for the currently loaded firmware can be viewed via the System Configuration Utility, described in Section 7.

5 SYSTEM OVERVIEW

The TORC ByWire XGV is a drive-by-wire platform capable of JAUS communications. The ByWire XGV is a multi-component system consisting of a Ford Hybrid Escape, multiple hardware subsystem control modules, a central embedded controller, and a TORC SafeStop ES-220 multi-level wireless emergency stop system designed to command pause and stop states in the event of an emergency.

5.1 Control Schema Overview

The XGV is capable of operating in three distinct modes of operation.

1) **Manual control** allows a user to drive the vehicle manually and collect data. This permits the user to determine system response as related to human commanded system inputs.

2) **Open loop drive-by-wire control** allows a user to command throttle and brake percentages, as well as steering commands and transmission gear. The XGV will also accept vehicle lights, signals, horn, and engine control commands. This mode is most useful for developing custom control algorithms for autonomous operation or for use with a joystick style Operator Control Unit (OCU).

3) **Closed loop drive-by-wire control** allows a user to command a desired acceleration, desired speed, desired steering curvature, and desired rate of change of curvature. The XGV will also accept vehicle lights, signals, and horn commands. This mode is most useful for autonomous vehicle operation.

5.2 Communications Diagram

The ByWire XGV is a system that integrates safety, communications, and vehicular controls. This system is able to be controlled by a variety of controllers using JAUS over Ethernet. These controllers can be the OCU software program that is packaged with the XGV, the TORC Autononav™, or any other JAUS-interoperable computing package or OCU.

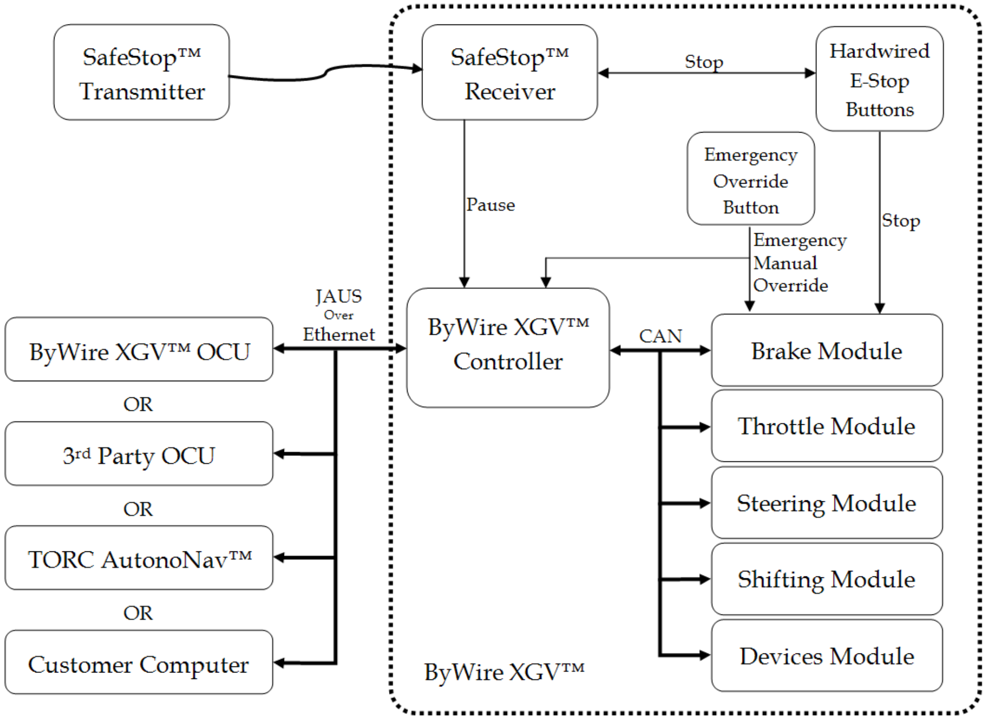


Figure 1. ByWire XGV Communications Overview.

The ByWire XGV ships with a demonstration Operator Control Unit (OCU), however this software component is not necessary to control the system. As long as the controlling software entity communicates through the JAUS protocol, any program is capable of controlling the vehicle.

5.3 System Integration via JAUS

The ByWire XGV is JAUS (Joint Architecture for Unmanned Systems) version 3.3 interoperable. It operates as a JAUS node within the vehicle subsystem, communicating to an OCU or other JAUS entities through JAUS messages. For more detailed information about the JAUS interface, consult Section 8.

The ByWire XGV is capable of being controlled by a JAUS-interoperable OCU, autonomy package, or other device interface, via JAUS over Ethernet, as illustrated in Figure 2.

Six JAUS components run on the ByWire XGV: a Node Manager, a Primitive Driver, a Velocity State Sensor, an experimental Motion Profiles Driver, an experimental Signals Driver, and an experimental Error Manager.

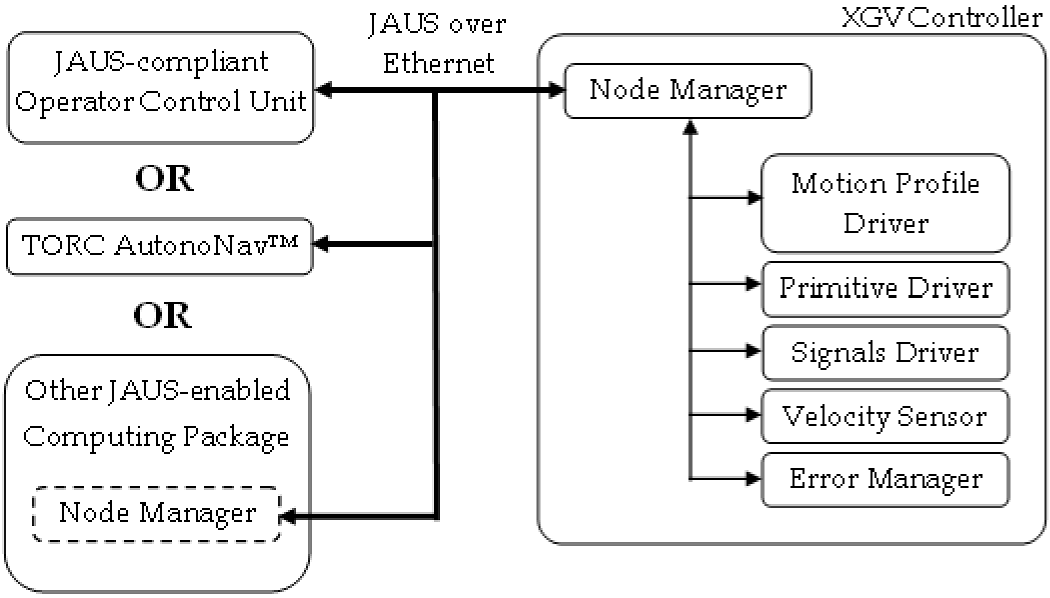


Figure 2. Possible control configurations for XGV.

For more information on the JAUS interface to the ByWire XGV, see Section 8.

5.4 Vehicle Coordinate Frame

The coordinate system orientation is defined as in the JAUS Reference Architecture version 3.3. This right-hand coordinate frame defines the X axis pointing towards the front of the vehicle and the Z axis pointing down from the vehicle as shown in Figure 3.

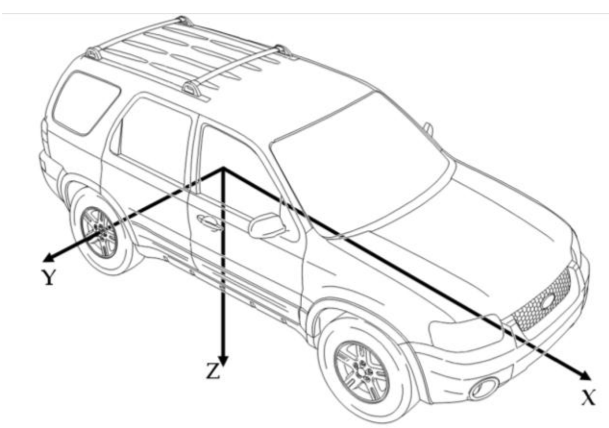


Figure 3. ByWire XGV coordinate system orientation.

JAUS, however, does not specify the origin of the coordinate frame relative to the vehicle. As is common in Ackerman-style vehicles, the origin of the XGV is located at the center of the rear axle.

5.5 Vehicle Mode Definition

The ByWire XGV has many different vehicle states and modes of operation. This section clarifies the schema to avoid confusion. First, the different modes are presented. Next, a flow chart illustrates the logic used to determine the final operating mode of the XGV.

There are three different vehicle modes: the control mode, the ready mode, and the safety mode. The **control mode** refers to the type of messages the XGV should execute : open-loop Wrench Efforts and Discrete Devices, or closed-loop Motion Profiles. The **ready mode** is a user-controlled software pause. Finally, the **safety mode** refers to the current operational state of the vehicle: Drive-by-Wire, Software Pause, E-Stop Pause, E-Stop Disable, and Manual Override. An illustration of the possible values for these three modes is shown in Figure 4.

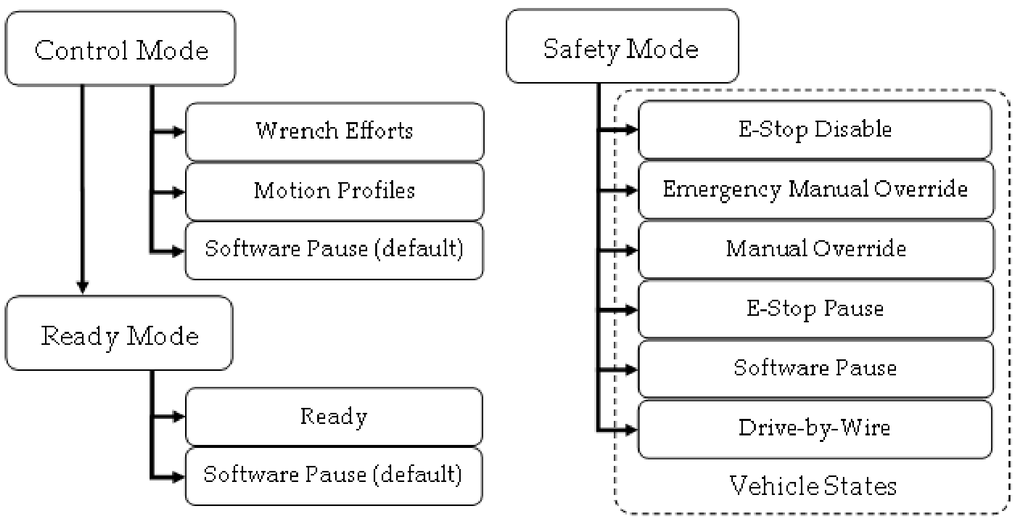


Figure 4. Illustration of the XGV vehicle modes and their possible values.

The three modes are enforced in increasing levels of criticality: (1: least critical) control mode, (2) ready mode, and (3: most critical) safety mode.

Control Mode

The control mode refers to the type of command messages the XGV should execute – wrench efforts and discrete devices (throttle %, brake %, steer %, transmission gear, engine on/off), or motion profiles (curvature and speed). Two different JAUS components, the Primitive Driver (PD) and the Motion Profile Driver (MPD) are responsible for handling these messages, and an OCU or planner sets the control mode by requesting control of the proper component, as illustrated in Figure 5.

In Figure 5(a), a control station or planner has obtained control of the Primitive Driver, placing the XGV into Wrench Efforts control mode. In Figure 5(b), a control station or planner has obtained control of the Motion Profile Driver, which in turn obtains control of the Primitive Driver; the vehicle is now in Motion Profiles control mode. Finally, in Figure 5(c), both the

Primitive Driver and Motion Profile Driver are controlled by other components. In this case, the control mode is Wrench Efforts, since the Motion Profile Driver is unable to obtain control of the Primitive Driver. In all other cases, the control mode defaults to Software Pause.

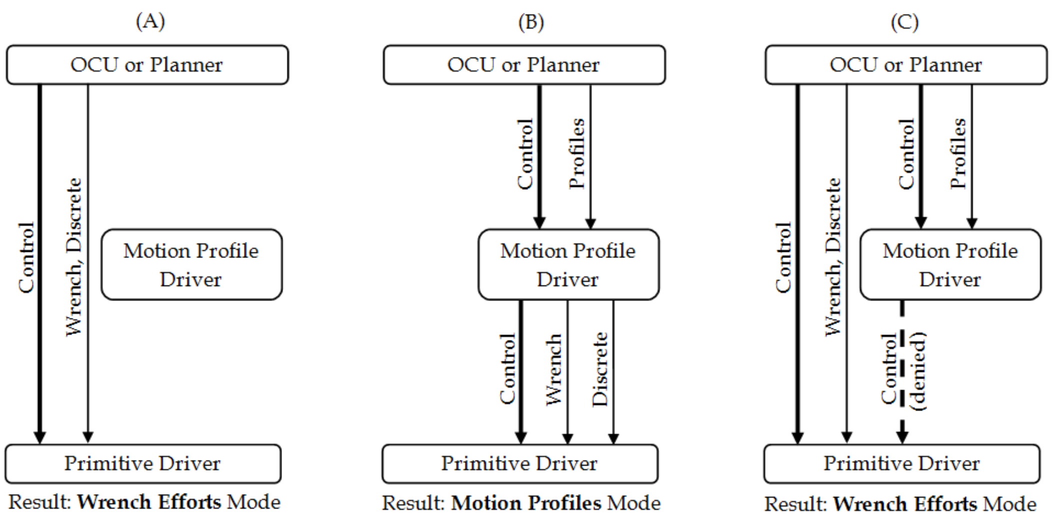


Figure 5. Resultant vehicle mode for a given control schema.

For more detail on the mechanism for requesting control of a component to set the control mode, see the FAQ “How do I obtain control of a component?” within Section 8.2. For information on monitoring the current control mode, see the FAQ “How do I figure out the vehicle mode?”, also within Section 8.2.

Ready Mode

Separately from the control mode, a software pause can be commanded to the XGV by controlling the component status (Initialize, Standby, Ready, Emergency, Failure) of the Primitive Driver and Motion Profile Driver JAUS components. The following rules govern this behavior:

- When the control mode is Motion Profiles, the Motion Profile Driver and Primitive Driver must both have a component status of “Ready” for motion to occur, or the vehicle defaults to Software Pause.
- When the control mode is Wrench Efforts, the Primitive Driver must have a component status of “Ready” for motion to occur, or the vehicle defaults to Software Pause.
- On startup, the component status for the Primitive Driver and Motion Profile Driver is “Standby”. Hence, a JAUS Resume message must be issued at least once to cancel this initial Software Pause.

For more information on how to affect the component status, consult the Status Subgroup heading within Section 8.3, and the Component Status heading within Section 8.1.

Safety Mode

The final operational state of the vehicle is referred to as the safety mode. The safety mode is controlled by, in increasing levels of priority, the control mode, the ready mode, internal errors, the status of the doors and liftgate, the SafeStop pause relay, the Manual Override selector (gearshift selector), and the SafeStop disable relay. If the system is not active, the XGV controller is not booted, and the vehicle remains in manual control.

NOTE: Some features of the safety mode behavior can be configured via the System Configuration Utility, such as whether the liftgate or liftgate glass being open causes a software pause.

The safety mode determines the response of the vehicle so that it will act in a manner that is safe, expected, and necessary to achieve the response commanded by the user.

These possible values for the safety mode are, in increasing levels of precedence:

1. Drive-By-Wire – The drive-by-wire state is the state where the vehicle is fully operable by the computer. This state is commanded if errors are clear from all systems and there are no “pause” or “disable” commands from the SafeStop. The control mode (discussed in above in heading: Control Mode), determines the type of command messages the XGV will execute. If the warning siren and/or light were purchased, and if they are configured to be active, they will be on in this mode.

2. Software Pause – This state is commanded anytime that the software determines that vehicle movement would be unsafe, for instance, when a door is open. In this state the brakes will apply to bring the vehicle to a stop at 4 m/s^2 (the rate of deceleration is configurable through the System Configuration Utility described in section 7, System Configuration Utility). Once the vehicle is stopped the brakes will continue to apply 50% braking effort. The throttle will not respond; it will apply 0% effort. The steering will continue to accept JAUS commands, ensuring that the vehicle will remain on its desired path until it has stopped. All commands to the vehicle that do not result in movement will continue to be allowed. The engine on/off, horn, lights, signals, and hazards will continue to respond to JAUS commands. If the warning siren option has been purchased and is configured to be active, it will turn off while the vehicle is in software pause. The exception to this is if the software pause was caused by an event that the XGV firmware can clear (for example – an internal error); in this situation the warning siren will remain on. This is to make the user aware that the vehicle may resume motion.

3. E-Stop Pause – The E-stop pause state is commanded from the toggle switch on the SafeStop transmitter. The default rate of deceleration is 4 m/s^2, this value is also configurable through the System Configuration Utility. If the warning siren option has

been purchased, the siren will be off in this state. In all other respects, this state is identical to the Software Pause state.

4. Manual Override – The XGV system is capable of being manually overridden at any time. If the shift selector is in any position other than "neutral" the vehicle will not respond to computer input, and all systems will be under manual control. However, whenever the XGV system is active, even if the manual override is engaged, the emergency stop system can still transition the vehicle to E-Stop Disable. If the warning siren and/or light were purchased, and if they are configured to be active, they will turn off in this mode.

5. Emergency Manual Override –This mode is functionally equivalent to Manual Override, except that it is accomplished via hardware, with no software in the loop. Emergency manual override is commanded by depressing the yellow button mounted on the center console between the front seats. If the warning siren and/or light were purchased, they will be off in this mode.

6. E-Stop Disable – E-Stop Disable can be commanded from either the "stop" button on the SafeStop transmitter or from the red hard-mounted emergency stop button(s). In this mode, the XGV will apply 100% braking effort to stop the vehicle. It will also shut off the engine (if configured to do so) and return throttle, shifting, and steering commands back to manual control. This mode takes precedence over all other modes. If the warning siren and/or light were purchased, they will be off in this mode.

7. Inactive – Finally, if the XGV system is not active (see Section 6.1 – System Activation), the XGV controller is not booted, none of the modes discussed above are calculated, and the vehicle remains under complete manual control.

Differing levels of control are allowed for each of these safety modes. The table below indicates what the control input is for each of the vehicle systems.

Safety Mode Control Chart							
	Inactive	**E-Stop Disable**	**Emergency Manual Override**	**Manual Override**	**E-Stop Pause**	**Software Pause**	**Drive-By-Wire**
Throttle	man	man	man	man	XGV ctrlr	XGV ctrlr	DBW
Brake	man	ISS	man	man	XGV ctrlr	XGV ctrlr	DBW
Steering	man	man	man	man	DBW	DBW	DBW
Shifting	man	man	man	man	XGV ctrlr	XGV ctrlr	DBW
Low Beams	man	DBW	man	man	DBW	DBW	DBW
High Beams	man	DBW	man	man	DBW	DBW	DBW
Parking Lights	man	DBW	man	man	DBW	DBW	DBW
Fog Lights	man	DBW	man	man	DBW	DBW	DBW
Turn Signals	man	DBW	man	man	DBW	DBW	DBW
Hazards	man	DBW	man	man	DBW	DBW	DBW
Horn	man	DBW	man	man	DBW	DBW	DBW

Engine	man	XGV ctrlr	man	man	DBW	DBW	DBW
Warning Light	off	off	off	off	on	on	on
Warning Siren	off	off	off	off	off	off*	on

The control types: **man**, **DBW**, **XGV Ctrlr**, and **ISS** are defined as follows.

man (manual): A driver can control the system manually, as one would in an unmodified car.

DBW (drive-by-wire): The user can command the system through the JAUS interface.

XGV Ctrlr (XGV Controller): Logic on the XGV Controller determines control for the system.

ISS (Independent safety system): A system independent of the XGV controller determines this control.

NOTE: If the safety mode is software pause, and this was caused by an internal software error, the warning siren will remain on. This is to notify the user that the XGV software can clear the error and resume operation. If a software pause is commanded for any other reason, the warning siren will be off.

5.6 Vehicle Mode Flow Chart

The flow chart in Figure 6 illustrates the logic used to incorporate the control mode, ready mode, and safety mode in determining the final operating state of the XGV. To read the diagram, begin at the black dots and work through the two parallel threads until they merge at the “Control Mode” block and continue to the “Safety Mode” block.

The result of this flow chart is the safety mode. To read more about the safety mode, refer to section 5.5.

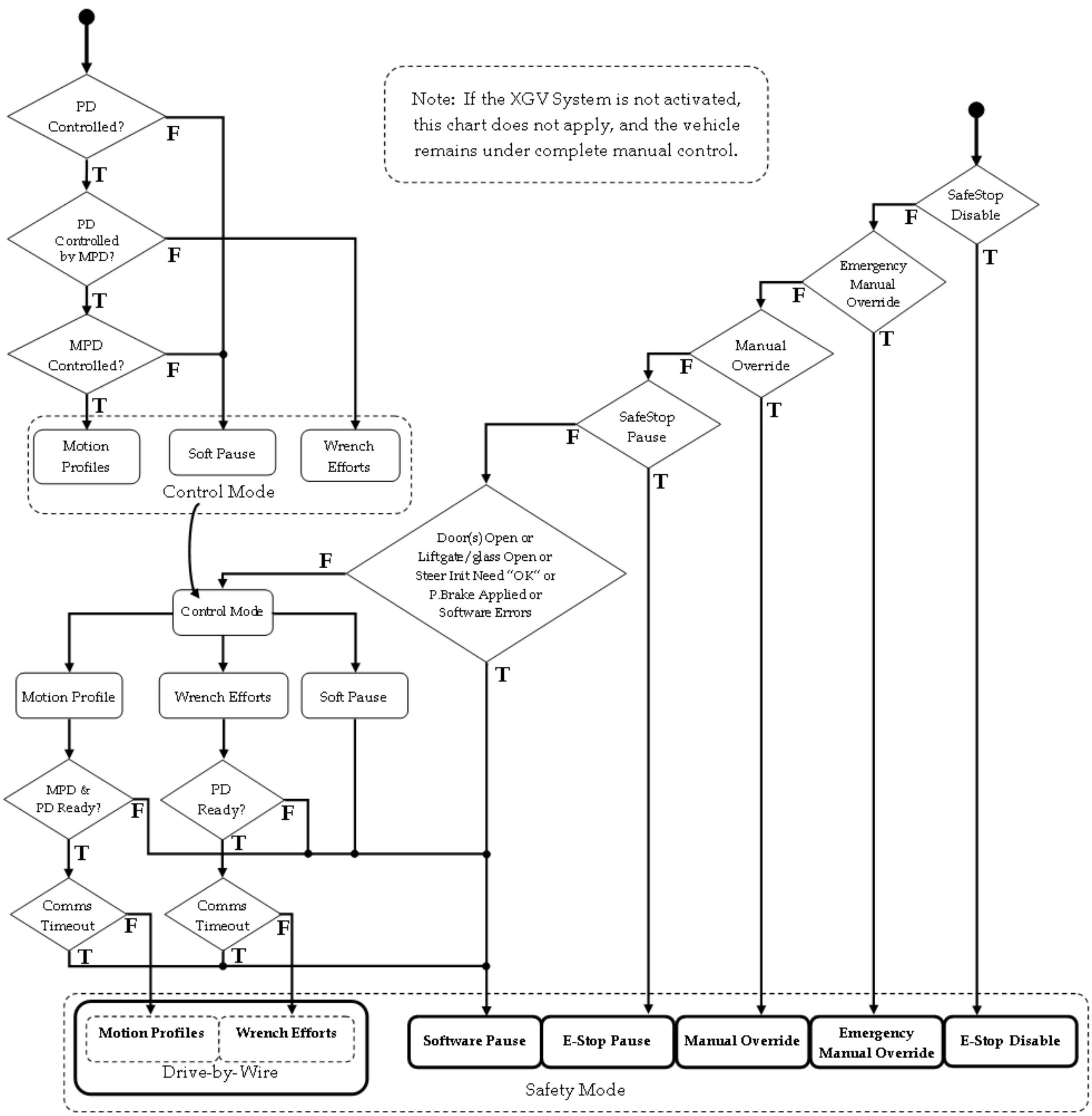


Figure 6. Vehicle Mode Chart. This flow chart describes the decisions that are made regarding vehicle mode. The abbreviations PD and MPD refer to the Primitive Driver and Motion Profile Driver JAUS components, respectively.

5.7 Hardware Component Locations

The ByWire XGV system is tightly coupled to the Hybrid Ford Escape. Many XGV components are out of view of an occupant. As a result, the XGV appears to be stock and the components are safeguarded from physical abuse.

Care must be taken when adding additional components to this vehicle. Before working on the Ford Hybrid Escape the user must understand that extremely large amounts of electrical power are stored in the vehicle's 330V DC battery pack located underneath the cargo area of the vehicle.

WARNING: Read Ford's Escape Modifier's Guide before making any modifications to this vehicle. Always pay attention to high voltage lines and regard any safety warnings.

The majority of the components that make up the ByWire XGV are located within the center console and behind the dash. However, there is wiring that runs throughout the vehicle to couple all of the components. Figure 7 illustrates the component locations and wire harness routing.

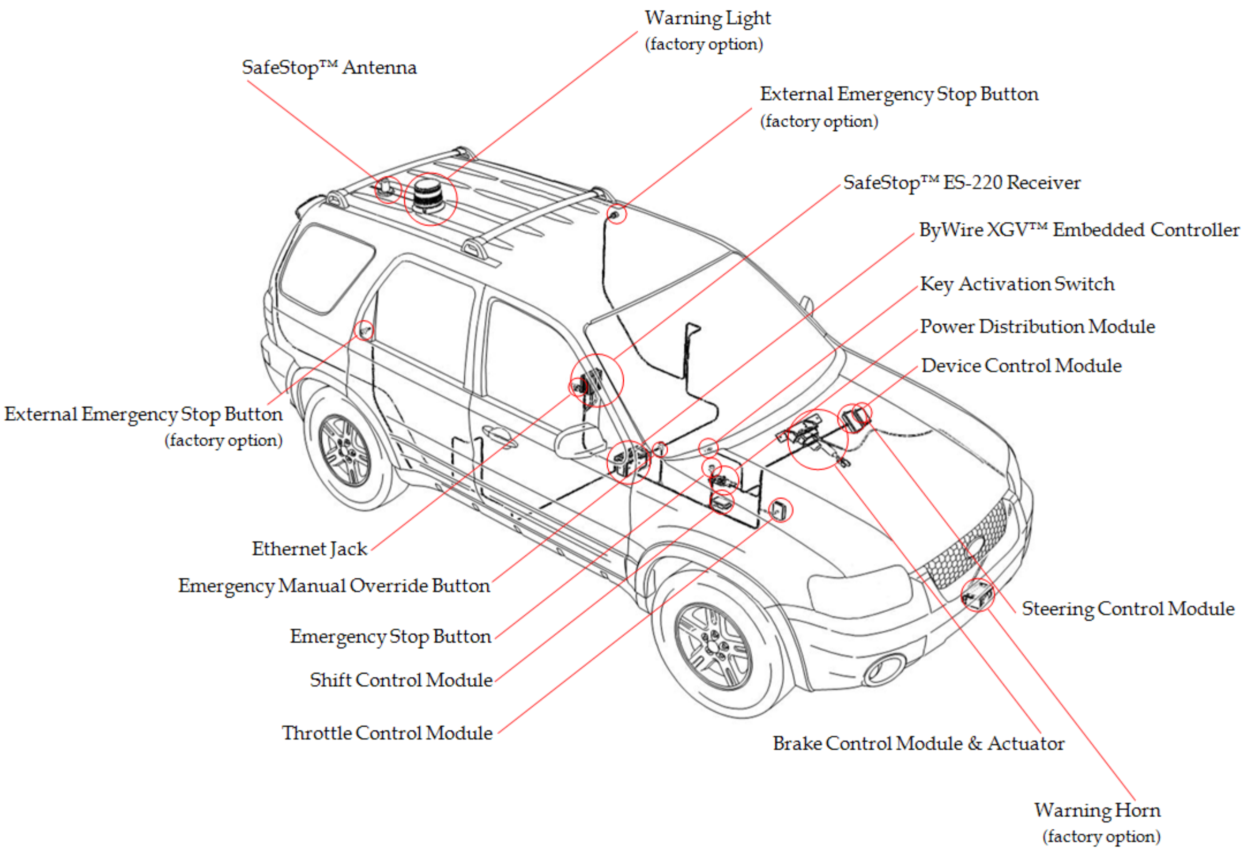


Figure 7. Component locations and descriptions as well as wire harness routing paths.

As with any work, be careful to avoid components and wiring when drilling or cutting through bulkheads, trim panels, or any other surface of the vehicle.

WARNING: The power stored on the Hybrid Ford Escape is **extremely deadly** if care is not taken when working with the system. **Always** disconnect the 330V battery pack and follow Ford's recommendations outlined in the publically available **Escape Modifiers Guide** when working on the system.

6 HARDWARE

The TORC ByWire XGV has been designed with a focus on safety. There are redundancies built into the system as well as safeguards to make sure that unintended drive-by-wire operation does not occur. However, as with any product, the user must remain alert at all times while operating the system.

6.1 System Activation

To activate the ByWire XGV control system, the user must turn the system activation key to the "1" position. The emergency brake system will immediately perform a brake actuator check. The system controller takes approximately 40 seconds to boot. Once it is fully booted it will perform a second brake check to fully test brake control.

If the key is left in the "0" position, the entire XGV system remains deactivated. This is the preferred system state while transporting the vehicle because the emergency stop system is deactivated. When the key is in the "0" position, depressing an emergency button will not cause any action and the vehicle will behave exactly as a stock Hybrid Escape.

Figure 8. Location of the system activation key on the center console.

Warning: Any time the system activation switch is in the "1" position, an E-Stop disable event will apply the brakes and may shut off the engine. To prevent unintended E-Stop disable events, the system activation switch should be placed in the "0" position while transporting the vehicle on roadways.

Warning: Do not turn the key to the "1" position while the vehicle is in motion. Upon activation the system performs two separate brake system checks. The first happens immediately and the second happens approximately 40 seconds after the system is activated.

If the system activation key switch is left in the “1” position when the vehicle ignition is turned off, the vehicle will chime as a reminder that the battery is being drained.

The ByWire XGV is delivered with two keys for use in the activation switch. If more copies are required, they can be purchased from TORC.

6.2 Manual Override

The manual override switch on the ByWire XGV is the transmission shifter. If the XGV system is active, the user allows the computer to have control of the vehicle by placing the shifter in the “neutral” position. In any other position the vehicle will respond exactly as a stock Ford Hybrid Escape. As a precaution, the shifter must remain in “neutral” for 1.0 second before the computer will assume control. This feature allows the user to shift between gears without unintended computer intervention.

CAUTION: Any time the ByWire XGV system is active, an E-Stop disable event will apply the brakes and, if configured to do so, will shut off the engine. E-Stop disable events are NOT overridden by the manual override.

6.3 Emergency Manual Override

The yellow emergency manual override button located behind the shifter on the center console allows a safety rider to regain manual control of the XGV at any time. The function of this button is identical to the manual override switch described in Section 6.2 but is implemented in hardware with no software in the loop. To accomplish this, the system interface modules are depowered causing all commands to revert to manual control. Furthermore, the brake actuator is shorted between ground and 12V causing it to retract and yield all control to the safety rider.

An emergency stop event, caused by either a hardwired emergency stop button or the SafeStop, will subsume an emergency manual override event. If the emergency manual override button, and an emergency stop button are both depressed, the safety mode will be EStop Disable.

6.4 Emergency Stop System

SAFESTOP™

The wireless emergency stop device integrated into the ByWire XGV system is a TORC SafeStop ES-220 Wireless Emergency Stop system.

The SafeStop ES-220 multi-level wireless emergency stop system consists of the ES-220T transmitter and the ES-220R receiver. The SafeStop system provides the ability to safely disable an unmanned or autonomous vehicle from a remote location up to 6 miles away. The compact, lightweight transmitter contains an internal rechargeable battery that allows the SafeStop system to operate up to 30 hours on a single charge. Two independently controlled contacts allow a vehicle to be placed in a paused state as well as disable power to actuators, fuel valves, etc. An audible alarm and indicator lights provide user feedback of contact position, link status, and battery life. Additionally, a serial port is provided for interfacing to an onboard computer, and a bypass switch allows for manual override of the system.

The SafeStop is a proven, off-the-shelf system that is capable of allowing three modes of operation: Run, E-Stop Pause, and E-Stop Disable. The operation of these modes can be found in the supplemental materials: SafeStop ES-220 Wireless Emergency Stop User Manual.

SafeStop Settings

The TORC SafeStop is capable of user configuration. For integration into the XGV system, the SafeStop has been configured in the following manner. For more information regarding the configuration settings of the SafeStop refer to the SafeStop ES-220 Wireless Emergency Stop User Manual.

Communications Loss Timeout Action

If there is a communication loss between the SafeStop transmitter and SafeStop receiver, a pause event will be commanded to the XGV controller.

Communications Loss Timeout Delay

The communications loss timeout delay is left at its default value of 2000 ms.

Latching Action

The latching action has been enabled for the ByWire XGV. This provides a level of safety against premature or inadvertent clearing of an emergency stop event.

External Stop Polarity

The external stop polarity of the SafeStop has been configured to be “Stop on Low External Input”.

EMERGENCY STOP CIRCUIT

The emergency stop circuit consists of an independent wiring loop that, during operation, is powered with 12V DC. The emergency stop circuit is enabled anytime the ByWire XGV system is active. Refer to Section 6.1, System Activation, for more information about activating the ByWire XGV system. If power is interrupted to the circuit, the brake actuator will apply 100% braking effort and the XGV software will be put in an “E-Stop Disable” state. There are two ways that power can be lost to the circuit in a way that will bring the vehicle to a stop. First, by pressing the E-stop button on the SafeStop transmitter the user will cause a contactor internal to the SafeStop receiver to break the emergency stop circuit, causing the vehicle to stop.

Second, the user can press either the internal hardwired emergency stop button (standard feature) or the external hardwired buttons (factory option) to cause E-stop disable mode.

If the emergency stop event was caused by the SafeStop transmitter, the user will need to perform two steps to clear the condition and return the SafeStop to “Run” mode. First, the SafeStop transmitter E-stop button needs to be reset by turning it clockwise. Second, the user must press and reset one of the hardwired buttons on the vehicle. This procedure is needed because the “latching” function has been enabled on the SafeStop. More information can be found regarding this feature in the SafeStop ES-220 Wireless Emergency Stop User Manual.

If the emergency stop event was caused by pressing a hardwired button, the user needs only to reset that button to return the vehicle to “run” mode.

CAUTION: If the XGV system is active, pressing an E-Stop button will cause the brake to apply whether or not the system is in manual override.

A diagram of the emergency stop circuit is given in Figure 9.

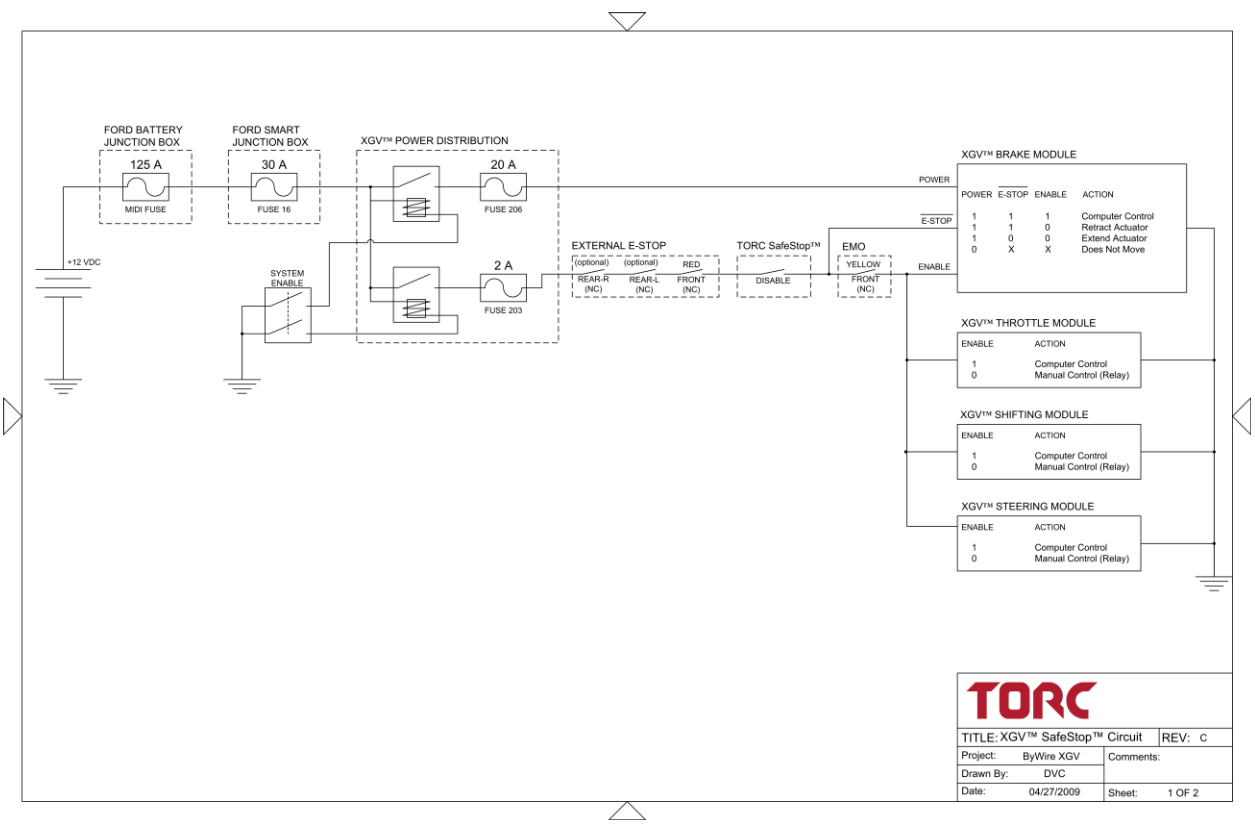


Figure 9. Emergency Stop Circuit

Internal Button

The internal emergency stop button is located on the center console just forward of the shifter. This button is a standard feature on the ByWire XGV.

EXTERNAL BUTTONS (FACTORY OPTION)

The external emergency stop buttons are located on the plastic sail panels on the exterior of the rear doors. These buttons are options available for purchase from the factory at the time of system purchase. They function in the same manner as the internal button located on the center console.

6.5 User Interface

The ByWire XGV utilizes Ford's in-dash Liquid Crystal Display (LCD) as a method of displaying information to the operator. The 20x2 character alpha-numeric display is a part of the Front Display Interface Module (FDIM), shown below. This display is used as a system menu for the ByWire XGV and to display any errors detected within the system.

Figure 10. Ford Escape LCD.

The user interface is controlled by the use of the stock radio controls or by the use of the multifunction switch on the steering column. To read more about the User Interface, refer to section 9.2.

6.6 System Fuses

The main power pull off for the ByWire XGV system is Fuse 16 in Ford's Smart Junction Box, located on the front right side of the center console. The original 15A fuse was removed and a fuse tap was inserted.

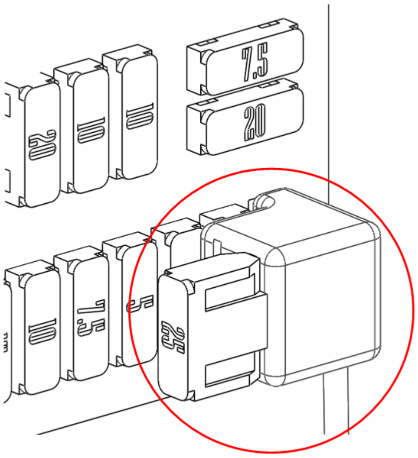


Figure 11. Fuse 16 in the Ford Smart Junction Box was replaced by a fuse tap to supply power to the XGV system.

A 25A fuse is used, which has enough capacity to power the XGV system. Should this fuse need to be replaced, a 25A fuse must be used.

All components of the ByWire XGV are fused individually to protect the system in the event that a single node is damaged. The ByWire XGV fuses can be accessed by removing the rubber lining of the change tray at the front of the center console. If a fuse needs to be replaced, an equivalent fuse must be used to avoid potential damage to the ByWire XGV electrical system. The fuse positions are shown below in Figure 12.

Figure 12. ByWire XGV system fuse positions.

All fuses are automotive mini-blade style fuses, Bussman ATM or Littelfuse 297 equivalent.

Fuse	Fuse Rating	Circuit Description
F201	2A	XGV Devices Module
F202	5A	XGV Interface Module
F203	2A	TORC SafeStop
F204	2A	XGV Warning Siren
F205	2A	XGV Warning Light
F206	20A	XGV Brake Module

WARNING: Use only the correctly rated fuse for each component. Using a fuse with incorrect rating could cause damage to the system, injury, or loss of life.

6.7 Networking

To interface with the ByWire XGV, a 10/100 Mbit Ethernet port is provided. A standard RJ-45 jack is installed on the rear of the center console adjacent to the rear power port. By default, the ByWire XGV is configured with a static IP address of 192.168.0.100 and a subnet mask

255.255.255.0. These defaults can be modified using the system configuration utility described in section 7.

If the IP address is unknown, the ByWire XGV user interface can be used to display the current IP settings or to reset the IP settings to factory default values; refer to Section 6.5, User Interface, for details.

6.8 Additional Equipment Power (Factory Option)

There are small amounts of power available from the Hybrid Ford Escape's stock power outlets to supply additional sensors and computing equipment. However, there is not enough power available to supply large sensor packages or racks of computing hardware.

TORC can install, as a factory option, a high voltage DC-DC converter for the XGV. This accessory converts the energy provided by the Ford Escape's hybrid power system to 3kW of power at 54VDC. This output can then be used to power a 120VAC option, one or more TORC PowerHub modules, or any other 54V device. A diagram showing the use of the high voltage DC-DC converter as installed in the vehicle is included as Figure 13. When the high voltage DC-DC is selected as an option to an XGV installation, the power connection is made under the rear passenger side seat. A 5ft cable is attached at this location, allowing the high voltage DC-DC option to be located anywhere in the XGV's cargo area. As a safety precaution, if this cable is unplugged from the High voltage DC-DC, a supplied terminating plug must be installed in order for the vehicle to operate.

WARNING: Always disconnect the high voltage battery pack as shown in the Ford Escape Owner's Manual before connecting or disconnecting the high voltage DC-DC accessory.

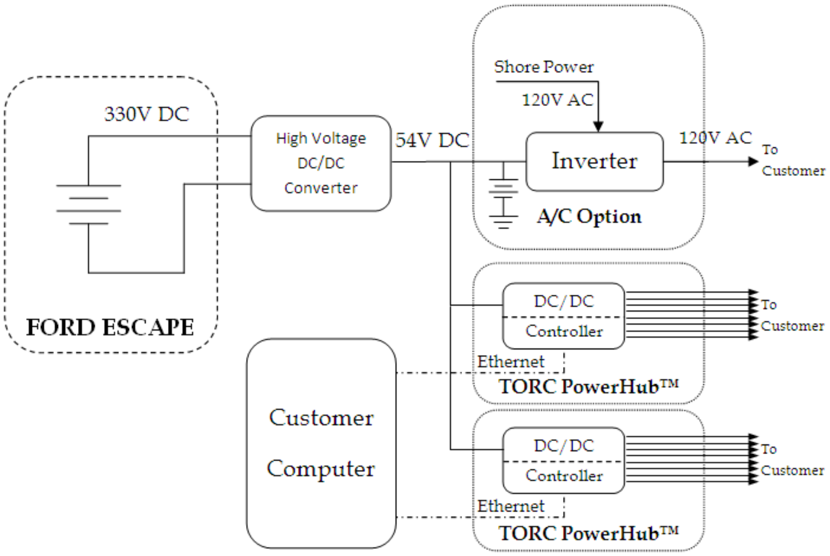


Figure 13: ByWire XGV managed power diagram.

WARNING: Never disconnect the high voltage power connection located under the rear passenger side seat.

To provide DC power to user devices, TORC PowerHub managed power conditioning units may be connected directly to the 54V output of the high voltage DC-DC converter. The PowerHub provides computer controlled power conversion and distribution designed for applications in unmanned systems. The PowerHub is available with a 5V, 12V, or 24V nominal output. Convenient control over Ethernet allows each of the 8 outputs to be switched and monitored remotely. An intuitive web interface allows the user to directly configure and use the PowerHub during testing and development, and a simple TCP protocol allows for computer control. For more information regarding the PowerHub line of products, please see the PowerHub user manual or contact TORC.

HIGH VOLTAGE DC-DC MODULE SPECIFICATIONS

The high voltage DC-DC option is a 3kW 330V to 54V converter, designed to be mounted in 1U of a standard 19” computing rack.

The front of the unit, pictured in Figure 14, includes the output enable switch (1), and six inlet fans for cooling (2). On the rear of the module, there is a remote enable input(1), module link connector(2), module activity LEDs (3), six 54V output jacks (4) and the 330V input jack (5), shown in Figure 15.

The remote enable connector is a 3 pin Molex MicroFit connector P/N: 43650-0304. The mating plug is Molex P/N: 43645-0300. The remote enable connection allows the DC-DC module to be enabled and disabled via external circuitry. This lets the DC-DC module operate in a very low power state when not enabled. If the remote enable capability is not required, a jumper can be used to connect pins one and three, configuring the DC-DC module to always be enabled when the Master Switch is in the ON position. Applying a voltage between 2-60 VDC to pin 3 in reference to ground, pin 2, enables the DC-DC module.

NOTE: When the XGV is started there will be a 5 second delay before the DC-DC accessory will turn on during vehicle initialization.

The module link connector is used for paralleling two 3KW High Voltage DC-DC Converters. For more information regarding parallel operation, refer to the parallel operation guide available from TORC.

CAUTION: When the module link cable is used, a separate cable must be used to connect the outputs of the DC-DC Converters together. If this cable is not present when the units are powered on, damage to the units will occur.

The output jacks are 2 pin Molex Mini-Fit Sr. connectors P/N: 42820-2212. The mating plug is Molex P/N: 42816-0212. Each output can supply up to 49 amps, but all are connected in parallel for the user’s convenience. On the output connectors, pin 1 is +54V and pin 2 is ground. The floating 330V input voltage is applied to pin A (+) and B (-) of the Amphenol series 97 circular connector. This input remains isolated from the output and vehicle ground. Pins C and D are internally connected in order to complete the vehicle's safety interlock link. If this connection is opened, shorted high, or shorted low, the high voltage system and vehicle will be disabled.

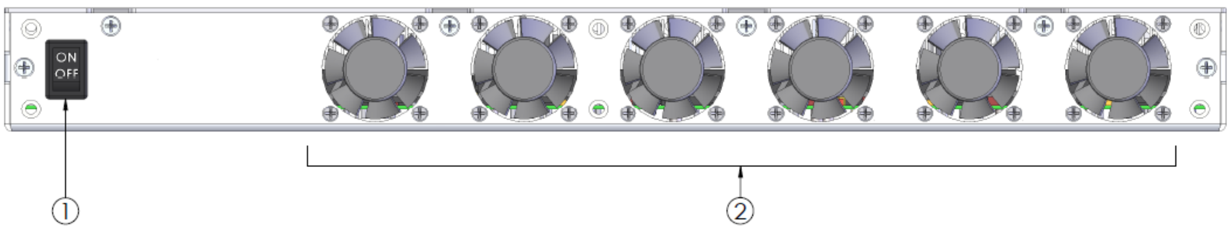


Figure 14: The front of the high voltage DC-DC accessory.

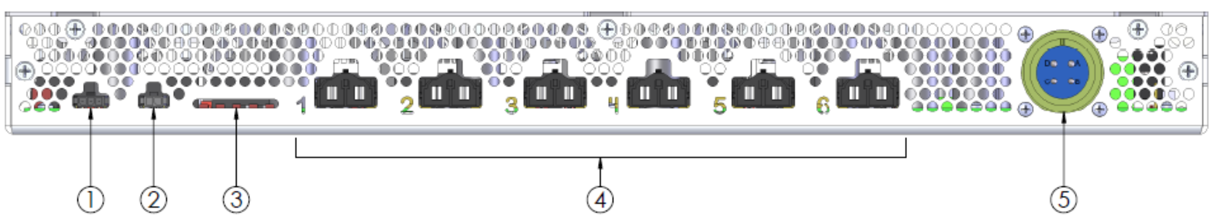


Figure 15: The rear of the high voltage DC-DC accessory.

The high voltage DC-DC includes protection circuitry designed to reduce the output voltage if an over current or over temperature condition exists. These faults can be cleared by turning the unit off and back on. The output of the converter is rated to supply 3kW at an ambient (inlet air) temperature of 60 degrees Celsius. Refer to Figure 16 for operation at other temperatures.

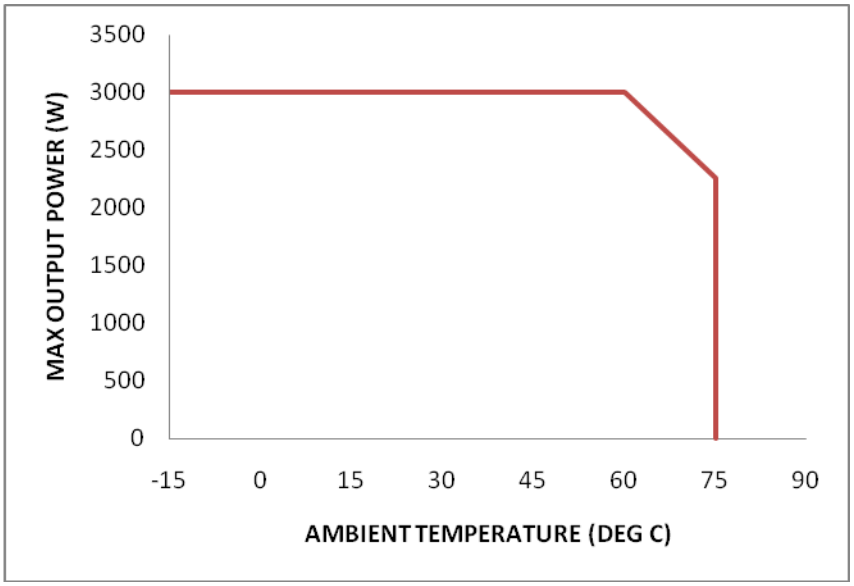


Figure 16: High voltage converter, XGVHVC02, output power derating.

CAUTION: The high voltage converter requires proper airflow to cool the internal components. Do not block any of the intake vents on the front of the unit or outlet vents on the rear of the unit.

AC POWER OPTION SPECIFICATIONS

The AC/shore power option includes a modified TrippLite SMART2600RM2U UPS. This UPS provides an integrated inverter, charger, and battery in a 2U rack mountable chassis. This unit allows 120VAC devices to be powered by the vehicle's hybrid power system while the vehicle is running. A cable with a 20A NEMA 5-20P plug is provided in order to supply the AC devices with power while the vehicle is off. The UPS batteries will continue to supply 120VAC and 54VDC power to the attached devices for a short time when the vehicle is off and not connected to an external 120VAC supply. A table of estimated runtimes is attached in Section 12.6.

For integration into the XGV, the audible UPS alarm has been disabled. Refer to the SMART2600RM2U user manual for alternative ways of monitoring the UPS's battery charge level.

While connected to an external 120VAC supply, the UPS can also provide up to 120W of power on the 54V bus without draining the internal batteries. If extended output power is required on the 54V bus when on wall power, please contact TORC for assistance.

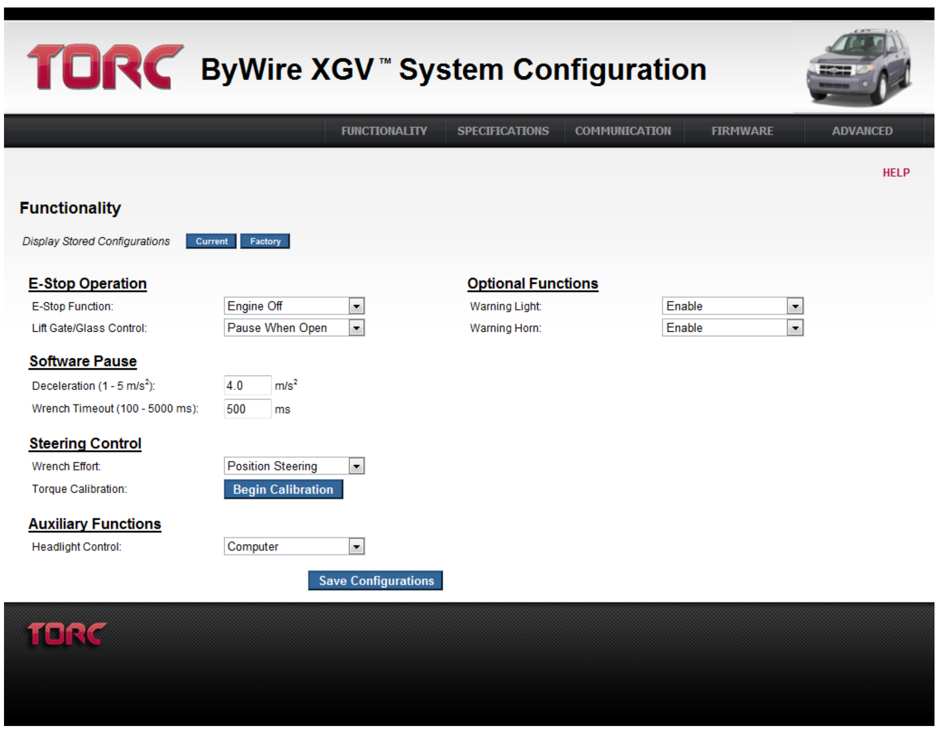
CAUTION: The TrippLite UPS does not turn off automatically. The user is responsible for turning it off after use. Not doing so may cause damage to the internal batteries.

7 SYSTEM CONFIGURATION UTILITY

7.1 Overview

The System Configuration Utility provides the interface to configure performance and communication parameters for the ByWire XGV. This configuration utility can be accessed using a web browser, such as Internet Explorer, on a computer connected via Ethernet to the XGV. The System Configuration Utility is only accessible when the gear shift lever is placed in “park”. The vehicle must remain in “park” for the duration of the session.

Once a computer is connected to the ByWire XGV, launch Internet Explorer and enter the IP address of the XGV (default IP: 192.168.0.100) into the *Address* field and press **Enter**. A dialog box will prompt the user for login information. Default login information is: user name = ByWireXGV; password = torctech. Once logged in, the Functionality configuration page will load. Links to the other configuration pages are located top-right; below the picture of the XGV.



As configurations are updated, be sure to save any changes before navigating away from a page or the changes will be lost. To save changes, click the Save Configurations button. Saving allows the user to navigate to other pages in order to continue making configuration changes. The items on the Functionality page will take effect immediately after saving. However, the changes on other pages will not take effect until the Restart XGV™ button is clicked.

This help information is also available on the XGV System Configuration Utility by clicking the HELP button.

7.2 XGV Configuration

FUNCTIONALITY

The Functionality configuration page provides the ability to change specific XGV functions:

XGV Configuration: *Functionality* Page	
E-stop Operation	**E-stop Function:** Controls whether or not the engine continues to run or is shutoff when the emergency stop system is engaged. ▪ *Engine On*: The engine will remain in its last commanded state when the E-Stop Disable is engaged. ▪ *Engine Off*: Engaging the E-Stop Disable will cause the engine to turn off. DEFAULT: ENGINE OFF **Liftgate /Liftgate Glass Control:** Controls whether or not the XGV can operate in drive-by-wire mode with the liftgate or liftgate glass open. ▪ *Pause When Open*: If the liftgate or liftgate glass is open, the vehicle will remain in Software Pause. ▪ *Run with Open*: The liftgate and liftgate glass have no effect on the safety mode. DEFAULT: PAUSE WHEN OPEN
Software Pause	**Deceleration:** Sets the rate at which the vehicle will come to a stop during a Software or E-Stop Pause. For details regarding the causes of a software pause, refer to the Safety Mode heading within Section 5.5. Limit: 1 to 5 m/s^2 DEFAULT: 4 m/s^2 **Wrench Timeout:** Sets the timeout threshold for incoming Set Wrench Effort command messages, when the control mode is Wrench Efforts. If a new command has not been received within this time, an error is triggered, and the vehicle enters Software Pause. This parameter is only used when the control mode is Wrench Efforts. Limit: 50 to 5000 ms DEFAULT: 500 ms
Steering Control	**Wrench Effort:** Controls the performance of steering when in wrench efforts control mode. ▪ *Effort Steering*: The steering command is the percentage of effort applied. ▪ *Position Steering*: The steering command is the desired angle, in percent. DEFAULT: POSITION STEERING **Torque Calibration:** Pressing "Begin Calibration" will recenter the zero torque value that the XGV uses to command the Escape. Use this feature if the steering is not balanced, meaning that it steers more easily to one side than to the other. Before initiating the calibration make sure that the steering wheel is centered and that nothing touches the wheel during calibration.
Auxiliary	**Headlight Control:**

Functions	Controls how the XGV headlights are controlled in drive-by-wire mode. ▪ *Computer*: Headlights are controlled via JAUS commands. ▪ *Manual*: The stock headlight switch controls the headlights. DEFAULT: COMPUTER

Optional Functions	**Warning Light:** Controls whether or not the warning light (XGV Factory Option) turns on when the XGV is in Pause or Drive-by-Wire modes (Described in Sections 5.5 and 5.6). ▪ *Enable*: The warning light will blink when the XGV is in Run, E-Stop Pause, or Software Pause mode. ▪ *Disable*: The warning light will be disabled. DEFAULT: ENABLE **Warning Horn:** Controls whether or not the warning horn (XGV Factory Option) turns on when the XGV is in Drive-by-Wire mode (Described in Sections 5.5 and 5.6). ▪ *Enable*: The warning horn will sound when the XGV is in Run mode. ▪ *Disable*: The warning horn will be disabled. DEFAULT: ENABLE

To change values on the XGV Functionality page, select the desired settings. Then, click *Save Configurations* to load these changes onto the XGV.

The current or factory default settings can be displayed for reference by clicking the Current or Factory buttons. Clicking these buttons will populate the Functionality page with the values that are currently loaded or the original factory values for the XGV. Displaying either of these values will cause the user to lose any unsaved data. These values will be loaded onto the XGV immediately after they are saved.

This information is also available on the XGV System Configuration Utility by clicking the HELP button.

Specifications

The Specifications configuration page provides the ability to change the vehicle parameters reported in JAUS message 0x4400: Report Platform Specifications (Described in Section 8.3).

<table>
<tr><th colspan="2">XGV Configuration: Specifications Page</th></tr>
<tr><td>Configurable Settings</td><td>
Platform Name:
Limit: 15 characters maximum
DEFAULT: ByWire_XGV

Distance from Origin to Vehicle Bounds:
Limit: 0 to 32.767 meters
DEFAULTS:
<table>
<tr><td>Front:</td><td>3.52 m</td><td>Back:</td><td>0.91 m</td></tr>
<tr><td>Left:</td><td>0.89 m</td><td>Right:</td><td>0.89 m</td></tr>
<tr><td>Top:</td><td>1.41 m</td><td>Bottom:</td><td>0.37 m</td></tr>
</table>
Distance from Origin to Center of Gravity
Limit: 0 to 32.767 meters
NOTE: These fields (X_{CG}, Y_{CG}, Z_{CG}) are not supported by the XGV since the standard JAUS message does not allow for negative coordinates.
DEFAULTS:
<table>
<tr><td>X_{CG}:</td><td>n/a</td></tr>
<tr><td>Y_{CG}:</td><td>n/a</td></tr>
<tr><td>Z_{CG}:</td><td>n/a</td></tr>
</table>
Static Rollover
Limits: 0 to 2.56 radians
ALL DEFAULTS: 0
</td></tr>
<tr><td>Constant Information</td><td>
This information is provided as a reference and cannot be modified by the user.
<table>
<tr><td>Turning Radius:</td><td>5.58 m</td></tr>
<tr><td>Track Width:</td><td>1.54 m</td></tr>
<tr><td>Wheel Base:</td><td>2.62 m</td></tr>
<tr><td>Maximum V_X:</td><td>46 m/s</td></tr>
<tr><td>Maximum V_Y:</td><td>0 m/s</td></tr>
<tr><td>Maximum V_Z:</td><td>0 m/s</td></tr>
<tr><td>Maximum ω_X:</td><td>0 rad/s</td></tr>
<tr><td>Maximum ω_Y:</td><td>0 rad/s</td></tr>
<tr><td>Maximum ω_Z:</td><td>0 rad/s</td></tr>
</table>
NOTE: The XGV accepts desired curvature or wrench effort as inputs to the steering, not a desired angular rate. For this reason the maximum angular rate is reported as 0 rad/s.
</td></tr>
</table>

To change values on the XGV Specifications page, input the desired parameters, and click *Save Configurations*. Once all configurations are complete, click *Restart XGV* to load these changes onto the XGV.

NOTE: The XGV will only be able to restart if the shifter is in the "park" position. The system restart will take approximately 40 seconds.

The current or factory default settings can be displayed for reference by clicking the *Current* or *Factory* buttons. Clicking these buttons will populate the Specifications page with the values that are currently loaded or the original factory values for the XGV. Displaying either of these values will cause the user to lose any unsaved data. These values will not be loaded onto the XGV unless the *Restart XGV* button is clicked.

This help information is also available on the XGV System Configuration Utility by clicking the HELP button.

COMMUNICATION

The Communication configuration page provides the ability to change the parameters required to communicate with the XGV:

XGV Configuration: *Communication* Page	
Network	**IP Address:** Sets the IP Address for the XGV. If the current IP address is unknown, it can be displayed using the LCD User Interface (Described in Section 9.2). The XGV IP address must be valid and cannot be a broadcast, loopback, or multicast address. DEFAULT: 192.168.0.100 **Subnet Mask:** Sets the subnet mask for the XGV. The XGV subnet mask must be a valid subnet mask. DEFAULT: 255.255.255.0 **Gateway:** Sets the gateway for the XGV. The XGV gateway must be a valid gateway. DEFAULT: 0.0.0.0
JAUS	**JAUS Subsystem** Sets the JAUS Subsystem ID for the XGV vehicle subsystem. Limit: 1 to 254 DEFAULT: 1 **JAUS Node:** Sets the JAUS Node ID for the XGV computer. Limit: 1 to 254 DEFAULT: 1 **JAUS Heartbeat Frequency:** Sets the JAUS heartbeat frequency for the XGV. If set to zero, the periodic Report

	Heartbeat Pulse message is disabled. Limit: 0 (disable) to 20 Hz DEFAULT: 0.3 Hz **JAUS Over UDP:** Sets the JAUS transport specification for the XGV. ▪ *JUDP Not In Use*: No JUDP header is applied to JAUS messages. ▪ *AS-5669 version 1*: Outgoing broadcast messages from the XGV will use the JUDP header in AS-5669 version 1. For non-broadcast outgoing messages, the XGV will use the JUDP version detected when receiving an incoming message from the JAUS ID to which the message is destined. ▪ *JAUS01.0 (OPC/ETG)*: Outgoing broadcast messages from the XGV will use the JAUS01.0 JUDP header defined by the ETG/OPC group. For non-broadcast outgoing messages, the XGV will use the JUDP version detected when receiving an incoming message from the JAUS ID to which the message is destined. DEFAULT: AS-5669 version 1

To change the XGV Communication configuration, input or select the desired parameters, then click *Save Configurations*. Once all configurations are complete, click *Restart XGV* to load these changes onto the XGV.

NOTE: The XGV will only be able to restart if the shifter is in the "park" position. The system restart will take approximately 40 seconds.

The current or factory default settings can be displayed for reference by clicking the *Current* or *Factory* buttons. Clicking these buttons will populate the Communication page with the values that are currently loaded or the original factory values for the XGV. Displaying either of these values will cause the user to lose any unsaved data. These values will not be loaded onto the XGV unless the *Restart XGV* button is clicked.

This help information is also available on the XGV System Configuration Utility by clicking the HELP button.

7.3 Update Firmware

If a firmware update is required, TORC will provide the necessary file(s). The Firmware page of the System Configuration Utility is used to perform the update task. This page also displays the current firmware version for reference. To update the firmware, use the Browse... button to select the new firmware file(s). Then click Update. The system will update the firmware, and then restart the XGV.

NOTE: Do not unplug the Ethernet cable or turn off the XGV until the update is complete. The XGV will automatically restart itself to finalize the update. The XGV will only be able to restart if the shifter is in the "park" position. The system restart will take approximately 40 seconds.

7.4 Advanced

The Advanced page provides the ability to change the login information for the System Configuration Utility.

To change the user name and/or password:

1. Enter both the *Existing User Name* and *Existing Password*.
2. Make desired changes by entering *New User Name* and/or *New Password/Verify New Password*. If only one field (user name or password) needs to be changed, leave the unchanged field(s) blank.
3. Click *Update Login*.

NOTE: The user name and password fields are each limited to 32 characters and can be any combination of alphanumeric and/or punctuation. Spaces can NOT be used.

If the current login information is unknown, the default user name and password can be restored (user name = ByWireXGV; password = torctech) using the "RESET" command on the User Interface, for more information on this topic refer to Section 9.2. Once reset, the user will be notified and will have to close and restart the browser to log on. The user should then proceed to the Advanced page to change the default login information.

8 JAUS COMMUNICATIONS INTERFACE

The communications interface to the ByWire XGV is JAUS (Joint Architecture for Unmanned Systems) over Ethernet. JAUS is a message-based interoperability standard designed to enhance modularity, interoperability, and software and hardware reuse. The official JAUS standards documents, called the Reference Architecture and the JAUS Transport Specification, are available at www.jauswg.org and www.sae.org, respectively.

This section describes the JAUS interface for the ByWire XGV. First, a general discussion of the basics of communicating with the XGV is presented, focusing on specifics of the JAUS implementation for the XGV. Next, a series of examples illustrates common tasks. Finally, the complete message set, including standard JAUS messages, is presented.

NOTE: Users unfamiliar with JAUS are advised to consult Appendix 12.1 of this manual. This appendix presents a small amount of relevant background material about JAUS, to minimize the amount of prior knowledge required.

8.1 JAUS Interoperability

This section describes the JAUS interface of the ByWire XGV, assuming some prior knowledge of JAUS. Users unfamiliar with JAUS are advised to consult Section 12.1, JAUS Background.

The XGV operates as a JAUS node, communicating via JAUS RA version 3.3 messages. Six JAUS components run on the XGV: a Node Manager, a Primitive Driver, a Velocity State Sensor, an experimental Motion Profiles Driver, an experimental Signals Driver, and an experimental Error Manager.

Version

The XGV operates using primarily JAUS version 3.3 messages. A set of experimental messages developed by the VictorTango DARPA Urban Challenge team is also included to support features such as turn signal control that are not currently included in JAUS.

Another small set of experimental messages used by the JAUS Experimentation Task Group is also supported for discovery. These messages, which are identical to the Query Identification, Query Services, and Query Configuration messages only with different message IDs, became a de facto standard during the extended time they were in evaluation. Hence, they are included to support interoperability with historical implementations developed during this period.

Due to the backwards compatibility of version 3.3 JAUS to version 3.2 JAUS, the XGV is interoperable with most version 3.2 implementations as well as version 3.3 implementations.

Transport Specification

The XGV supports the SAE AS-5669 version 1 JUDP (JAUS-over-UDP) transport specification, which is available for purchase from SAE. No header compression or multipart messaging is supported, and the XGV can accept a maximum of five (5) JAUS messages per JUDP packet. For convenience, a simplified illustration of the packet structure for an AS-5669 version 1 JUDP packet is reproduced in the table below.

Offset	Length	Field	Interpretation/Use
0 bytes	1 byte	JUDP Version	0x01 for AS-5669 version 1
1	2	1st message header compression flags	Not used by XGV. Set to zero.
3	2	1st message length (L1)	Big Endian length of field to follow
5	L1	1st message	JAUS Message (16-byte header and data)
5+L1	2	2nd message header compression flags	Not used by XGV. Set to zero
7+L1	2	2nd message length (L2)	Big Endian length of field to follow
9+L1	L2	2nd message	JAUS message (16-byte header and data)
…			

The XGV expects to receive incoming JAUS messages at port 3794, the IANA-assigned port for JAUS, and transmits all outgoing messages to this port.

Other Transport Specifications

SAE AS-5669 is the only published transport specification for JAUS, however a prior transport specification for internal use by the standards development committee has seen wide enough use that it became an ad hoc standard. To support interoperability with these historical implementations, the XGV also supports this rudimentary transport specification, which has the following packet structure.

Legacy JAUS 1.0 Transport Packet Structure	
Section	**Interpretation**
JUDP Preamble	8 ASCII characters "JAUS01.0"
JAUS message	16-byte header and data

Finally, the XGV can be run in a mode where no transport specification is in use, and the JUDP packets contain only raw JAUS messages.

The active transport specification can be changed via the System Configuration Utility, discussed in Section 7.

Components and Messages

This section outlines the components and lists their supported messages. For full descriptions of the messages, including an explanation of their effects and contents, see Section 8.3, Message Listing.

The ByWire XGV's controller operates as a JAUS node in the XGV vehicle subsystem, running a set of six components: a Node Manager (component ID 1), a Primitive Driver (33), a Velocity State Sensor (42), an experimental Motion Profile Driver (10), an experimental Signals Driver (11), and an experimental Error Manager (12). In this document, these components are sometimes referred to by the following abbreviations: NM, PD, VSS, MPD, SigD, EM, respectively. The instance ID for all components is left as 1.

Core Messages

All of the components support a subset of the JAUS core messages. For presentation, they are grouped into functional categories.

JAUS Core Messages		
Discovery	**Input**	0x2B00 Query Identification 0x2B03 Query Services 0xD2A4 Query Identification (Experimental OPC/ETG message) 0xD2A7 Query Services (Experimental OPC/ETG message)
	Output	0x4B00 Report Identification 0x4B03 Report Services 0xD4A5 Report Identification (Experimental OPC/ETG message) 0xD4A7 Report Services (Experimental OPC/ETG message)
Event Subscription	**Input**	0x0008 Create Service Connection 0x000C Terminate Service Connection
	Output	0x0009 Confirm Service Connection 0x000C Terminate Service Connection
Control/Authority	**Input**	0x000D Request Component Control 0x000E Release Component Control 0x200D Query Component Control 0x0001 Set Component Authority 0x2001 Query Component Authority
	Output	0x000F Confirm Component Control 0x0010 Reject Component Control 0x400D Report Component Control 0x4001 Report Component Authority
Status	**Input**	0x0003 Standby 0x0004 Resume (to Ready) 0x0005 Reset 0x0006 Set Emergency 0x0007 Clear Emergency 0x2002 Query Component Status
	Output	0x4002 Report Component Status
Liveliness	**Input**	0x2202 Query Heartbeat Pulse
	Output	0x4202 Report Heartbeat Pulse
Time	**Input**	0x0011 Set Time 0x2011 Query Time
	Output	0x4011 Report Time

Node Manager (component ID 1)

The Node Manager is responsible for routing messages within the node and maintaining the node configuration.

Node Manager Messages	
Input	0x2B01 Query Configuration 0xD2A6 Query Configuration (Experimental OPC/ETG message)
Output	0x4B01 Report Configuration ▪ Listing of component IDs running on XGV node 0xD4A6 Report Configuration (Experimental OPC/ETG message) ▪ Same as Report Configuration

Primitive Driver (component ID 33)

The Primitive Driver is the low-level interface to the XGV platform, allowing control and monitoring of the throttle, brakes, steering, transmission gear, engine, fuel level, and other platform-related items. The XGV Primitive Driver supports one experimental message, for monitoring of the individual wheel speeds for the Escape platform.

Primitive Driver Messages	
Input	0x0405 Set Wrench Effort ▪ Throttle, Brake, Steer (percent) 0x0406 Set Discrete Devices ▪ Engine On/Off (Hybrid Ready-To-Run) ▪ Transmission Gear – user cannot command gear “Park”; available gears are Low, Drive, Neutral, and Reverse 0x2405 Query Wrench Effort 0x2406 Query Discrete Devices 0x2400 Query Platform Operational Data 0x2401 Query Platform Specifications 0xE22E Query Wheel Speeds (Experimental)
Output	0x4405 Report Wrench Efforts ▪ Current Throttle pedal position, Brake, Steer 0x4401 Report Platform Operational Data ▪ Fuel Level 0x4406 Report Discrete Devices ▪ Engine On/Off (Hybrid Ready-To-Run) ▪ Transmission Gear: Park, Low, Drive, Neutral, Reverse ▪ Parking Brake 0x4400 Report Platform Specifications ▪ Dimensions/specifications/description of vehicle 0xE42E Report Wheel Speeds (Experimental) ▪ 4x individual wheel speeds in m/s

NOTE: The **Set Wrench Effort** and **Set Discrete Devices** messages are ignored by the Primitive Driver if the originating component does not have control of the Primitive Driver (via the Request Control mechanism).

The XGV's Primitive Driver can be configured to execute the Propulsive Rotational Z (steering) field in the Set Wrench Effort message in two different modes.

1. Effort Steering: The command corresponds to steering effort. A value of zero does not center the wheels, only applies no steering effort.

2. Position Steering: The command corresponds to steering angle, in percent. A value of zero centers the wheels.

The wrench steering mode is configured using via the System Configuration Utility, discussed in Section 7.

Velocity State Sensor (component ID 42)

The Velocity State Sensor allows access to the on-board speed measurement from the Ford Escape. The forward speed of the vehicle is available in the Report Velocity State message as the Velocity X field.

Velocity State Sensor Messages	
Input	0x2404 Query Velocity State
Output	0x4404 Report Velocity State ▪ X vehicle velocity in m/s

Motion Profile Driver (component ID 10, experimental)

The Motion Profile Driver allows vehicle-independent closed-loop velocity and curvature control for the XGV. The current curvature trajectory (calculated from the steering angle, vehicle speed, and vehicle dimensions) is also available for query.

Motion Profile Driver Messages	
Input	0xE328 Set Motion Profile (Experimental) ▪ Array of Motions ○ Desired Velocity ○ Maximum Acceleration ○ Desired Curvature ○ Rate of Change of Curvature ○ Time Duration 0xE255 Query Curvature (Experimental)
Output	0xE455 Report Curvature (Experimental) ▪ Current Curvature Trajectory calculated from steering angle

NOTE: The **Set Motion Profile** message is ignored by the Motion Profile Driver if the originating component does not have control of the Motion Profile Driver (via the Request Control mechanism).

About Motion Profiles

The Set Motion Profile message was developed by DARPA Urban Challenge team VictorTango for use on the vehicle "Odin". This experimental message allows for closed-loop velocity and curvature control of the XGV, in a vehicle-independent fashion. Vehicle-specific attributes such as steering angle are not used, allowing the Motion Profile Driver (MPD) to incorporate effects such as understeer.

The message is structured as a list of motion commands which are executed in sequential order. The time duration field in each motion specifies how long the MPD should execute a motion, before it proceeds to the next motion in the list. If another message is received while the MPD is executing a profile, the current motion profile is overwritten and the MPD immediately starts to execute the new message, beginning with the first motion, this process is explained visually in Figure 17. If the last motion command of a motion profile message completes without receiving a new message, an error message will be set and the vehicle will come to a controlled stop.

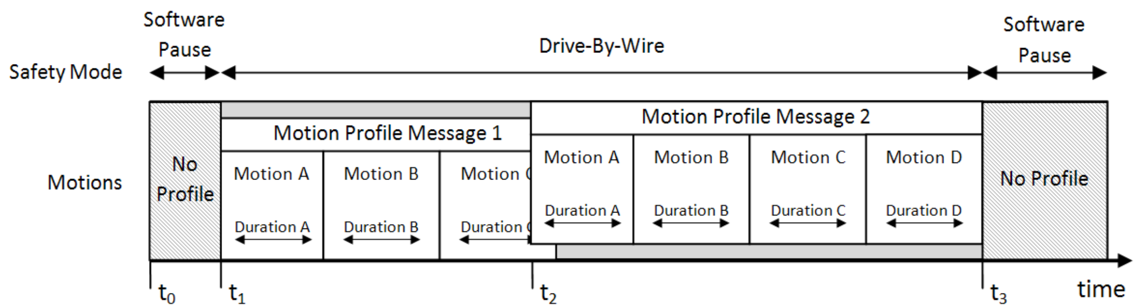


Figure 17. Motion profile execution. At time t_0, no motion profile message has arrived so the XGV safety mode is "software pause". At time t_1 the first motion profile message, MP_1, is received, the safety mode is changed to "drive-by-wire" and the MPD starts to execute it. At time t_2, MP_2 is received and the MPD immediately starts to parse and execute it. At time t_3, MP_2 expires and a new motion profile message is not received so the XGV changes its safety mode to "software pause".

The MPD achieves the command as aggressively as possible, keeping the overshoot within acceptable levels. To control how aggressively the vehicle behaves, the maximum acceleration limits the amount of acceleration the MPD can use to achieve the command. The desired velocity can be thought of as the set point, and the maximum acceleration the limit on the control effort. As shown in Figure 18, if the desired velocity is attained before the time duration expires, the MPD will hold the desired velocity for the duration of the motion.

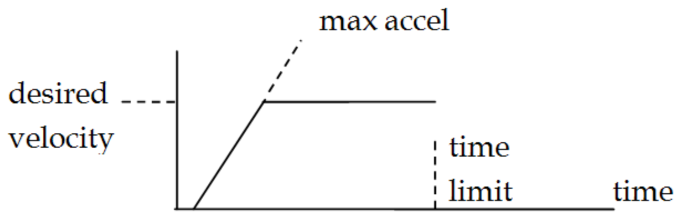


Figure 18. Motion Profile execution – speed.

Curvature is defined as the inverse of turning radius (1/m), and positive values indicate a right-hand turn. For curvature control, the MPD attempts to track the rate of change of curvature as closely as possible until the desired curvature is reached. If the desired curvature is attained before the time duration expires, the MPD will hold the desired curvature for the duration of the motion, as shown in Figure 19.

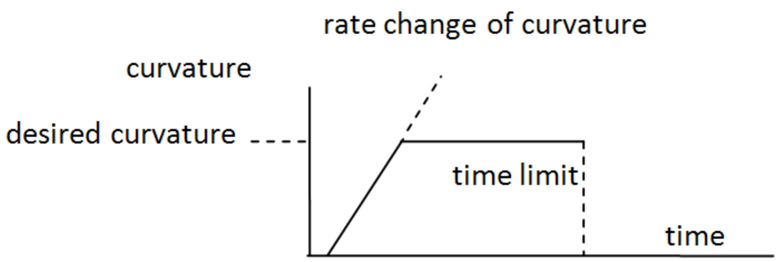


Figure 19. Motion Profile execution – curvature.

- **Guidelines for generating Motion Profiles**

The MPD will perform the best if the following rules are followed when generating motion profiles to send to the MPD.

1. Update the values of each field of the motion profile as infrequently as possible; this will allow smoother control by the MPD.
2. The speed controller is tuned to provide a comfortable ride at the expense of extreme accuracy. While on hills, in situations where vehicle operating room is constrained; more accurate, less comfortable control can be achieved by activating a secondary speed control mode. This secondary mode is automatically activated when the motion profile command conforms to the following values.
    a. The magnitude of the desired velocity is < 1.5 m/s.
    b. The desired acceleration is < 0.5 m/s^2.
3. Desired acceleration should not exceed 0.6*(desired velocity).

4. Desired acceleration should never be equal to 0.

5. Curvature is a derived value whose dynamic inputs are: wheel angle and vehicle speed; it is implemented on the XGV using the following equation:

$$Curvature = \frac{\tan\left(\frac{\theta}{1+v^2k}\right)}{wheel\ base}$$

Where θ is the steering angle (at the wheels) in radians, v is the velocity of the XGV in m/s, k is a unit-less understeer coefficient, and $wheel\ base$ is the distance from the rear axle to the front axle in meters. The value that is used for the understeer coefficient is 0.0015.

Signals Driver (component ID 11, experimental)

The Signals Driver provides control and monitoring of the audio-visual driving indicators on the ByWire XGV – the horn, turn signals, and headlights.

Signals Driver Messages	
Input	0xE322 Set Signals (Experimental) ▪ Turn Signal Status (Off / Left / Right / Flashers) ▪ Horn Status (Off / On) ▪ Headlights ○ Off / Parking Lights / On ○ High beams On/Off ○ Fog lights On/Off 0xE245 Query Signals
Output	0xE445 Report Signals (Experimental) ▪ Same as Set Signals

Error Manager (component ID 12, experimental)

The Error Manager maintains a list of all active errors and warnings in the ByWire XGV. Using the Query Error Count and Query Error messages, a control station or planner can obtain a list of the active error codes and a human-readable description of each error.

Error Manager Messages	
Input	0xE252 Query Error (Experimental) 0xE251 Query Error Count (Experimental)
Output	0xE452 Report Error (Experimental) ▪ Error Code ▪ Error Description ▪ Criticality ▪ Set/Clear ▪ Timestamp 0xE451 Report Error Count (Experimental) ▪ List of the active error codes

OTHER INTEROPERABILITY NOTES

Coordinate Frame Origin

Though it specifies coordinate frame orientation, JAUS does not specify the origin of the coordinate frame relative to the vehicle. As is common practice in Ackerman style vehicles, the XGV coordinate frame origin is at the center of the rear axle. X is forward, Y to the right, and Z down, in right-hand style.

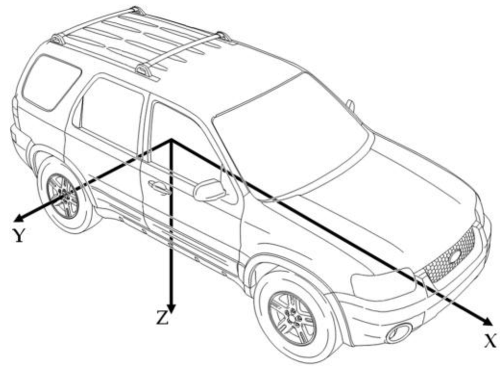


Figure 20. ByWire XGV coordinate system orientation.

Access Control

The **Set Wrench Effort**, **Set Discrete Devices**, and **Set Motion Profile** messages are ignored by the components on the XGV if the originating component does not have control (via the Request Control mechanism).

A component remains controlled until the controlling component releases control or another component subsumes control, even during communications timeouts. To clear the current controller, the component may be issued a Reset message.

To allow for possible message loss, the XGV will re-send the Confirm Component Control message if a component which already has control requests control again. This case can come up if the Confirm Component Control message never arrives to the controller, and the requestor sends another Request Component Control message even though it is already in control of the component.

Service Connections

Service connections are the preferred method of obtaining periodic information from the XGV. The following messages are available for service connections, at the given maximum update rate.

Service Connection Max Update Rates	
Node Manager	Report Component Status – 1 Hz
Primitive Driver	Report Component Control – 1 Hz Report Component Status – 5 Hz

	Report Wrench Effort – 20 Hz Report Discrete Devices – 10 Hz Report Platform Operational Data – 5 Hz Report Wheel Speeds – 50 Hz
Velocity State Sensor	Report Velocity State – 50 Hz
Motion Profile Driver	Report Component Control – 1 Hz Report Component Status – 5 Hz Report Current Curvature – 50 Hz
Signals Driver	Report Signals – 5 Hz
Error Manager	Report Error Count – 5 Hz

To allow for possible message loss, components on the XGV will re-confirm a service connection that already exists if another Create Service Connection message is received. This case can arise when the Confirm Service Connection message never arrives to the requestor, and the requestor sends another Create Service Connection message even though the service connection already exists with the provider.

Communications Timeout

In a communications timeout, there is no automated cleanup. When communications are lost, no change occurs to any service connections or component control established before the communications timeout. To clear component control and remove all service connections, components may be issued a Reset message, or the XGV controller may be rebooted.

The XGV will however enter a Software Pause if no wrench efforts are received in Wrench Effort mode, or if the current motion profile expires in Motion Profiles mode. Once commands are received again, the XGV will resume normal operation. In Manual mode, communications timeouts have no effect at all.

Discovery

The JAUS discovery protocol is implemented per JAUS version 3.3. The XGV's Node Manager produces a periodic Report Heartbeat message, sent via UDP broadcast. In typical JAUS 3.3 style, another node receiving the XGV's heartbeat could send it a Query Configuration and Query Identification message. Upon receipt of the resulting Report Identification message from the XGV, that node now has a list of the components running on the XGV, and can query the individual components for their capabilities using the Query Services message.

In order to respond to a particular JAUS ID, the XGV needs only to receive at least one JAUS message from that JAUS ID. Each time the XGV receives a message from a JAUS ID, the source IP address and JUDP version are stored in a table, and outgoing messages to that JAUS ID are sent to the same IP address, port 3794. Communications timeouts do not affect this table.

Component Status

To enhance safety and interoperability, the component status state machine implemented on the XGV treats status in a slightly different manner than some other JAUS implementations.

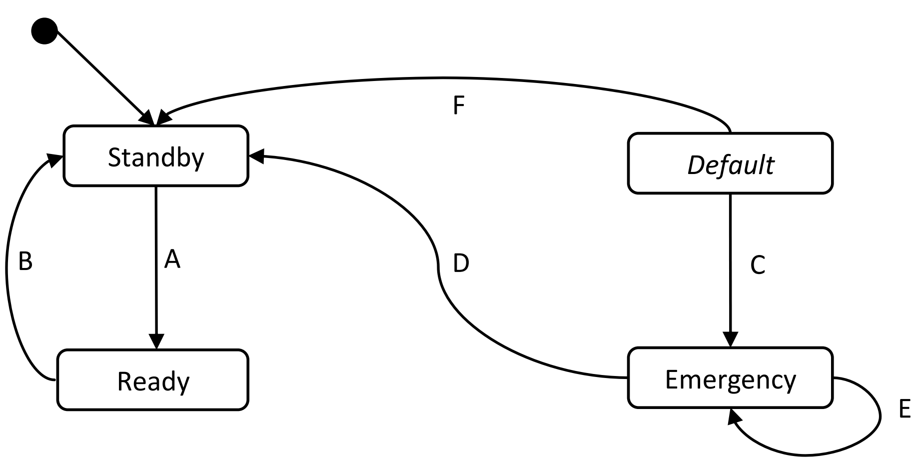
First, to enhance the safety of the XGV, a component stores the JAUS IDs of all components that have sent it a Set Emergency message. Only when every component that set an emergency has issued a Clear Emergency does the status change from Emergency. After all emergencies are cleared, the component transitions to the Standby state.

Second, the status values: Initialize, Shutdown, and Failure, have no meaning for the XGV; the status will only take on the values: Standby, Ready, or Emergency.

In addition, component control is not required to issue commands such as Standby, Resume, Reset, Set Emergency, and Clear Emergency.

The state machine describing this behavior is given below. The following notes help explain the diagram:

- The initial state of the diagram is noted with a black dot.
- States are indicated with labeled boxes.
- State transitions are indicated with labeled arrows. A transition comprises a Trigger (some event that provokes the transition), a Guard (a set of conditions that must be true to execute the transition), and an Action (a set of actions that occur in parallel with the transition).
- The "default" state is used to simplify the diagram, allowing transitions that originate from multiple states to be presented more concisely.



State Transition Table			
Label	**Trigger**	**Guard**	**Action**
A	Resume message received		
B	Standby message received		

C	Set Emergency message received	!idStored	storeId
D	Clear Emergency message received	idStored AND isOnlyStoredId	removeStoredId
E	Clear Emergency message received	idStored AND !isOnlyStoredId	removeStoredId
F	Reset message received		clearController, cancelEvents

Guard Condition Table	
Condition	**Interpretation**
idStored	True if the JAUS ID of the sender is already stored.
isOnlyIdStored	True if the JAUS ID of the sender is the only ID stored in the list.

Action Table	
Action	**Interpretation**
storeId	Store the JAUS ID of the sender in the "stored IDs" list.
removeStoredId	Remove the sender's JAUS ID from the "stored IDs" list.
cancelEvents	Cancel any active service connections and events (by sending a Terminate Service Connection message to the peer).
clearController	Clear the current controller, sending a Reject Component Control message to the current controller.

Note: The XGV's Primitive Driver component will enter Emergency when the safety mode is E-Stop Disable. Since this is accomplished via the Primitive Driver sending itself Set Emergency and Clear Emergency messages, the overall behavior is the same.

Ack/Nak

When sending a message to a component on the XGV, the JAUS Ack/Nak (Acknowledge/Not Acknowledge) field can be used to request an acknowledgement that the message was received by the component.

For the XGV, Ack/Nak is treated as a delivered/not-delivered mechanism. An ack/nak response has no bearing on whether the message is supported or not, only whether it was received. If the component is unknown to the Node Manager, it will Nak on behalf of the component.

Large Data Sets and Multi-part Messages

Since none of the input messages to the XGV can be large enough to warrant a multi-part message, the XGV will ignore any messages with the data-flags indicating the message is part of a multi-part message.

Maximum Input Message Rate

CAUTION: The XGV can accept incoming messages at a collective maximum rate of 50 Hertz. Exceeding this rate will cause unsafe delay in the system. To obtain periodic data from the XGV, service connections should be used rather than periodic queries.

Effect of Reset Message

Issuing a Reset message to a component causes the following: clear controller, send reject control, cancel all service connections, status to standby or ready.

8.2 Communication FAQs

This section answers frequently asked questions about communicating with the XGV, through examples of common interactions with the ByWire XGV.

JAUS FAQs
How do I…
…Make sure my JAUS code is communicating with the XGV There are two things to check here. First, verify that your software is receiving a Report Heartbeat Pulse message from the XGV. Second, if your software can send a query message to a component on the XGV and receive a response, the XGV has properly registered your software and is communicating with it. **NOTE**: A common mistake is to assign your software the same JAUS ID as the XGV, or to assign JAUS IDs such that the subsystem configuration does not make sense. Make sure to use unique JAUS IDs, and to implement a proper subsystem configuration.
…Obtain Information from the XGV To obtain information from the XGV, send a query message to the proper component on the XGV. For example, to obtain the fuel level, your software could send a Query Platform Operational Data message to the Primitive Driver component. The component your software queried will respond with the associated Report message, in this case Report Platform Operational Data. Your software should expect this message and parse it accordingly. **NOTE**: To obtain periodic information from the XGV, service connections are preferred over periodic queries.
…Obtain Periodic Information from the XGV To obtain periodic information from the XGV, your software should establish a service connection for the desired message. A service connection simply requests that the XGV send a particular message periodically, at a requestor-determined rate. This subscription-based method of receiving data is far more efficient than a repetitive query, as it cuts the messaging traffic by half. For more information on establishing service connections, see the FAQ below, "How do I establish a service connection for a periodic message from the XGV?"
…Figure out the current vehicle mode? Herein, we refer to three different vehicle modes: the control mode, the ready mode, and the safety mode; these modes are discussed in detail in Section 5.5. The control mode refers to the type of messages the XGV should execute – Wrench Efforts and Discrete Devices, or Motion Profiles. The ready mode is a software pause that can be commanded by user software. The safety mode refers to the current operational state of the vehicle, as controlled by the control mode, ready mode, and the safety devices such as the emergency stop and manual override. Additionally, the status of the E-Stop relays, the manual override, and other devices affecting the safety mode are available. The three modes are enforced in increasing levels of precedence: control mode, ready mode, and safety mode. For a complete flowchart illustrating the logic used to calculate these modes, see Section 5.6. *Control Mode* To switch between open loop Wrench Effort mode and closed loop Motion Profile mode, an OCU or planner requests control of either the Primitive Driver or Motion Profile Driver using the Request Control mechanism. If neither is controlled, the XGV defaults to an Unknown mode, causing a Software Pause.

NOTE: In Motion Profiles mode, the Motion Profile Driver requests control of the Primitive Driver, since the Motion Profile Driver is generating the wrench efforts and discrete devices commands for the Primitive Driver.

To determine what control mode the XGV is in, one can monitor the Report Control message of the Primitive Driver (PD) and the Motion Profile Driver (MPD) components.

- PD not controlled: Unknown, causing Software Pause
- PD controlled, not by MPD: Wrench Efforts
- PD controlled by MPD and MPD not controlled: Unknown, causing Software Pause
- PD controlled by MPD and MPD controlled: Motion Profiles

These cases are illustrated graphically in Section 5.1.

Ready Mode

Separately from the control mode, a software pause can be commanded to the XGV by commanding the component status (Initialize, Standby, Ready, Emergency, Failure) of the Primitive Driver and Motion Profile Driver components. The following rules govern this behavior:

- In Motion Profiles control mode, the MPD and PD must both be in Ready for motion to occur, or the vehicle defaults to Software Pause.
- In Wrench Effort control mode, the PD must be in Ready for motion to occur, or the vehicle defaults to Software Pause.
- On startup, the component status for the PD and MPD is Standby. Hence, a JAUS Resume message must be issued at least once to cancel the initial Software Pause.

To determine what ready mode the vehicle is in, a control station or planner can monitor the Report Component Status messages from the PD and MPD. The field to examine is the Primary Status.

Safety Mode

The safety mode is controlled by, in increasing levels of priority, the control mode, the ready mode, internal errors, and safety devices such as the emergency stop and manual override selector.

The safety mode can be determined using the information about the Safety Devices, as illustrated in the Vehicle Mode Flow Chart in Section 5.6.

Safety Devices

The safety devices that affect the safety mode can be monitored in the Report Component Status message from the Primitive Driver and the Motion Profile Driver. The status of the manual override, the E-Stop relays, and other safety devices is contained in the Secondary Status field of this message. The Status Subgroup heading in Section 8.3 describes the bit encoding for this message.

…Put the vehicle into Wrench Effort control mode

To put the XGV into Wrench Effort mode, a control station or planner should obtain control of the Primitive Driver component using the Request Control message. For a more in depth explanation of component control, see the FAQ below titled "How do I obtain control of a component on the XGV?"

To verify that the XGV is actually in Wrench Effort mode, one can monitor the Report Component Control message as described in the FAQ above titled "How do I figure out the current vehicle mode?"

Note that this only modifies the control mode. A Resume message must be issued to the Primitive Driver to affect the ready mode, and the manual override and emergency stop must be configured to set the safety mode.

…Put the vehicle into Motion Profiles control mode

To put the XGV into Motion Profile mode, a control station or planner should obtain control of the Motion Profile Driver component using the Request Control message. For a complete explanation of component control, see the FAQ below titled "How do I obtain control of a component on the XGV?".

NOTE: Because the Motion Profile Driver needs to obtain control of the Primitive Driver, the vehicle may not be in Motion Profiles mode even though the control station or planner has control of the Motion Profile Driver. In order for the Motion Profile Driver to obtain control of the Primitive Driver, anything that previously had control of the Primitive Driver must first release control. Only once the Motion Profile Driver can successfully obtain control of the Primitive Driver will the mode transition to Motion Profiles. This is illustrated graphically in Section 5.5.

To verify that the XGV is actually in Motion Profiles control mode, one can monitor the Report Component Control message as described in the FAQ above titled "How do I figure out the current vehicle mode?"

Note that this only modifies the control mode. A Resume message must be issued to the Primitive Driver and Motion Profile Driver to affect the ready mode, and the manual override and emergency stop must be configured to set the safety mode.

…Get a list of active Errors from the vehicle

The Error Manager component on the XGV maintains a list of all active errors or warnings detected. To obtain this list, a control station or planner can send the Query Error Count message to the Error Manager. The resulting Report Error Count message contains a list of all active error codes.

Subsequently, the control station or planner can use the Query Error message to request more detailed information about a particular error code in Report Error Count. The resulting Report Error message contains additional information, such as the time of the error, a severity, and a human-readable description.

In this way, a remote component, such as a Health Monitor, could maintain a list of all active errors, in the following manner:

- Establish a service connection for the Report Error Count message
- Whenever the Report Error Count message arrives, query (using the Query Error message) for any new errors that the Health Monitor does not have full knowledge of. Remove any errors that are no longer included in the Report Error Count message as they have been cleared.

…Obtain control of a component on the XGV

To obtain control of a component on the XGV, a control station or planner should send that component the Request Component Control message. When the XGV component receives this message, it will return a Confirm Component Control message indicating whether control was granted.

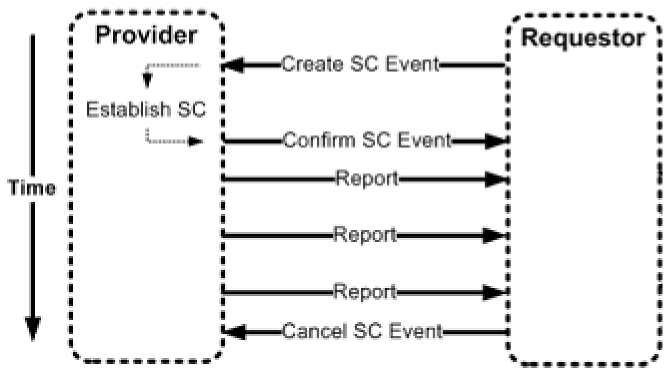
During operation, if the XGV component needs to cancel control for any reason – it was issued a "Reset", or a component with higher control authority subsumes control – a Reject Component Control message will be sent to the original controller.

A component remains controlled until the controlling component releases control via the Release Component Control message or another component subsumes control, even through communications timeouts. To clear the current controller, the component may be issued a Reset message.

To monitor whether or not the control station or planner has control of the component, it can monitor the Report Component Control message.

…Establish a service connection for a periodic message from the XGV

To obtain periodic information from the XGV, your software should establish a service connection for the desired message. A service connection simply requests that the XGV send a particular message periodically, at a requestor-determined rate, as shown below. This subscription-based method of receiving data is far more efficient than a repetitive query.



To establish a service connection, your software should send a Create Service Connection message, specifying the desired message and desired rate, to the proper component on the XGV. For example, to obtain periodic updates of the turn signal status at 5 Hz, send a Create Service Connection message for Report Signals to the Signals Driver. The XGV will reply with a Confirm Service Connection message, and the confirmed periodic rate; note that it may be lower than the requested rate. Your software should store the information contained within this Confirm Service Connection message, as well as the JAUS ID of the component that you requested the service connection from. This information will be needed later, to terminate the service connection. At this point the XGV's Signals Driver will begin sending the Report Signals message to your software at the confirmed rate. To terminate the service connection, send a Terminate Service connection message to the component, filling in the stored information from the Confirm Service Connection message. After the service connection is terminated, the XGV will discontinue sending the periodic message.
…Set the Time on the XGV Controller To set the time on the XGV controller, send a Set Time message to any of the JAUS components, described in the Time Subgroup heading within Section 8.3. The current time can be queried using the Query Time message.

8.3 Message Listing

This section lists the input and output messages for the ByWire XGV. Where a particular field is not supported by the XGV, it is indicated with a ~~strikethrough~~.

Common Elements

All JAUS messages include a 16-byte header, discussed in Section 12.1. At a minimum, a JAUS message consists of this header, and may also contain additional payload data fields if specified below.

Many JAUS messages define a timestamp as one of the data fields; the time is expressed in UTC and is encoded as indicated below.

Timestamp Definition

Field	Name	Type	Units	Interpretation
1	Time in UTC	U32 (Unsigned Integer)	n/a	Bits 0-9: milliseconds, range 0..999 Bits 10-15: Seconds, range 0..59 Bits 16 – 21: Minutes, range 0..59 Bits 22-26: Hour (24 hour clock), range 0..23 Bits 27-31: Day, range 1..31

Core Messages

The following messages are supported by all of the components running on the XGV. For presentation, the messages are divided into groups: discovery, events, control/authority, status, and liveliness. Input messages are presented first, followed by output messages.

Discovery Subgroup

The discovery messages allow for automated discovery of the capabilities, configuration, and identification of components.

- **Query Identification (code 0x2B00)**

This message can be used to request an identification summary of the subsystem, node, or component as requested in the query message. Receipt of this message causes the receiving component to respond with the Report Identification message. The experimental OPC/ETG message Query Identification has identical message encoding, only with command code 0xD2A4 experimental.

Field	Name	Type	Units	Interpretation
1	Query Type	U8 (Byte)	n/a	0: Reserved 1: System Identification 2: Subsystem Identification 3: Node Identification 4: Component Identification 5-255: Reserved

- **Query Services (code 0x2B03)**

This message can be used to request a summary of a component's capabilities. Receipt of this message causes the receiving component to respond with the Report Services message. The experimental OPC/ETG message Query Services has identical message encoding, only with command code 0xD2A7 experimental.

- **Report Identification (code 0x4B00)**

This message reports an identification summary of the subsystem, node, or component as requested in the query message. The experimental OPC/ETG message Report Identification has identical message encoding, only with command code 0xD4A5 experimental.

Field	Name	Type	Units	Interpretation
1	Query Type	U8 (Byte)	n/a	Used to mark the type of identification being reported. Copied from the original query message. 0: Reserved 1: System Identification 2: Subsystem Identification 3: Node Identification 4: Component Identification 5-255: Reserved
2	Authority	U8 (Byte)	n/a	Lowest level of authority required to gain control of component.
3	Type	U16 (Unsigned Short	n/a	This field identifies the particular Unmanned Vehicle Type, Node Type or Component Type. 10001 = Vehicle TBD
4	Identification	U8 (Byte) Array	n/a	Human-recognizable name of the subsystem, node, or component. This shall be a null-terminated ASCII string.

- **Report Services (code 0x4B03)**

This message reports a summary of a component's capabilities. The experimental OPC/ETG message Report Services has identical message encoding, only with command code 0xD4A7 experimental.

Field	Name	Type	Units	Interpretation
1	Service Count	U8 (Byte)	n/a	# of services to follow
2…	Service	Service		See Service definition below

Service Definition

Field	Name	Type	Units	Interpretation
1	Service Type	U16 (Unsigned Short)	n/a	See Service Type Table
2	Input Message Count	U8 (Byte)	n/a	# of input messages to follow
3…	Input Message	Message		See Message definition
4	Output Message Count	U8 (Byte)	n/a	# of output messages to follow
5…	Output Message	Message		See Message definition

Message Definition

Field	Name	Type	Units	Interpretation
1	Message Code	U16 (Unsigned Short)	n/a	Message code for supported message
2	Presence Vector	U32 (Unsigned Integer)	n/a	Presence vector for message code in previous field. This field is always 32 bits. For presence vectors less than 32 bits, the representative data should be inserted with matching bit significance.

Service Type	Interpretation
0	Core Message Support
1	Node Manager
10	Motion Profile Driver
11	Signals Driver
12	Error Manager
33	Primitive Driver
42	Velocity State Sensor

Note: The Service Type Table presented here is abbreviated. For a full version of the table, see JAUS RA version 3.3, Part 3.

Events / Service Connections Subgroup

These messages can be used to request and cancel service connections (periodic updates of a particular message, at a particular rate). This is the recommended way to obtain periodic data from the XGV's components.

- **Create Service Connection (code 0x0008)**

This message can be used to request a periodic update of a particular message at a particular rate. Receipt of this message causes the receiving component to respond with the Confirm Service Connection message.

Note: The presence vector field allows the requesting control station or planner to determine which data fields of the report message are included, if the report message has a presence vector in its definition.

Field	Name	Type	Units	Interpretation
1	Command Code	U16 (Unsigned Short Integer)	n/a	Command code of the message to be sent on the service connection
2	Requested Periodic Update Rate	Scaled U16 (Scaled Unsigned Short Integer)	Hz	Lower Limit = 0 Upper Limit =1092 Lower limit presented for conversion purposes only. Slowest allowable service connection is 0.016667 Hz.
3	Presence Vector	U32 (Unsigned Integer)	n/a	As defined by the specification of the command code specified in field #1

- **Terminate Service Connection (code 0x000C)**

This message can be used to cancel a periodic update of a particular message at a particular rate.

Field	Name	Type	Units	Interpretation
1	Command Code	U16 (Unsigned Short Integer)	n/a	Command code of the message being sent on the service connection
2	Instance ID	U8 (Byte)	n/a	The specific service connection for the message indicated in field #1

- **Confirm Service Connection (code 0x0009)**

This message is sent in response to the Create Service Connection message, notifying the requestor of the result. The message provides the requestor with an instance ID of the specific service connection, the confirmed periodic update rate for the service connection, and a response code. If the provider could not support the requested periodic update rate, and established the service connection at a lower rate instead, the lower, actual rate is reported.

Field	Name	Type	Units	Interpretation
1	Command Code	U16 (Unsigned Short Integer)	n/a	Command code of the message to be sent on the service connection
2	Instance Id	U8 (Byte)	n/a	Specific service connection for the message indicated in field #1

3	Confirmed Periodic Update Rate	Scaled U16 (Scaled Unsigned Short Integer)	Hz	Lower Limit = 0 Upper Limit =1092 Lower limit presented for conversion purposes only. Slowest allowable service connection is 0.016667 Hz.
3	Response Code	U8 (Byte)		Bits 0-3: 0: successful 1: node not SC capable 2: component not SC capable 3: insufficient authority 4: connection refused 5: Create SC command not supported Bits 4-7: Not used.

Control/Authority Subgroup

These messages are used for access control on the XGV. There is a subset of command messages that are ignored unless the sender has previously obtained control using the Request Control message.

- **Request Component Control (code 0x000D)**

This message is used to request exclusive control of the receiving component. If a component on the XGV is sent this message, it will respond with the Confirm Component Control message.

Field	Name	Type	Units	Interpretation
1	Authority Code	U8 (Byte)	n/a	Authority of requesting component.

- **Release Component Control (code 0x000E)**

This message is used to relinquish exclusive control of the receiving component. There are no data fields associated with this message.

- **Query Component Control (code 0x200D)**

This message can be used to figure out what component is in control of the receiving component. Receipt of this message causes the receiving component to reply with the Report Component Control message. There are no data fields associated with this message.

- **Set Component Authority (code 0x0001)**

This message sets the authority of the receiving component.

Field	Name	Type	Units	Interpretation
1	Authority Code	U8 (Byte)	n/a	0…255

- **Query Component Authority (code 0x2001)**

This message can be used to obtain the authority level of the receiving component. Receipt of this message causes the receiving component to reply with the Report Component Authority message. There are no data fields associated with this message.

- **Confirm Component Control (code 0x000F)**

This message is sent in response to Request Component Control, and notifies the receiving component of the result of the request for control.

Field	Name	Type	Units	Interpretation
1	Response Code	U8 (Byte)	n/a	Bit 0-1: 0: Control accepted 1: exclusive control not supported 2: Control not accepted Bits 2-7: Reserved

- **Reject Component Control (code 0x0010)**

This message is sent to the current controller when the originating component cancels exclusive control. Exclusive control can be cancelled if a component with higher authority requests and subsumes control, or if the component is shutdown or reset. There are no data fields associated with this message.

- **Report Component Control (code 0x400D)**

This message reports the JAUS ID of the component currently controlling a component. It is sent in response to Query Component Control. If there is no component in control, the ID fields are set to zero.

Field	Name	Type	Units	Interpretation
1	Subsystem ID of current controller	U8 (Byte)	n/a	0…254
2	Node ID of current controller	U8 (Byte)	n/a	0…254
3	Component ID of current controller	U8 (Byte)	n/a	0…254
4	Instance ID of	U8 (Byte)	n/a	0…254

	current controller			
5	Authority Code of current controller	U8 (Byte)	n/a	0…255

- **Report Component Authority (code 0x4001)**

This message reports the authority level of a component. It is sent in response to Query Component Authority.

Field	Name	Type	Units	Interpretation
1	Authority Code	U8 (Byte)	n/a	0…255

Status Subgroup

The following messages are used to control and monitor the status (Initialize, Standby, Ready, Emergency, Shutdown, Failure) of components running on the XGV. For the Primitive Driver and Motion Profile Driver, the status of the manual override, SafeStop relays, and other safety devices can also be monitored.

- **Standby (code 0x0003)**

This message transitions the receiving component to a Standby state. This command is only effective when the receiving component is in the Ready state. There are no data fields associated with this message.

- **Resume (code 0x0004)**

This message transitions the receiving component out of the Standby state. This command is only effective when the receiving component is in the Standby state. There are no data fields associated with this message.

- **Reset (code 0x0005)**

This message causes the receiving component to reinitialize. For XGV components, this amounts to booting off the current controller (sending a Reject Control), cancelling all service connections, and returning to a Standby state. There are no data fields associated with this message.

- **Set Emergency (code 0x0006)**

This message alerts the receiving component to a safety critical situation. Receipt of this message causes the receiving component to transition to the Emergency state.

NOTE: JAUS defines data fields for this message, but to enhance safety, the XGV does not examine the data fields. The receipt of a message with command code 0x0006 is sufficient to transition a component to the Emergency state.

Field	Name	Type	Units	Interpretation
1	Emergency Code	U16 (Unsigned Short Integer)	n/a	Bit 0 = Perform transition to emergency state Bits 1-16: Reserved

- **Clear Emergency (code 0x0007)**

This message notifies the receiving component that the current emergency condition is to be reset and the component shall transition out of the Emergency state, provided that all emergency conditions have been cleared. The XGV ignores the data fields in this message.

NOTE: Components on the XGV also maintain a list of all the components that issued a Set Emergency message to them. Each component that issued a Set Emergency must also issue a Clear Emergency message before the XGV component will transition from the Emergency state.

NOTE: The XGV's Primitive Driver will also enter an Emergency state when the SafeStop Disable is engaged, or one of the E-Stop buttons is engaged. Once the E-Stop is disengaged, the Emergency is cleared. Since this is achieved through the Primitive Driver sending itself Set Emergency and Clear Emergency messages, the overall emergent behavior is the same.

Field	Name	Type	Units	Interpretation
1	Emergency Code	U16 (Unsigned Short Integer)	n/a	Bit 0 = Stop Bits 1-16: Reserved

- **Query Component Status (code 0x2002)**

This message causes the receiving component to respond with Report Component Status message. There are no data fields associated with this message.

- **Report Component Status (code 0x4002)**

This message reports the status of the originating component. Four different statuses are reported: the primary status, a secondary status, and vendor-specific primary and secondary statuses. For the XGV's Primitive Driver and Motion Profile Driver, the secondary vendor status is used to report the status of the manual override, the SafeStop relays, and other safety devices.

Field	Name	Type	Units	Interpretation
1	Primary Status Code	U8 (Byte)	n/a	Bits 0-3: 0: Initialize 1: Ready 2: Standby 3: Shutdown 4: Failure

				5: Emergency Bits 4-7: Vendor use. Not used by XGV.
2	Secondary Status Code	U16 (Unsigned Short Integer)	n/a	Bits 0-15: Reserved Bits 16-31: Vendor use… see following note for XGV-specific interpretation.

The Report Status messages from the Primitive Driver and Motion Profile Driver make use of the vendor bits to report extra information that cannot be passed in JAUS, in the following manner:

- The vendor bits for the primary status are not currently in use.
- The vendor bits for secondary status indicate the following, regardless of the primary status:

Bit	Interpretation	
0 (16)	Manual override	F: disengaged, T: engaged
1 (17)	SafeStop pause relay	F: run, T: pause
2 (18)	SafeStop stop relay	F: run, T: stop
3-4 (19-20)	SafeStop link status	0: no link, 1: bypass, 2: link good
5 (21)	External E-Stop button	F: run, T: stop
6 (22)	Partial mode override: steering	F: computer control, T: manual control
7 (23)	Partial mode override: speed	F: computer control, T: manual control
8 (24)	Door/Liftgate pause	F: run, T: pause
9 (25)	Error-caused pause*	F: run, T: pause
10 (26)	Emergency manual override*	F: disengaged, T: engaged
11 (27)	Steering needs initialization*	F: initialized, T: uninitialized
12 (28)	Steering initialization waiting on user input*	F: initialized, T: user must init steering manually or press OK

* Bits 9 thru 12 are not supported in version 1.0 and 1.1 of the XGV controller firmware.

Liveliness Subgroup

- **Query Heartbeat Pulse (code 0x2202)**

This message causes the receiving component to respond with Report Heartbeat Pulse message. There are no data fields associated with this message.

- **Report Heartbeat Pulse (code 0x4202)**

This message reports that the originating component exists. There are no data fields associated with this message.

NOTE: The XGV is configured to send a periodic Report Heartbeat Pulse message. The rate can be adjusted using the described in Section 7, System Configuration Utility.

Time Subgroup

These messages can be used to set and query the system time on the XGV controller.

- **Set Time (code 0x0011)**

This message allows setting the current system time on the XGV controller.

Field	Name	Type	Units	Interpretation
1	Presence Vector	U8 (Byte)	n/a	Bits 0 and 1 correspond to fields 2 and 3 respectively
2	Time	U32 (Unsigned Integer)	n/a	Bits 0-9: milliseconds, range 0…999 Bits 10-15: seconds, range 0…59 Bits 16-21: minutes, range 0…59 Bits 22-26: hour (24h clock) range 0…23 Bits 27-31: day, range 1…31
3	Date	U16 (Unsigned Short Integer)	n/a	Bits 0-4: day, range 1…31 Bits 5-8: month, range 1…12 Bits 9-15: year, range 2000…2127 where 0 is 2000, 1 is 2001, etc.

- **Query Time (code 0x2011)**

This message causes the receiving component to respond with Report Time message.

Field	Name	Type	Units	Interpretation
1	Presence Vector	U8 (Byte)	n/a	See Set Time message

- **Report Time (code 0x4011)**

This message reports the current system time set on the XGV's computer. The encoding for this message is identical to the Set Time message.

Component-Specific Messages

The specific messages related to each component are presented below. Note that each component also supports the core messages presented above.

Node Manager

- **Query Configuration (code 0x2B01)**

This message can be used to request a configuration summary of the subsystem, or node. Receipt of this message causes the receiving component to respond with the Report Configuration message. The experimental OPC/ETG message Query Configuration has identical message encoding, only with command code 0xD2A6 experimental.

The XGV will only respond to this message if the Query Type is 3: Node Configuration.

Field	Name	Type	Units	Interpretation
1	Query Type	U8 (Byte)	n/a	0-1: Reserved 2: Subsystem Configuration 3: Node Configuration 4-255: Reserved

- **Report Configuration (code 0x4B01)**

This message reports a table of all existing components residing on the source's subsystem or node, depending on field 1 of the Query Configuration message. The experimental OPC/ETG message Report Configuration has identical message encoding, only with command code 0xD4A6 experimental.

Field	Name	Type	Units	Interpretation
1	Node Count	U8 (Byte)	n/a	# of Nodes to follow
2…	Node	Node		See Node definition

Node definition

Field	Name	Type	Units	Interpretation
1	Node ID	U8 (Byte)	n/a	Node ID of node
2	Component Count	U8 (Byte)	n/a	# of components to follow
3…	Component	Component	n/a	See Component definition

Component definition

Field	Name	Type	Units	Interpretation
1	Component ID	U8 (Byte)	n/a	Component ID of component
2	Instance ID	U8 (Byte)	n/a	Instance ID of component

Primitive Driver

➢ **Set Wrench Effort (code 0x0405)**

This message controls the throttle, brake, and steering in an open-loop mode. The fields Propulsive Linear X, Propulsive Rotational Z, and Resistive Linear X are mapped to throttle, steering, and brakes, respectively. A negative throttle command is ignored. Positive steering is to the right.

The propulsive rotational Z field (steering) can be configured via the Configuration Utility, to control either the steering position or the steering effort. In position mode, a 50% wrench would position the wheels at half the maximum steering angle for a right turn; in effort mode, a 50% wrench would continue to move the wheels to the right at half the maximum effort. The mode can be configured via the System Configuration Utility described in Section 7.

NOTE: The Primitive Driver will not accept this message unless the originator of the message has obtained control using the Request Component Control message.

Field	Name	Type	Units	Interpretation
1	Presence Vector	U16 (Unsigned Short Integer)	n/a	Indicates presence of subsequent fields: T: present, F: omitted bit 0: field 2 bit 1: field 3 bit 2: field 4 bit 3: field 5 bit 4: field 6 bit 5: field 7 bit 6: field 8 bit 7: field 9 bit 8: field 10 bit 9: field 11 bit 10: field 12 bit 11: field 13 other bits reserved
2	Propulsive Linear X (Throttle)	Scaled I16 (Scaled Short Integer)	%	Lower Limit -100 Upper limit 100
3	~~Propulsive Linear Y~~			
4	~~Propulsive Linear Z~~			
5	~~Propulsive Rotational X~~			
6	~~Propulsive Rotational Y~~			
7	Propulsive Rotational Z (Steering effort or position… see description)			
8	Resistive Linear X (Brakes)	Scaled U8 (Scaled Byte)	%	Lower Limit 0 Upper limit 100
9	~~Resistive Linear Y~~			

10	~~Resistive Linear Z~~			
11	~~Resistive Rotational X~~			
12	~~Resistive Rotational Y~~			
13	~~Resistive Rotational Z~~			

- **Set Discrete Devices (code 0x0406)**

This message controls the ready-to-run on/off state and the transmission gear. Note that because the XGV is a gas-electric hybrid, the engine on/off does not correlate to when the gasoline engine is actually running, rather correlates to whether the vehicle is "ready-to-run".

Field 2 controls the ready-to-run state. To turn the vehicle "On", set bits 0, 1, and 6 to True. To turn the vehicle off, set bit 0 or 1 to False, or 7 to True.

NOTE: The XGV will only initiate a start sequence when the auto-start bit changes from 0 to 1, and this change must occur when the safety mode is "Drive-by-wire", "Software Pause", or "E-Stop Pause", and the ignition key is in "Run". If this command is received when the safety mode is "Manual Override", "E-Stop Disable" or "Inactive", the vehicle will not turn on. In this case, once the safety mode is changed to "Drive-by-wire", "Software Pause", or "E-Stop Pause", the auto start bit must be toggled to 0 and back to 1 to re-initiate the start sequence.

Field 3 controls the parking brake and horn and is not supported by the XGV. To control the horn, use the Set Signals message. Field 4 controls the transmission gear. For safety reasons, the XGV cannot be commanded to enter Park, however, it will report when it is actually in Park. Field 5 controls the transfer case and is not supported by the XGV, since the Ford Escape does not have a Transfer Case.

NOTE: The Primitive Driver will not accept this message unless the originator of the message has obtained control using the Request Component Control message.

Field	Name	Type	Units	Interpretation
1	Presence Vector	U8 (Byte)	n/a	Indicates presence of fields: bit 0: field 2 bit 1: field 3 bit 2: field 4 bit 3: field 5
2	Main Propulsion	U8 (Byte)	n/a	Bit 0: On/Off, 1=On, 0=Off Bit 1: Main Energy / Fuel Supply: 1=On, 0=Off Bit 2: Auxiliary Energy / Fuel Supply: 1=On, 0=Off ~~Bit 3: Power to Aux Devices: 1=On, 0=Off~~ ~~Bit 4: Starter: 1=On, 0=Off~~ ~~Bit 5: Cold Start True/False~~ Bit 6: 1 = Begin Auto Start Sequence, 0 = Nothing

				Bit 7: 1 = Begin Auto Shutdown Sequence, 0 = Nothing
3	~~Parking Brake and Horn~~	U8 (Byte)	n/a	Bit 0: Parking Brake: 1=Set, 0=Release Bit 1: Horn: 1=On, 0: Off
4	Gear	U8 (Byte)	n/a	Desired Gear ~~0: Park~~. The XGV cannot be commanded into Park, and will ignore commands to enter Park. 1: Low 2-127: Drive 128: Neutral 129-255: Reverse
5	~~Transfer Case~~	U8 (Byte)	n/a	0-127: Low 128: Neutral 129-255: High

- **Query Wrench Effort (code 0x2405)**

This message instructs the receiving component (the Primitive Driver) to respond with Report Wrench Effort message. When responding, the receiving component performs a logical AND on the requested presence vector with the available presence vector bits, and the resulting Report message has the result of the operation as the presence vector.

Field	Name	Type	Units	Interpretation
1	Presence Vector	See Report Wrench Effort message	n/a	See Report Wrench Effort message

- **Query Discrete Devices (code 0x2406)**

This message instructs the receiving component (the Primitive Driver) to respond with Report Discrete Devices message. When responding, the receiving component performs a logical AND on the requested presence vector with the available presence vector bits, and the resulting Report message has the result of the operation as the presence vector.

Field	Name	Type	Units	Interpretation
1	Presence Vector	See Report Discrete Devices message	n/a	See Report Discrete Devices message

- **Query Platform Operational Data (code 0x2401)**

This message instructs the receiving component (the Primitive Driver) to respond with Report Platform Operational Data message. When responding, the receiving component performs a logical AND on the requested presence vector with the available presence vector bits, and the resulting Report message has the result of the operation as the presence vector.

Field	Name	Type	Units	Interpretation
1	Presence Vector	See Report Platform Operational Data message	n/a	See Report Platform Operational Data message

- **Query Platform Specifications (code 0x2400)**

This message instructs the receiving component (the Primitive Driver) to respond with Report Platform Specifications message. When responding, the receiving component performs a logical AND on the requested presence vector with the available presence vector bits, and the resulting Report message has the result of the operation as the presence vector.

Field	Name	Type	Units	Interpretation
1	Presence Vector	See Report Platform Specifications message	n/a	See Report Platform Specifications message

- **Query Wheel Speeds (code 0xE22E, experimental)**

This message instructs the receiving component (the Primitive Driver) to respond with Report Wheel Speeds message.

Field	Name	Type	Units	Interpretation
1	Version	U8 (Byte)	n/a	VictorTango experimental message version. Should be set to 0.

- **Report Wrench Effort (code 0x4405)**

This message reports the current throttle pedal position, brake, and steering percentages. The fields Propulsive Linear X, Propulsive Rotational Z, and Resistive Linear X are mapped to throttle, steering, and brakes, respectively. Positive steering is to the right.

NOTE: Though the Set Wrench Effort message can be configured to control steering by position or by effort, the Report Wrench Effort message always returns the steering position.

Field	Name	Type	Units	Interpretation
1	Presence Vector	U16 (Unsigned Short Integer)	n/a	Indicates presence of subsequent fields: T: present, F: omitted bit 0: field 2 bit 1: field 3 bit 2: field 4 bit 3: field 5 bit 4: field 6 bit 5: field 7 bit 6: field 8

				bit 7: field 9 bit 8: field 10 bit 9: field 11 bit 10: field 12 bit 11: field 13 other bits reserved
2	Propulsive Linear X (Throttle)	Scaled I16 (Scaled Short Integer)	%	Lower Limit -100 Upper limit 100
3	~~Propulsive Linear Y~~			
4	~~Propulsive Linear Z~~			
5	~~Propulsive Rotational X~~			
6	~~Propulsive Rotational Y~~			
7	Propulsive Rotational Z (Steering)			
8	Resistive Linear X (Brakes)	Scaled U8 (Scaled Byte)	%	Lower Limit 0 Upper limit 100
9	~~Resistive Linear Y~~			
10	~~Resistive Linear Z~~			
11	~~Resistive Rotational X~~			
12	~~Resistive Rotational Y~~			
13	~~Resistive Rotational Z~~			

- **Report Discrete Devices (code 0x4406)**

This message reports the engine ready-to-run on/off state, and the gear shifter. Note that because the XGV is a gas-electric hybrid, the engine on/off does not correlate to when the gasoline engine is actually running, rather correlates to whether the vehicle is "ready-to-run".

Field 2 describes the ready-to-run state. When the vehicle is on and ready-to-run, bits 0 and 1 are reported True; when the vehicle is in the process of turning on, bits 0, 1, and 6 are reported True; and when the vehicle is in the process of turning off, bits 0, 1, and 7 are reported True. Field 3 indicates the status of the parking brake and horn. Field 4 indicates the gear position. For safety reasons, the XGV cannot be commanded to enter Park in Drive-by-Wire mode, however will report when it is actually in Park. Field 5 indicates the status of the transfer case and is not supported by the XGV, since the Ford Escape does not have a Transfer Case.

Field	Name	Type	Units	Interpretation
1	Presence Vector	U8 (Byte)	n/a	Indicates presence of fields: bit 0: field 2 bit 1: field 3 bit 2: field 4 bit 3: field 5
2	Main	U8 (Byte)	n/a	Bit 0: On/Off, 1=On, 0=Off

	Propulsion			Bit 1: Main Energy / Fuel Supply: 1=On, 0=Off Bit 2: Auxiliary Energy / Fuel Supply: 1=On, 0=Off ~~Bit 3: Power to Aux Devices: 1=On, 0=Off~~ ~~Bit 4: Starter: 1=On, 0=Off~~ ~~Bit 5: Cold Start True/False~~ Bit 6: 1 = Auto Start Sequence In Progress, 0 = Nothing Bit 7: 1 = Auto Shutdown Sequence In Progress, 0 = Nothing
3	Parking Brake and Horn	U8 (Byte)	n/a	Bit 0: Parking Brake: 1=Set, 0=Released Bit 1: Horn: 1=On, 0: Off
4	Gear	U8 (Byte)	n/a	Transmission Gear 0: Park. 1: Low 2-127: Drive 128: Neutral 129-255: Reverse
5	~~Transfer Case~~	U8 (Byte)	n/a	0-127: Low 128: Neutral 129-255: High

- **Report Platform Operational Data (code 0x4401)**

This message reports the fuel level for the XGV.

Field	Name	Type	Units	Interpretation
1	Presence Vector	U8 (Byte)	n/a	Indicates presence of fields: bit 0: field 2 bit 1: field 3 bit 2: field 4 bit 3: field 5 bit 4: field 6
2	~~Engine Temperature~~	Scaled I16 (Scaled Short Integer)	degree Celsius	Lower Limit = -75 C Upper Limit = 180 C
3	~~Odometer~~	U32 (Unsigned Integer	meters	Cumulative distance travelled by vehicle
4	~~Battery Voltage~~	Scaled U8 (Scaled Byte)	percent	Lower Limit = 0% Upper Limit = 127%
5	Fuel Level	Scaled U8 (Scaled Byte)	percent	Lower Limit = 0% Upper Limit = 100%
6	~~Oil Pressure~~	Scaled U8 (Scaled Byte)	percent	Lower Limit = 0% Upper Limit = 127%

- **Report Platform Specifications (code 0x4400)**

This message provides the specifications of the XGV platform, including its name, dimensions, location of its center of gravity, turning radius, wheelbase, track width, static pitch and roll-over angles, and maximum velocities and angular rates the platform is capable of achieving.

NOTE: By default, the values reported in this message are for the stock XGV as provided by TORC, and do not take into account any additional equipment added by the end user. Fields 3-8 and 15-16 can be modified via the System Configuration Utility, described in Section 7.

NOTE: Fields 9-11 (location of vehicle center of gravity) are not supported by the XGV, since this standard JAUS message does not allow for negative coordinates.

Field	Name	Type	Units	Interpretation
1	Presence Vector	U32 (Unsigned Integer)	n/a	Indicates presence of fields: bit 0: field 2 bit 1: field 3 bit 2: field 4 bit 3: field 5 bit 4: field 6
2	Mobility Platform Name	String	n/a	15-character fixed-length string
3	Front	Scaled U16 (Scaled Unsigned Short Integer)	meters	Distance from vehicle origin to the bounding planes of the mobility platform. Lower Limit: 0 Upper Limit 32.767
4	Back			
5	Right			
6	Left			
7	Bottom			
8	Top			
9	~~Xcg~~	Scaled U16 (Scaled Unsigned Short Integer)	meters	Center of gravity coordinates with respect to mobility platform origin. Lower Limit: 0 Upper Limit 32.767
10	~~Ycg~~			
11	~~Zcg~~			
12	Turning Radius	Scaled U16 (Scaled Unsigned Short Integer)	meters	Minimum turning radius of platform. Lower Limit: 0 Upper Limit 65.535
13	Wheel Base	Scaled U16 (Scaled Unsigned Short Integer)	meters	Distance between foremost and aftmost axles Lower Limit: 0 Upper Limit 65.535
14	Track Width	Scaled U16 (Scaled Unsigned Short Integer)	meters	Distance between centerlines of leftmost and rightmost driving devices Lower Limit: 0 Upper Limit 65.535
15	Static Pitchover	Scaled U16 (Scaled Unsigned Short Integer)	radians	Incline angle at which mobility platform will pitch over backwards Lower Limit: 0 Upper Limit 2.56
16	Static Rollover	Scaled U16 (Scaled Unsigned Short Integer)	radians	Roll angle at which mobility platform will roll over sideways Lower Limit: 0 Upper Limit 2.56
17	Maximum velocity X	Scaled U16 (Scaled Unsigned Short Integer)	meters per second	Lower Limit = 0 Upper Limit = 65.534
18	Maximum velocity Y			

19	Maximum velocity Z			
20	Maximum roll rate	Scaled U16 (Scaled Unsigned Short Integer)	radians per second	Lower Limit = 0 Upper Limit = 32.767
21	Maximum pitch rate			
22	Maximum yaw rate			

- **Report Wheel Speeds (code 0xE42E, experimental)**

This message provides the four individual wheel speeds for the XGV, in meters per second.

Field	Name	Type	Units	Interpretation
1	Version	U8 (Byte)	n/a	VictorTango experimental message version. Should be set to 0.
2	Right Front	Scaled U16 (Scaled Unsigned Short Integer)	m/s	Lower Limit = -65.535 Upper Limit = 65.535
3	Left Front			
4	Right Rear			
5	Left Rear			
6	Timestamp	Timestamp	n/a	See Timestamp definition

Motion Profile Driver

- **Set Motion Profile (code 0xE328, experimental)**

This message is used for closed-loop velocity and curvature control, in a vehicle-independent fashion. Vehicle-specific attributes such as steering angle are not used, allowing the Motion Profile Driver (MPD) to incorporate effects such as under steer.

For a more in-depth discussion of the Set Motion Profile message and how the XGV executes motion profiles, see heading About Motion Profiles in Section 8.1.

NOTE: The Motion Profile Driver will not accept this message unless the originator of the message has obtained control using the Request Component Control message.

Field	Name	Type	Units	Interpretation
1	Version	U8 (Byte)	n/a	VictorTango experimental message version. This should be set to 1. Version 0 is supported, but is obsolete.
2	Number of Motions (N)	U8 (Byte)	n/a	# of motions to follow
3 +5n	Desired Velocity	Scaled U16 (Scaled Unsigned Short Integer)	m/s	Lower Limit = -65.535 Upper Limit = 65.535
4+5n	Maximum Acceleration (absolute value)	Scaled U16 (Scaled Unsigned Short Integer)	m/s^2	Lower Limit = 0 Upper Limit = 100

5+5n	Arctangent of Desired Curvature (see note below)	Scaled U16 (Scaled Unsigned Short Integer)	atan(1/m)	Positive values to right Lower Limit = -pi/2 Upper Limit = pi/2
6+5n	Rate of change of curvature	Scaled U16 (Scaled Unsigned Short Integer)	1/(m-s)	Lower Limit = 0 Upper Limit = 10
7+5n	Time Duration	U16 (Unsigned Short Integer	ms	Number of milliseconds until next motion

NOTE: The Desired Curvature field is encoded as the arctangent of curvature, in order to provide a more evenly distributed resolution across the scaled integer.

- **Query Curvature (code 0xE255, experimental)**

This message instructs the receiving component (the Motion Profile Driver) to respond with Report Curvature message.

Field	Name	Type	Units	Interpretation
1	Version	U8 (Byte)	n/a	VictorTango experimental message version. Should be set to 0 or 1.

- **Report Curvature (code 0xE455, experimental)**

This message reports the current curvature trajectory for the XGV. This value is calculated from the current steering angle, vehicle speed, and vehicle parameters.

Field	Name	Type	Units	Interpretation
1	Version	U8 (Byte)	n/a	VictorTango experimental message version. This should be set to 1. Version 0 is supported, but is obsolete.
2	Arctangent of Current Curvature (see note below)	Scaled U16 (Scaled Unsigned Short Integer)	atan(1/m)	Lower Limit = -pi/2 Upper Limit = pi/2
3	Timestamp	Timestamp	n/a	See Timestamp definition

NOTE: The Current Curvature field is encoded as the arctangent of curvature, in order to provide a more evenly distributed resolution across the scaled integer.

Signals Driver

- **Set Signals (code 0xE322, experimental)**

This message is used to command the audiovisual driving indicators on the XGV.

NOTE: If a component has acquired control of the Signals Driver using the Request Control messages, the Signals Driver will ignore this command unless it originates from the component that has control. If no component is in control of the Signals Driver, then the command is accepted from any component.

Field	Name	Type	Units	Interpretation
1	Version	U8 (Byte)	n/a	VictorTango experimental message version. Should be set to 0.
2	Presence Vector	U8 (Byte)	n/a	Bits 0, 1, 2 correspond to fields 3, 4-6, and 7-9 respectively
3	Turn Signal Status	U8 (Byte)	n/a	0: Off 1: Left 2: Right 3: Flashers 4-255: Reserved
4	Horn Status	U8 (Byte)	n/a	0: Off 1: On ~~2: Once (time on in field 4)~~ ~~3: Periodic (duty cycle in field 4/5)~~ ~~4-255: Reserved~~
5	~~Horn Period On~~	Scaled U8 (Scaled Byte)	seconds	Lower Limit = 0 Upper Limit = 10
6	~~Horn Period Off~~	Scaled U8 (Scaled Byte)	seconds	Lower Limit = 0 Upper Limit = 10
7	Headlights Status	U8 (Byte)	n/a	Bits 0-2: Lights Status ▪ 0: Off ▪ 1: Parking Lights ▪ 2: On ~~▪ 3: Once (time on in field 7)~~ ~~▪ 4: Periodic (duty cycle in field 4/5)~~ ~~▪ 5-7: Reserved~~ Bit 3: High beams (T:on, F:off), only on if Lights Status = 2 Bit 4: Fog lights (T:on, F:off), only on if Lights Status = 2 Bits 5-7: Reserved
8	~~Lights Period On~~	Scaled U8 (Scaled Byte)	seconds	Lower Limit = 0 Upper Limit = 10
9	~~Lights Period Off~~	Scaled U8 (Scaled Byte)	seconds	Lower Limit = 0 Upper Limit = 10

- **Query Signals (code 0xE245, experimental)**

This message instructs the receiving component (the Signals Driver) to respond with the Report Signals message. When responding, the receiving component performs a logical AND on the requested presence vector with the available presence vector bits, and the resulting Report message has the result of the operation as the presence vector.

Field	Name	Type	Units	Interpretation

1	Version	U8 (Byte)	n/a	VictorTango experimental message version. Should be set to 0.
2	Presence Vector	See Report Signals message	n/a	See Report Signals message

- **Report Signals (code 0xE445, experimental)**

  This message reports the status of the audiovisual driving indicators on the XGV. Encoding for this message is identical to the Set Signals message.

Velocity State Sensor

- **Query Velocity State (code 0x2404)**

  This message instructs the receiving component (the Velocity State Sensor) to respond with the Report Velocity State message. When responding, the receiving component performs a logical AND on the requested presence vector with the available presence vector bits, and the resulting Report message has the result of the operation as the presence vector.

Field	Name	Type	Units	Interpretation
1	Presence Vector	See Report Velocity State message	n/a	See Report Velocity State message

- **Report Velocity State (code 0x4404)**

  This message reports the current velocity state of the XGV. Only the linear X velocity is available from the XGV.

Field	Name	Type	Units	Interpretation
1	Presence Vector	U16 (Unsigned Short Integer)	n/a	Bits 0, 1, 2, 3, 4, 5, 6, 7, and 8 correspond to fields 2, 3, 4, 5, 6, 7, 8, 9, and 10, respectively.
2	Velocity X	Scaled I32 (Scaled Integer)	m/s	Lower Limit = -65.534 Upper Limit = 65.534
3	~~Velocity Y~~			
4	~~Velocity Z~~			
5	~~Velocity RMS~~	Scaled U32 (Unsigned Integer	m/s	A value indicating the validity of the velocity data Lower Limit = 0 Upper Limit = 100
6	~~Roll Rate~~	Scaled I16 (Scaled Short Integer)	rad/s	Lower Limit = -32.767 Upper Limit = 32.767
7	~~Pitch Rate~~			
8	~~Yaw Rate~~			
9	~~Rate RMS~~	Scaled U16 (Scaled Unsigned Short Integer)	n/a	Lower Limit = 0 Upper Limit = pi

10	Time Stamp	Timestamp	n/a	See Timestamp definition in Section 8.3.

Error Manager

These messages allow another component to obtain a list of active errors. For more information on how to use these messages to do this, see the FAQ titled "How do I obtain a list of the errors on the XGV?" in Section 8.2.

- **Query Error Count (code 0xE251, experimental)**

This message instructs the receiving component (the Error Manager) to respond with the Report Error Count message.

Field	Name	Type	Units	Interpretation
1	Version	U8 (Byte)	n/a	VictorTango experimental message version. Should be set to 0.
2	Reserved	U8 (Byte)	n/a	Reserved

- **Query Error (code 0xE252, experimental)**

This message instructs the receiving component (the Error Manager) to respond with the Report Error message for the desired Error.

Field	Name	Type	Units	Interpretation
1	Version	U8 (Byte)	n/a	VictorTango experimental message version. Should be set to 0.
2	Reserved	U8 (Byte)	n/a	Reserved
3	Error Code	I32 (Integer)	n/a	Desired error code to be sent in the Report Error message

- **Report Error Count (code 0xE451, experimental)**

This message reports the active error codes. This message includes only errors that are currently present.

Field	Name	Type	Units	Interpretation
1	Version:	U8 (Byte)	n/a	VictorTango experimental message version. Should be set to 0.
2	Reserved	U8 (Byte)	n/a	Reserved
3	Number of Errors	U8 (Byte)	n/a	# of Errors to follow
4…	Error	Integer	n/a	Error code for active error

- **Report Error (code 0xE452, experimental)**

This message reports a particular error that occurred.

Field	Name	Type	Units	Interpretation
1	Version	U8 (Byte)	n/a	VictorTango experimental message version. Should be set to 0.
2	Error Info	U8 (Byte)	n/a	Bit 0-1: Error Criticality 0: Warning 1: Serious Level 1 2: Serious Level 2 3: Catastrophic Bit 3-6: Reserved Bit 7: Error/No Error T: Error F: No Error
3	Reserved	U8 (Byte)	n/a	Reserved
4	Timestamp	Timestamp	n/a	Time at which the Error occurred or was cleared
5	Error code	I32 (Integer)	n/a	Error code
6	Error description	NUL-Terminated String	n/a	Description of Error

9 OPERATIONS

9.1 Safety

The ByWire XGV was designed with safety as a top priority. There are many layers of safety checks built into the firmware as well as within the hardware and the user controls.

The primary safety control for normal manned operation is the system activation key switch. If this switch is in the “0” position the XGV system is completely deactivated and the vehicle will operate in exactly the same manner as a stock Hybrid Escape. To read more about activating the system refer to Section 6.1.

The primary safety control while the system is active is the manual override selector. If the shift selector is in a position other than “neutral” the safety mode is “manual override”. This feature is extremely useful for safe and efficient testing of control code. To read more about this feature refer to Section 6.2.

CAUTION: Any time the ByWire XGV system is active, an E-Stop disable event will apply the brakes and, if configured to do so will shut off the engine. E-Stop disable events are not overridden by the manual override or emergency manual override.

Also, while the system is active, the vehicle will maintain a “software pause” state (no speed allowed, brake commanded) if any of the doors are open, or if the parking brake is applied. This feature ensures the safety of persons entering or exiting the vehicle. Once the door is closed or the parking brake disengaged, the mode will return to drive-by-wire.

NOTE: By default, an open lift gate and/or open lift glass will pause the vehicle. There is no distinction between liftgate status and liftgate glass status. If the user desires to run with the lift glass open, this option can be changed via the System Configuration Utility, described in Section 7.

As an indication of vehicle state, a warning light and warning horn are available as factory options for the XGV. If these items were purchased, and are enabled, they will alert bystanders of the current operating state.

Warning Device State		
Vehicle State (Safety Mode)	Warning Horn State	Warning Light State
E-Stop Disable	Off	Off
Emergency Manual Override	Off	Off
Manual Override	Off	Off
E-Stop Pause	Off	On
Software Pause	Off*	On
Drive-by-Wire	On	On

NOTE: The warning light and warning horn can be disabled using the System Configuration Utility. More details about the System Configuration Utility can be found in section 7.

***NOTE:** If the safety mode is software pause, and this was caused by an internal software error, the warning siren will remain on. This is to notify the user that the XGV software can clear the error and resume operation. If a software pause is commanded for any other reason, the warning siren will be off.

There are times during operation that a safety rider may wish to slow down but not necessarily place the XGV into manual override. A safety rider always has the option of pressing the brake pedal. This will add to the computer's braking decision.

CAUTION: Pressing on the brake pedal will not change the desired speed of the vehicle. If the XGV is operating in Motion Profile mode and the safety rider presses on the brake pedal (causing the actual speed to drop below the desired speed), the XGV controller will apply throttle in order to achieve the desired speed.

As long as the ByWire XGV system is active, the emergency stop circuit is live. This means that pressing an E-Stop button will always cause the brake to apply and the throttle, shifter, and steering to return to manual control. The only exception to this is that if the SafeStop receiver is placed in "bypass" mode, the user is not able to remotely trigger an emergency stop event.

A yellow emergency manual override button is located on the center console near the cup holders. Pressing this button will depower the steering, throttle, and shifting interface modules causing the control mode to revert to manual control. Furthermore, the brake actuator will retract in order to yield full braking control to the safety rider. These actions are carried out in hardware, with no software in the loop.

WARNING: Do not press the emergency manual override button if there is not a safety rider in the driver's seat. If this button has been pressed, it is not possible for the XGV software to bring the vehicle to a stop. The only ways to stop the vehicle in the event of an emergency manual override are: manually, by pressing on the brake pedal; or pressing an emergency stop button either locally, or remotely through the use of the SafeStop.

If the system activation key switch is in the "0" position, the ByWire XGV system is not active and the emergency stop circuit is not live. This is the preferred system state for transporting the vehicle. This feature ensures that an unintentional E-Stop button press does not bring the vehicle to a stop.

9.2 User Interface

The ByWire XGV utilizes Ford's in-dash Liquid Crystal Display (LCD) as a method of displaying information to the operator. The 20x2 character alpha-numeric display is a part of the Front Display Interface Module (FDIM), shown below. This display is used as a system menu for the ByWire XGV and to display any errors detected within the system.

CAUTION: Using the ByWire XGV Menu when operating the vehicle may cause distraction to the safety rider. Using this feature is only recommended when the vehicle is not moving.

STEERING INITIALIZATION

The ByWire XGV user interface is used on system startup to notify the operator if the steering feedback needs to be initialized. If initialization is required when the manual override is disengaged, the user is prompted to "PRESS OK" to begin the automatic steering initialization process. For more details about this process, see "Steering Initialization" in section 9.4.

BYWIRE XGV MENU

The ByWire XGV menu allows selection of advanced drive-by-wire (DBW) modes, displays system configuration settings, and allows the user to reset the XGV controller networking addresses to factory default values. The menu tree describing the structure of the XGV menu can be found in a table below.

ByWire XGV Menu Tree			
Menu Tree			Description
ByWire XGV MENU (PRESS OK)			
	ADVANCED MODES		
		MANUAL STEERING	Enters Manual Steering Mode
		MANUAL SPEED	Enters Manual Speed Mode

		FULL DRIVE-BY-WIRE	Resets the mode to default full drive-by-wire
		RETURN	Exits submenu
	SYSTEM INFORMATION		
		IP XXX.XXX.XXX.XXX	Displays current XGV IP address
		MSK XXX.XXX.XXX.XXX	Displays current XGV subnet mask
		JAUS ID XX.XX.XX.XX	Displays JAUS subsystem and node number
		VERSION X.X	Displays XGV Firmware version
		RESET	Resets IP address subnet mask values to factory defaults
		RETURN	Exits submenu
	EXIT MENU		Exits menu

Menu Interaction

Two methods of user interaction with this menu are available. The recommended method is to use the factory radio controls. For vehicles that do not include the factory radio, a secondary method of control exists. This method uses the multifunction switch on the steering column.

The primary method of menu interaction is using the factory radio's TUNE wheel, MENU and OK buttons. To enter the ByWire XGV menu, the MENU button should be pressed while the radio is off. A confirmation will then be displayed, requesting the user to "PRESS OK". Once the menu is active, the Tune Wheel is used to scroll through menu options and the OK button is used to select the displayed option.

Figure 21. Radio buttons use to control XGV User Interface

The secondary method of control replaces the function of the factory radio's TUNE wheel, MENU, and OK buttons with the multifunction switch on the steering column. In this method of operation, the menu button is replaced with 3 fast downward (left signal) movements of the multifunction switch. As a safety measure, the vehicle shift selector must be in "Park" for the multifunction switch to enter the menu. The OK function is replaced by pulling the switch toward the operator (flash to pass) and the TUNE wheel is replaced by upward (right signal) and downward (left signal) movements of the multifunction switch.

Figure 22. Multifunction switch, used as secondary control for the user interface

Advanced Drive-by-Wire Modes

The advanced drive-by-wire modes available for the ByWire XGV are "Manual Steering", "Manual Speed", and "Full Drive-by-Wire". The first two are partial drive-by-wire modes allowing the system developer to test individual components of their system while maintaining manual control of others. Each time the ByWire XGV system is activated, the drive-by-wire mode defaults to "Full Drive-By-Wire".

Active Systems while in Partial Modes			
System Described	**Partial Mode Selected**		
	Manual Steering	**Manual Speed**	**Full Drive-by-Wire**
Steering	Manual (steering wheel)	Drive-by-wire	Drive-by-wire
Throttle	Drive-by-wire	Manual (throttle pedal)	Drive-by-wire
Brake	Drive-by-wire	Manual (brake pedal)	Drive-by-wire
Transmission	Drive-by-wire	See Note below.	Drive-by-wire
Engine (Ready-To-Run)	Drive-by-wire	Manual / E-Stop	Drive-by-wire
SafeStop	Disable/Pause	Disable	Disable/Pause

NOTE: If partial mode "Manual Speed" is selected, the transmission gear will remain the same as it was before the "manual speed" mode was selected or the manual override was disengaged, whichever occurred more recently.

Displaying Current Configuration

System configuration settings can be viewed by selecting the "System Information" menu option. Included in this menu are the IP address, subnet mask, and JAUS subsystem and node IDs.

Resetting to Factory Defaults

The RESET option allows the user to reset the IP address and the subnet mask of the XGV to the factory default values. This option also resets the User Login Name and Password to the System Configuration Utility. To perform this function the shift selector must be in “park” or changes will not take effect. Once selected, any user set values will be lost. After resetting the IP address, subnet mask and Login information, the XGV controller will automatically reboot.

Error Reporting

At any time, if an error is detected within the ByWire XGV system, an error message will be displayed on the LCD. Once any active errors are cleared, the display will return to normal operation.

9.3 ByWire XGV Response to User Input

ByWire XGV Response to User Input	
Occurrence:	**Vehicle is turned on (ignition key is turned to “start”).**
Result:	Whether or not the XGV system is active, the vehicle will act just like a stock Ford Hybrid Escape when started. However, if the XGV system is active, the E-Stop Disable was engaged when the system was under Drive-by-Wire control, and the E-Stop Disable is still engaged, the engine will turn off when the key is released from “start” to “run”. To clear this condition, clear the E-Stop Disable before starting the engine manually.
Occurrence:	**Vehicle is turned off (ignition key is turned to “off”).**
Result:	The vehicle will shut off just as a stock Ford Hybrid Escape will. If the XGV controller is powered, the vehicle will chime reminding the user that the battery is being drained. This chime is the same as the one that Ford activates if the headlights are left on when the vehicle is turned off.
Occurrence:	**Key activation switch is turned ON to “1” position.**
Result:	Once the XGV activation key switch is turned on, the XGV controller will boot, this takes about 40 seconds. Almost immediately the individual system control modules turn on and are active. The SafeStop receiver turns on and initializes, this takes 1-2 seconds. During initialization, two separate brake system checks are performed. The first happens immediately, this is an E-Stop system brake check. The second happens when the controller finishes booting; this is a controller brake check.
Occurrence:	**Key activation switch is turned OFF to “0” position.**
Result:	The key is able to be removed from the switch. The power to all XGV components is lost. If the brake actuator was applied, it will stay applied.
Occurrence:	**Shift selector is placed in “neutral” position.**
Result:	If the XGV controller is powered and booted, the “neutral” shift lever position is used to allow computer control of the vehicle’s systems. If the shift selector is left in “neutral” for more than 1 second the computer will subsume control of the systems for which the user has granted it permission.
Occurrence:	**Shift selector is placed in any position other than “neutral”.**
Result:	The shift selector is used as a manual override for the XGV controller. If the shift selector is moved to any position other than “neutral”, full manual control will instantly be restored of all of the Ford Escape’s systems. The transmission will shift to which ever gear the shift selector indicates. **CAUTION:** The emergency Stop circuit remains live anytime the XGV system is active, this includes when the system is manually overridden. Pressing an E-stop button will cause the vehicle to stop and may turn off the engine.
Occurrence:	**“Manual steering” partial mode is selected from the user interface.**
Result:	When the manual override is disengaged (shift to “neutral”) the computer will **NOT** subsume control of the steering wheel; the user will have full manual control of vehicle steering. The computer will have control of the throttle, brake, shifter, ignition, lighting functions, and horn. For more information about placing the vehicle in a partial control mode refer to the heading: User

	Interface in Section 9.2.
Occurrence:	**“Manual speed” partial mode is selected from the user interface.**
Result:	When the manual override is disengaged (shift to “neutral”) the computer will not subsume control of the throttle or brake; it will control the steering. The computer will also have control of the lighting functions and horn. The gear is held steady as whichever gear the transmission was previously in. If the user desires to shift while in manual speed mode, he or she should manually place the shifter in the desired gear, then shift back to neutral. For more information about placing the vehicle in a partial control mode refer to the heading: User Interface in Section 9.2.
Occurrence:	**Vehicle is placed in “full drive-by-wire” mode from the user interface.**
Result:	When the shift selector is placed in the “neutral” position the computer will subsume control of the throttle, brake, steering and transmission. Also, the computer will be allowed to control the ignition, lights, and vehicle horn. For more information about placing the vehicle in a partial control mode refer to the heading: User Interface in Section 9.2.
Occurrence:	**Vehicle door is opened.**
Result:	If the XGV system is active and it is NOT in manual override; software pause mode is entered. This means that the vehicle will stop, with an acceleration of 4 m/s^2 (deceleration rate is user-configurable via the System Configuration Utility described in Section 7) and will apply 50% brake effort once the vehicle is stopped. The XGV controller will continue to issue JAUS commands to the steering, ignition, lights, and horn while the vehicle is in software pause.
Occurrence:	**Vehicle door is closed.**
Result:	If the XGV system is active and it is NOT in manual override; software pause mode was initiated when the door was open. Once the door is closed the mode will switch from software pause to drive-by-wire. This means that the most recent JAUS issued command will be executed.
Occurrence:	**Hardwired E-Stop button is pressed.**
Result:	If a hardwired E-stop button is pressed and the system activation keyswitch is in the “1” position, the brake actuator will apply 100% braking effort. The controller will also enter a disable state and command the engine to turn off if configured to do so. The throttle control will be disabled and return to manual control. The steering will return to manual control and due to vehicle dynamics the wheels will auto center, causing the path of the vehicle to straighten. Upon reset of the E-stop button the internal disable state will change to run. The engine will remain off, if it is configured to shut off during an E-Stop, but will accept JAUS commands to be turned back on. If the system activation keyswitch is in the “0” position, pressing a hardwired E-Stop button will not cause an E-Stop event.
Occurrence:	**SafeStop is placed in bypass mode.**
Result:	If the SafeStop receiver is placed in bypass mode, the user cannot influence the state of the XGV from the SafeStop transmitter. The vehicle will be allowed to transition to any mode with no intervention from the SafeStop wireless emergency stop system.

Occurrence:	**SafeStop remote Stop is commanded.**
Result:	If a "remote disable" is commanded from the SafeStop transmitter while the XGV system is active and the SafeStop is not in bypass mode, the brake actuator will apply 100% braking effort. The controller will also enter a disable state and if configured to do so, will command the engine to turn off. The throttle control will be disabled and return to manual control. The steering will return to manual control and due to vehicle dynamics the wheels will auto center, causing the path of the vehicle to straighten. Once the remote E-stop condition has been cleared (the button on the SafeStop transmitter is reset) the vehicle will remain in a disable state; this functionality is caused by the latching option on the SafeStop. To clear this state, one of the hardwired E-stop buttons must be depressed and then released after the remote E-stop condition has been cleared. Upon reset of the E-stop button the internal disable state will change to run. The engine will remain off, if it was configured to shut off, but will accept JAUS commands to be turned back on.
Occurrence:	**SafeStop remote pause is commanded**
Result:	If the XGV system is active and in use, and the SafeStop is not in bypass mode, commanding a pause on the SafeStop transmitter will cause the vehicle to enter an E-Stop Pause mode. Flipping the toggle switch on the SafeStop transmitter from "pause" to "run" will enable the XGV system to enter run mode.
Occurrence:	**Vehicle is placed in "Wrench Efforts" control mode**
Result:	Wrench Efforts mode is a mode of operation commanded via JAUS messages. This mode is a method of control in which the controlling software (usually an OCU or planner) can command a throttle percent (range of 0-100), brake percent (range of 0-100), and steering position or effort (range of -100 to 100), the transmission gear (neutral, reverse, drive, and low), the engine on/off state, as well as the turn signals, horn, and headlights. If a new Set Wrench Effort message has not been received by the XGV controller within a specified timeout, the vehicle will enter the software pause state. Refer to the "How do I Put the vehicle into Wrench Effort control mode" FAQ in Section 8.2.
Occurrence:	**Vehicle is placed in "Motion Profiles" control mode**
Result:	Motion Profiles mode is a mode of operation commanded via JAUS messages. This mode is method of control in which the controlling software (usually an OCU or planner) can command list of motions, each comprising a desired speed (m/s), desired acceleration (m/s²), desired steering curvature (1/r), desired steering rate of curvature change (Δ/r) and a timeout (ms). For a detailed explanation of the Motion Profiles definition refer to the Components and Messages heading within Section 8.1. Refer to the "How do I Put the vehicle into Motion Profiles control mode" FAQ in Section 8.2.

9.4 Steering Initialization

To attain steering feedback, the XGV system uses the steering position sensor that is stock on the Hybrid Ford Escape. If the XGV system is activated and that sensor has not yet been initialized, it will need to be done so. Once the shift selector has been moved to neutral, thus disengaging the manual override, the XGV will prompt the user (via the User Interface LCD, described in Section 9.2) to initialize the steering. Initialization can be done in the following two ways.

The steering can be initialized manually by engaging the manual override, and turning the steering wheel to right lock and then by turning back toward the left until the prompt from the user interface clears.

Secondly, the user can command the XGV to systematically initialize the steering by pressing "OK".

WARNING: The steering wheel will move quickly during initialization and is not able to be overpowered by human power. Keep hands clear of the steering wheel to avoid injury.

To allow for unmanned engine start and stop, the XGV only requires the steering initialization to be confirmed once. Once the safety rider has confirmed the first steering initialization prompt after the XGV system is activated, future initializations are automated. If the steering calibration is lost (the engine is turned off for more than approximately 3 seconds), the calibration will initiate automatically (without requiring OK to be pressed) once the engine is turned back on and the manual override is disengaged.

WARNING: Once the safety rider has confirmed the first steering initialization prompt, future steering initializations are automated and will initiate without requiring confirmation. Keep hands clear of the steering wheel to avoid injury.

If the XGV controller is rebooted, this auto-initialization is cancelled and the first prompt to appear must be confirmed by pressing OK.

9.5 Operational Notes

Miscellaneous Operational Notes
If the brake actuator is applied when the system activation key is turned to "0", it will remain applied. If the brake actuator needs to be disengaged after turning off the XGV; simply turn the system activation key back to "1" for a few seconds to allow it to retract. Once the actuator is fully retracted turn the activation key back to "0".
The vehicle cannot be programmatically started when in manual speed mode. The XGV controller cannot start the vehicle in manual speed mode because the vehicle transmission needs to be in park for the engine to start. It is not possible to shift to park in manual speed because shifting and braking control has been relinquished. To start the vehicle the safety rider must manually shift to "park", and then start the vehicle manually. Alternatively, the mode could be changed to "full drive-by-wire"; the XGV controller would then have permission to apply the brakes, shift to "park", and start the vehicle.
CAN bus communications are connected to pins on the OBDII port Plugging a commercially available OBDII reader into the OBDII port of the XGV Escape will interrupt the XGV communications backbone. Refer to the wiring diagrams in the appendix to know which pins are on the TORC CAN bus.
Upon system activation the brake module will perform two separate brake system checks. Immediately after startup of the XGV System the emergency brake system performs a brake actuator check. Approximately 40 seconds later, when the XGV controller has fully booted, the brake control system performs a

second check. Do not activate the system while the vehicle is in motion.
There are two types of Wrenches Efforts steering control. If the selected mode of operation is Wrench Effort mode, the user has the option of the commanding either effort or position. Effort mode is a command for the wheels to turn either right (values 0-100) or left (values -100-0). In effort mode, commanding a value of 0 is analogous to removing your hands from the steering wheel. Position mode allows for a specific steering angle to be commanded. In position mode, a value of -100 corresponds to left lock, 0 to center, and 100 to right lock. Effort control may be preferred if the vehicle were to be controlled through an OCU using a joystick or if the user prefers to write their own steering position controller. Position control would probably be preferred for use by a vehicle motion planner. Changing between modes is accomplished via the Configuration Utility described in Section 7. Regardless of which command mode is active for control, feedback indicates the current steering position.
Steering torque center value can be calibrated by the user. If the steering of the XGV is not balanced, it steers more easily to one direction than to the other or the closed loop steering control oscillates, it can be recalibrated. To do this, refer to the Functionality heading of section 7.2. Before recalibrating the steering make sure that the steering wheel is centered and there is nothing touching the wheel.
Manually starting the Vehicle with the XGV System active. If a safety rider desires to start the vehicle, he or she must place the shifter in the "Park" position. If an E-Stop Disable was engaged when the shifter was in the "Neutral" position, the engine may turn off immediately after the safety rider turns the engine on. To clear this condition, clear the E-Stop Disable before starting the engine manually.
XGV Controller DIP Switches need to be configured properly for proper operation. The XGV Controller located within the center console storage compartment has five DIP switches on its front panel. These switches are configured correctly upon installation. Care should be taken to not change the position of these switches. The proper position of all DIP switches is toward the passenger side of the vehicle.

9.6 Error Codes

ByWire XGV Error Codes			
Code	**Severity**	**Description**	**Explanation**
0	n/a	no error	
9101	error	steering initialization error	The steering system did not initialize correctly. It will continue attempting to initialize.
9103	error	steering comms error	XGV internal communications error
9104	error	steering feedback error	XGV internal communications error
9106	error	throttle comms error	XGV internal communications error
9107	error	speed feedback error	XGV internal communications error The XGV controller is not receiving speed feedback from the vehicle. The vehicle should be brought to a Ford Dealer for service.
9108	error	wheel speed feedback error	XGV internal communications error The XGV controller is not receiving wheel speed feedback from the vehicle. The vehicle should be brought to a Ford Dealer for service.
9109	error	brake error	Brake module did not pass its health check at system startup.
9110	error	brake comms error	XGV internal communications error
9111	error	brake reduced duty cycle	Brake actuator is experiencing more resistance than it can safely handle, duty cycle is reduced to not cause permanent damage to the system.

9113	error	shifter comms error	XGV internal communications error The XGV controller is not receiving shifter feedback from the vehicle. The vehicle should be brought to a Ford Dealer for service.
9115	error	transmission comms error	XGV internal communications error The XGV controller is not receiving gear feedback from the vehicle. The vehicle should be brought to a Ford Dealer for service.
9137	error	SafeStop comms error	XGV internal communications error
9138	error	SafeStop link loss	The wireless link between the SafeStop transmitter and receiver has been lost.
9139	error	check fuses	A fuse has been blown or removed
9143	warning	E-stop disable	The vehicle state (safety mode) is E-Stop disable
9144	warning	E-stop pause	The vehicle state (safety mode) is E-Stop pause
9145	error	power distribution comms error	XGV internal communications error
9149	error	devices comms error	XGV internal communications error
9150	error	warning horn error	The warning horn has not turned on/off within 3 seconds of being commanded to do so.
9153	error	warning light error	The warning light has not turned on/off within 3 seconds of being commanded to do so.
9156	error	warning module comms error	XGV internal communications error
9157	error	motion profiles timeout	The XGV controller has not received a new motion profile before the current profile expired.
9158	error	wrench efforts timeout	The XGV controller has not received wrench effort commands within its set timeout period.
9159	error	TORC CAN bus error	The TORC CAN bus is not operational. Make sure an OBDII reader tool is not connected to the OBDII port on the vehicle.
9160	error	Ford CAN bus error	The vehicle CAN bus is not operational. Bring the vehicle to a Ford Dealer for service.
9161	error	fuel level feedback error	XGV internal communications error. The XGV controller is not receiving fuel level feedback from the vehicle. The vehicle should be brought to a Ford Dealer for service.
9162	error	door status comms error	XGV internal communications error.
9163	error	12V Battery Voltage	The 12V battery charge is outside of its proper operating range.
9164	error	CPU Usage High	The XGV controller CPU is operating at a capacity that will cause the communications to lag. Reduce messaging demands to lower CPU usage.
9165	error	Reset to defaults failed	Resetting the IP, Subnet Mask, Gateway, and SCU Login information has failed. Try again or cycle power to the XGV using the system activation key to clear the error.
9175	warning	parking brake applied	The XGV controller will not clear a software pause until the parking brake is released.
9176	warning	door open	The XGV controller will not clear a software pause until doors are closed.
9177	warning	steering not initialized	The XGV controller will not clear a software pause until the steering is initialized.
9178	warning	not ready to run	The XGV controller will not clear a software pause until the vehicle's hybrid power plant is "ready to run".
9179	warning	restarting controller	The XGV controller is restarting. This could have been caused by the user commanding a restart for new settings to take effect, or because of an internal fatal error that forced a

			restart.
9180	warning	updating XGV controller firmware	The firmware for the XGV controller is currently being updated.

10 DEMONSTRATION OCU

10.1 Overview

The ByWire XGV ships with a simple demonstration Operator Control Unit (OCU) program that can be used to interface with the XGV controller for verification purposes. The OCU is an executable program that runs on a host computer and communicates with the XGV controller via JAUS over Ethernet. The flow of these JAUS messages is illustrated in Figure 23.

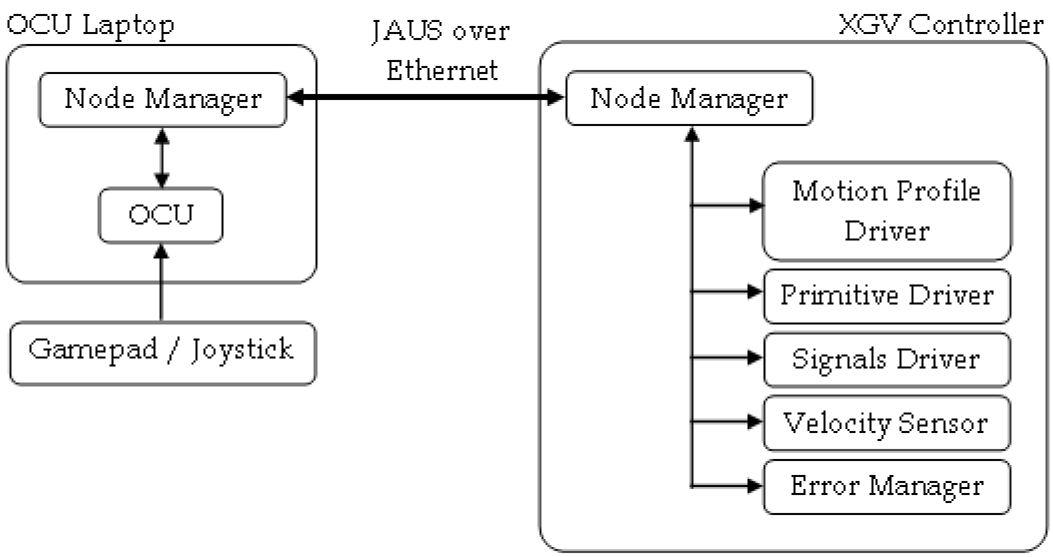


Figure 23. JAUS communications when controlled by the included OCU.

In order to run the OCU the user will need a JAUS Node Manager (included in the distribution) and a standard Ethernet crossover cable (included in the distribution). The network settings of the OCU computer need to be compatible with the settings of the XGV controller, with a unique IP that is on the same subnet. The user can interface any Windows HID compatible USB gamepad or joystick with the OCU; for convenience a USB Gamepad is included with the ByWire XGV.

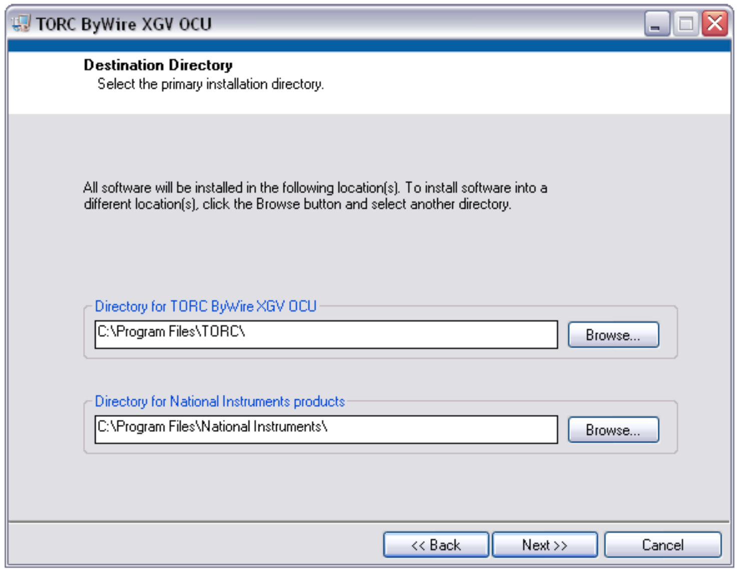
INSTALLING THE OCU PROGRAM

The installer for the XGV OCU will install the following items:

1. TORC XGV OCU.exe – the TORC XGV OCU program
2. jausNM.exe – the TORC JAUS Node Manager
3. LabVIEW Runtime Engine 8.5.1
4. Supporting files

The following steps are needed to install the previously mentioned items.

1. Select “setup.exe” in the XGV OCU Installation folder
2. Select a directory for the installation



3. Follow the various instructions on the screens that appear until the installation has completed

   You can run the XGV OCU by clicking Start->All Programs->TORC ByWire XGV OCU.

OPERATING THE OCU PROGRAM

STARTING AND STOPPING:

Run the OCU by clicking “Start -> All Programs ->TORC ByWire XGV OCU -> XGV OCU”. To stop the program simply click on the Windows “X” in the title bar. The program will close all of the necessary JAUS communications and exit.

CONNECTION STATUS:

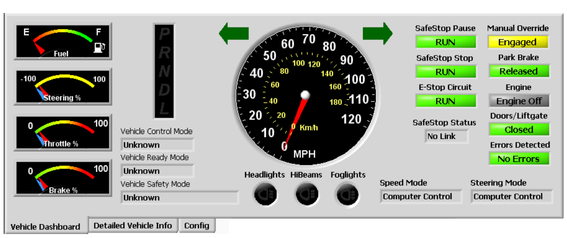


Figure 24. Vehicle Dashboard tab while a connection to the XGV is present

Figure 25. Vehicle dashboard tab while a connection to the XGV is NOT present

Once the OCU has been started, the Indications tabs will be active as shown in Figure 24. If communications with the XGV are OK, the Indications tabs will remain active. However, if there is a communications problem, the Indications tabs will be disabled and grayed out as shown in Figure 25. The Indications tabs will remain disabled and grayed out until the communications are restored. The Config page will always remain active in order to allow the user to change the OCU's settings.

LAYOUT

The OCU is composed of three separate areas, each with their own function.

Vehicle Dashboard Tab provides the majority of information to the user. The most important information regarding the vehicle function and state is presented in this tab. More specific vehicle information is located on the Detailed Vehicle Info tab located behind the Vehicle Dashboard tab. Additionally, the Config tab allows the user to modify how the joystick is used and make changes to the JAUS settings of the OCU.

Controls Tab contains the various JAUS component specific controls and related indications

Vehicle States provides both control and feedback of the JAUS commanded vehicle mode; this includes the motion profile driver and primitive driver control requests, as well as their component statuses.

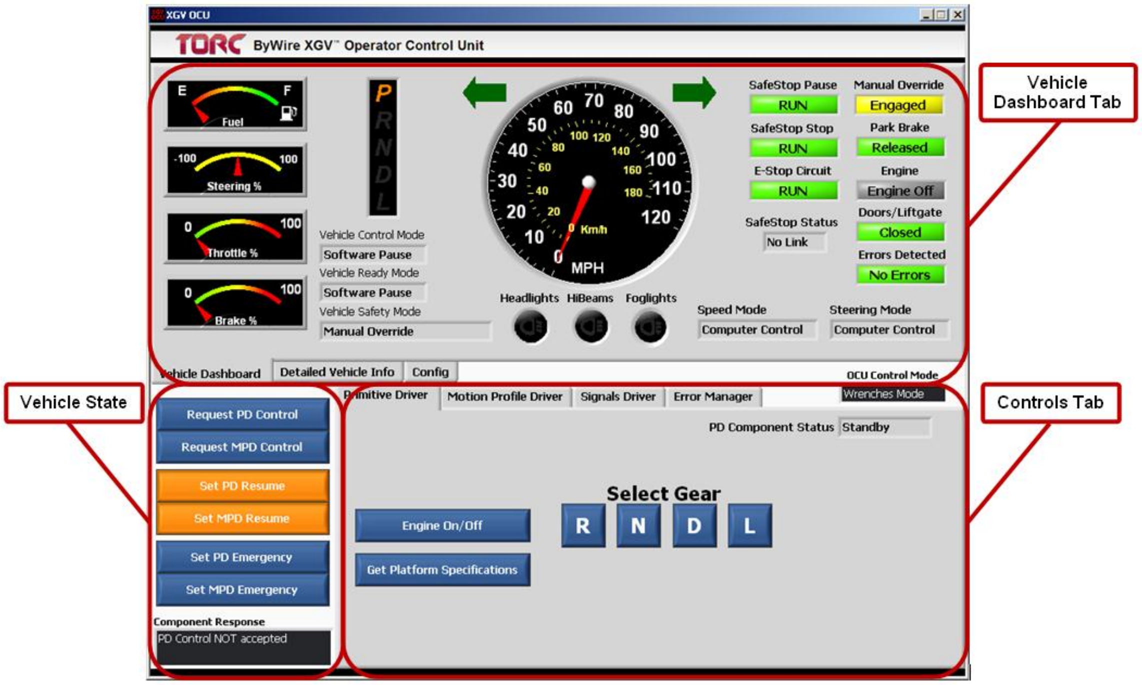
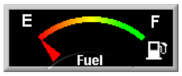
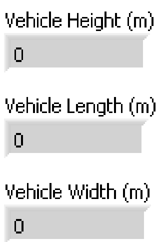
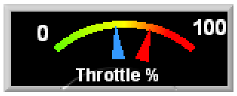
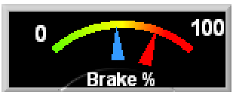
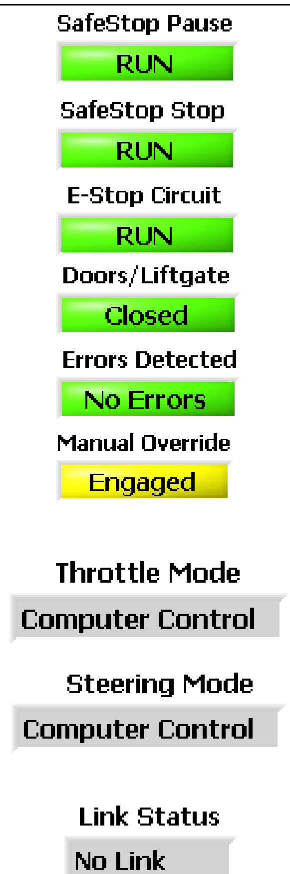


Figure 26. ByWire XGV OCU controls and indicator layout

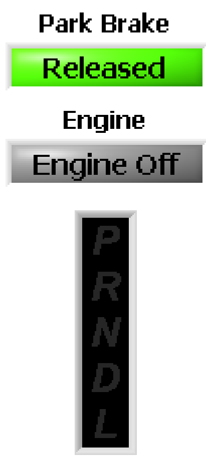
10.2 Indicator Descriptions

Indicator	Description
	**Fuel Gauge:** This indicator reports the amount of fuel on the XGV. This indicator receives its data using the JAUS report and query messages for Platform Operational Data [0x4401, 0x2401]. Using the Config Tab, the user can configure the rate this indicator is updated by varying the "rate" key within the [Platform Op Data SC] section of the configuration file. When the Report Platform Operational Data [4401h] message is received, the OCU parses the data and displays the fuel percentage. Within JAUS Report Platform Operational Data [4401h] message the fuel level is reported as a percentage with a lower limit of 0% and an upper limit of 100%.
	**Platform Specifications** The OCU uses the JAUS messages to report and query for the Platform Specifications of the XGV [0x4400, 0x2400]. Within the JAUS message Report Platform Specifications [0x4400], the OCU uses the information contained in the fields "Front", "Back", "Right", "Left", "Top", and "Bottom" to determine the XGV's dimensions according to the following formulas and displays the results in meters. *Vehicle Length = Front + Back* *Vehicle Width = Left + Right* *Vehicle Height = Top + Bottom*
	**Get Platform Specifications** When the user clicks the control "Get Platform Specifications" the JAUS message Query Platform Specifications [0x2400] is sent to the XGV.
	**Velocity Indicator** This indicator displays the vehicle speed (in miles per hour and kilometers per hour) of the XGV. This indicator receives data using the JAUS report/query messages for Velocity State [0x4404, 0x2404]. Using the Config Tab, the user can configure the rate this indicator is updated by varying the "rate" key within the [Velocity State SC] section of the configuration file. Once a Report Velocity State [0x4404] message has been received the OCU parses the report and displays the velocity in Miles per Hour. Within the JAUS message Report Velocity State [0x4404] there are a variety of items that can be used to determine the linear and rotational rates of the vehicle. The OCU displays the value of the "Velocity X" component of the Report Velocity State [0x4404] message which is represented by an integer with a lower limit of -65.534 and an upper limit of 65.534 meters per second.
	**Wrench Efforts** These indicators represent the commanded and reported Wrench Efforts. The data for these indicators is obtained using the JAUS report and query messages for Wrench Efforts [0x4405, 0x2405]. Using the Config Tab, the user can configure the rate these indicators are updated by varying the "rate" key within the [Wrench Efforts SC] section of the configuration file. The OCU will then initiate a service connection with the XGV at the corresponding "rate" from the configuration file. Once a Report Wrench Efforts [0x4405] message is received the OCU combines this information with the commanded Wrench Efforts from the joystick and displays the values on the indicators. Blue needles represent the commanded Wrench Effort (from the joystick) and the red

	needles represent the reported Wrench Effort from the XGV. Within the JAUS Wrench Effort message there are a variety of fields that can be used to command a vehicle. The OCU and the XGV make use of three of these fields: "Propulsive Linear Effort X", "Propulsive Rotational Effort Z", and "Resistive Linear Effort X". Each of these three fields has a range from -100% to 100%. The field "Propulsive Linear Effort X" is used to command throttle on the XGV and acceptable ranges are from 0% to 100%. The field "Propulsive Rotational Effort Z" is used to command steering on the XGV and has a range of -100% to 100%. Finally, "Resistive Linear Effort X" is used to command the brake on the XGV and has a range of 0% to 100%.
	**PD Component Status** The Report Component Status message [0x4002] contains information for a variety of indicators on the OCU. Using the Config Tab, the user can configure the rate these indicators are updated by varying the "rate" key within the [PD Status SC] section of the configuration file. The OCU will then initiate a service connection with the XGV at the corresponding rate from the configuration file. The status of the Primitive Driver component is reported using the JAUS Report Component Status [0x4002] message by the field "Primary Status Code" within the message. This is displayed on the OCU in the Primitive Driver tab by the PD Component Status indicator. Possible values for this indicator are Initialize, Standby, Ready, Emergency, and Shutdown.
	**Additional Status Indicators** Additional status indications are received from the XGV which make use of the "Secondary Status Code" field of the Component Status message and use the available bits 16-31. Using these bits the status of the following components are received: SafeStop Link status, Manual Override status, SafeStop Pause relay status, SafeStop Stop relay status, E-Stop circuit status, Steering Mode, Throttle Mode, and whether the liftgate or liftgate glass is causing a Pause. The exact bit encoding for this field is given under the Status Subgroup heading in Section 8.3.

Component Control

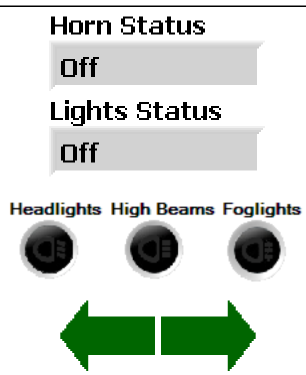
The JAUS message Request Component Control [0x000D] is used to request control of the Primitive Driver (PD) or the Motion Profile Driver (MPD). More detail on the specific controls to send this message will be discussed in the Controls section. Once the OCU has sent a Request Component Control [0x000D] message, the OCU then waits for a Confirm Component Control [0x000F] message to be received. In the lower left corner of the OCU the indicator "Component Response" will show the result of sending the Request Component Control [0x000D] message. Possible values are PD Control Accepted, PD Control Not Accepted, PD Exclusive Control Not Supported, MPD Control Accepted, MPD Control Not Accepted, and MPD Exclusive Control Not Supported.



Discrete Devices

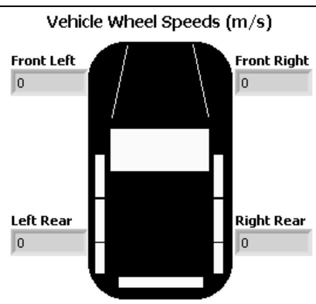
The JAUS report and query Discrete Devices messages [0x4406, 0x2406] are used to provide the user with information regarding the actual transmission gear of the XGV, the state of the engine on the XGV, and the parking brake status on the XGV. The indicators and the interpretation of the message and the displayed result are located in the table below.

Interpretation	Possible Values
On/Off (Hybrid "ready-to-run")	F: Engine OFF, T: Engine ON
Parking Brake Status	F: Released, T: Engaged
Current Transmission Gear	0 = Park 1 = Low 2,… 127 = Drive 128 = Neutral 129,… 255 = Reverse



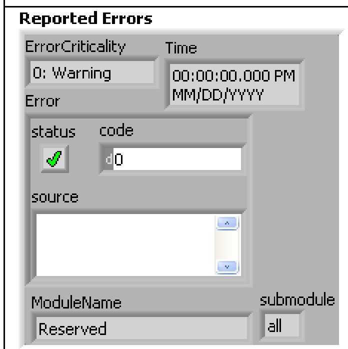
Signals

The TORC experimental messages Report and Query Signals [0xE445, 0xE245] are used to display information about the signals and indicators on the XGV. These include the status of the headlights, parking lights, the XGV's horn, and the status of the turn signals. The following are the indicators for the Signals messages. Using the Config Tab, the user can configure the rate these indicators are updated by varying the "rate" key within the [Signals SC] section of the configuration file. The OCU will then initiate a service connection with the XGV at the corresponding rate from the configuration file. Upon receipt of the Report Signals [0xE445] message the OCU parses the data and updates the indicators accordingly.



Wheel Speeds

The wheel speeds are reported in meters per second. Using the Config Tab, the user can configure the rate the wheel speed indicators are updated by varying the "rate" key within the [Wheel Speeds SC] section of the configuration file. The OCU will then initiate a service connection with the XGV at the corresponding rate from the configuration file. Once a service connection is established with the XGV, the vehicle will respond with the experimental JAUS message Report Wheel Speeds [0xE42E]. The OCU then parses the report and displays the data contained in the message.

	**Error Codes** The "Error Codes" indicator displays the error codes currently active on the XGV. Using the Config Tab, the user can configure the rate these indicators are updated by varying the "rate" key within the [Error Count SC] section of the configuration file. The OCU will then initiate a service connection with the XGV at the corresponding rate from the configuration file. These codes are reported as integers and can be further expanded upon by sending a query to the XGV with the code using the Query Error Code message.
	**Reported Errors** The reported errors indicator relays detailed information about a specific error code to the user. This information is requested by using the "Send Error Query" and "Query Error Code" controls which are described in the OCU Controls section. This indicator is updated when the user clicks the "Send Error Query" control and sends the Query Error Code message [0xE252] to the XGV. The XGV then responds with the Report Error message [0xE452] which contains detailed information about a specific error code.
	**OCU Mode** During operation the OCU maintains a value for its "mode" which controls how information from the joystick is interpreted and sent to the XGV. To control the mode of the OCU, the tab pages on the front panel are used. When the "Primitive Driver" page is the frontmost page, the OCU will be in "Wrenches Mode". Joystick commands for throttle and steering will be sent as Wrench Efforts and component controls will be sent to the Primitive Driver component. When the tab page shows "Motion Profile Driver" as the frontmost page, the OCU will be in "Motion Profiles Mode". Joystick commands for throttle and steering will be sent as Motion Profiles and component controls will be sent to the Motion Profile Driver component. The other pages have no effect on the OCU mode. The OCU Mode indicator serves as a quick way to understand what mode the OCU is currently in.
	**Communications Timeout** The communication timeout indicator is used to indicate communications troubles between the XGV and the OCU. This image is what will appear when the OCU is experiencing a problem with communicaions. When communications are working properly this indicator will not be visible. This indicator is controlled by monitoring for the Report Component Status message [0x4002] from either the Primitive Driver component or the Motion Profile Driver component. If the OCU has not received a Report Component Status message [0x4002] within 1000 milliseconds this indicator will appear.
	**Vehicle Control Mode** This indicator shows the Control Mode of the vehicle – whether the vehicle will execute Wrench Efforts and Discrete Devices, or Motion Profiles. It is calculated using the Report

	Component Control messages from the Primitive Driver and Motion Profile Driver, as described under the Control Mode heading in Section 5.5. Possible values for this indicator are: Unknown, Wrench Efforts, Motion Profiles, and Software Pause.
Vehicle Ready Mode Software Pause	**Vehicle Ready Mode** This indicator shows the current Ready Mode of the vehicle. The value is calculated using the control mode (above) and the Report Status messages from the Primitive Driver and Motion Profile Driver, as described under the Status Subgroup heading in Section 5.5. Possible values are: Unknown, Software Pause, and Ready.
Vehicle Safety Mode Manual Override	**Vehicle Safety Mode** This indicator shows the current Safety Mode of the vehicle. The value is calculated using the Report Status messages from the Primitive Driver, and the control mode and ready mode, according to the flowchart in Section 5.6. Possible values are: Unknown, Software Pause, Drive-by-Wire, E-Stop Pause, E-Stop Disable, Emergency Manual Override, and Manual Override.

10.3 Using the OCU

DASHBOARD TAB

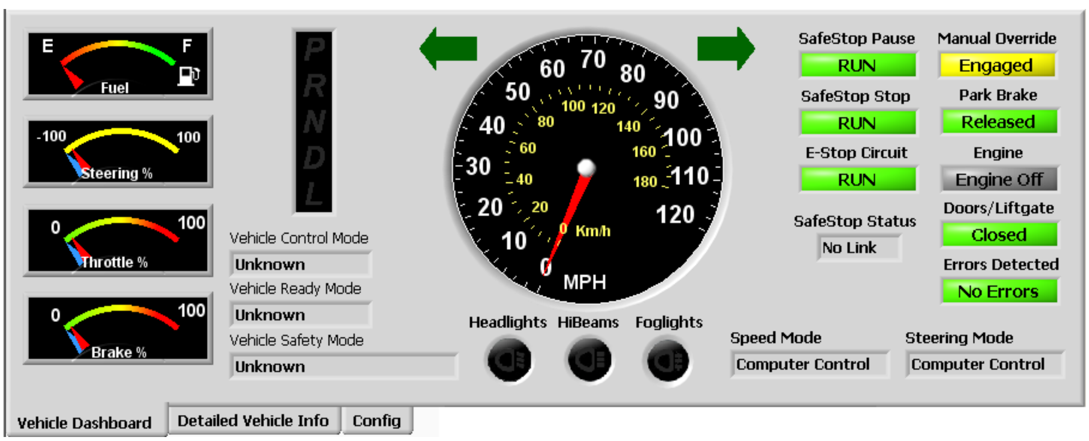


Figure 27. Dashboard tab: used to indicate the state of the XGV.

TheVehicle Dashboard Tab provides the user with the majority of information from the XGV regarding the state of the system.

VEHICLE STATE SECTION

The controls within the vehicle state section are used to set component states and request/release control of the Primitive Driver and Motion Profile Driver components on the XGV. When the user clicks these controls a corresponding JAUS message is sent to the XGV. This process is detailed in the Controls and Indicators listing section. The figures below show the default state of the controls, Figure 1, and the controls after they have been selected, shown in Figure 2. In addition to the user being able to change the state of the control, the OCU will alter the state of the controls based on the component status reported by the XGV. These cases are described below.

Component Controls:

Figure 28. Component Controls (default)

Figure 29. Component Controls (user selected)

- If the request PD control has been clicked by the user and is in the state shown in Figure 29, it will remain in this state while the OCU has control of the Primitive Driver component. If the XGV loses control of the Primitive Driver component for any reason the control will revert to its default state shown in Figure 28. This action is controlled by the information contained in the JAUS message Report Component Control [0x400D]. The OCU compares the JAUS ID of the OCU to the Controller ID reported by the Report Component Control message.
- If the request MPD control has been clicked by the user and is in the state shown in Figure 29, it will remain in this state while the OCU has control of the Motion Profile Driver component. If the XGV loses control of the Motion Profile Driver component for any reason the control will revert to its default state shown in Figure 28. This action is controlled by the information contained in the JAUS message Report Component Control [0x400D]. The OCU compares the JAUS ID of the OCU to the Controller ID reported by the Report Component Control message.
- The Set PD Standby control is normally in the state shown in Figure 28. However, if the XGV reports that the Primitive Driver component is in a standby state the control will be automatically changed to the state shown in Figure 29. This action is controlled by the information contained in the JAUS message Report Component Status [0x4002]. The OCU uses the Primary Status value to determine the current state of the Primitive Driver.
- The Set MPD Standby control is normally in the state shown in Figure 28. However, if the XGV reports that the Motion Profile Driver component is in a standby state the control will be automatically changed to the state shown in Figure 29. This action is controlled by the information contained in the JAUS message Report Component Status [0x4002]. The OCU uses the Primary Status value to determine the current state of the Motion Profile Driver.
- The Set PD Emergency control is normally in the state shown in Figure 28. However, if the XGV reports that the Primitive Driver component is in an emergency state the control will be automatically changed to the state shown in Figure 29. This action is controlled by the

information contained in the JAUS message Report Component Status [0x4002]. The OCU uses the Primary Status value to determine the current state of the Primitive Driver.

- The Set MPD Emergency control is normally in the state shown in Figure 28. However, if the XGV reports that the Motion Profile Driver component is in an emergency state the control will be automatically changed to the state shown in Figure 29. This action is controlled by the information contained in the JAUS message Report Component Status [0x4002]. The OCU uses the Primary Status value to determine the current state of the Motion Profile Driver.

CONFIG TAB

Figure 30. Configurations Tab: used to configure the joystick for the XGV OCU

The Config Tab allows the user to control all the configuration settings of the OCU. Within the Config Tab are two other tabs, Joystick Settings, and OCU JAUS Settings. From the Joystick Settings tab, the user can change the function of each button of the joystick (button map), set the throttle and steering analog axes, and configure how these axes are interpreted (axis settings). Using the section “OCU JAUS Settings” allows the user to edit the JAUS IDs the OCU will send messages to, modify the rates of the service connections, enable/disable the service connections, and configure how the OCU communicates with the Node Manager.

CONTROLS TAB

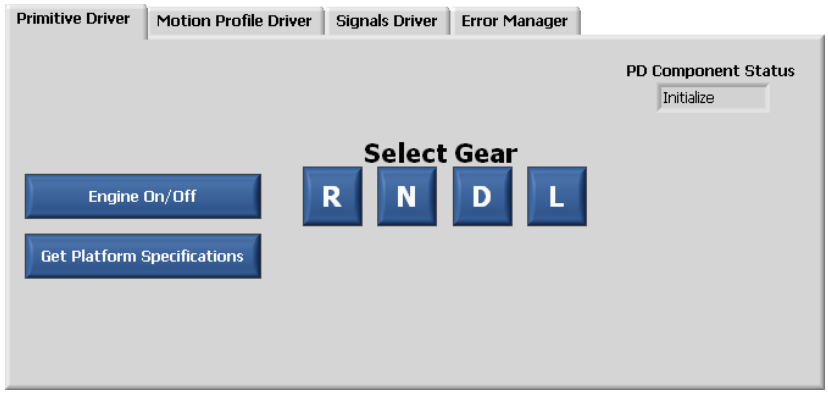


Figure 31: Primitive Driver tab indicates wrenches mode

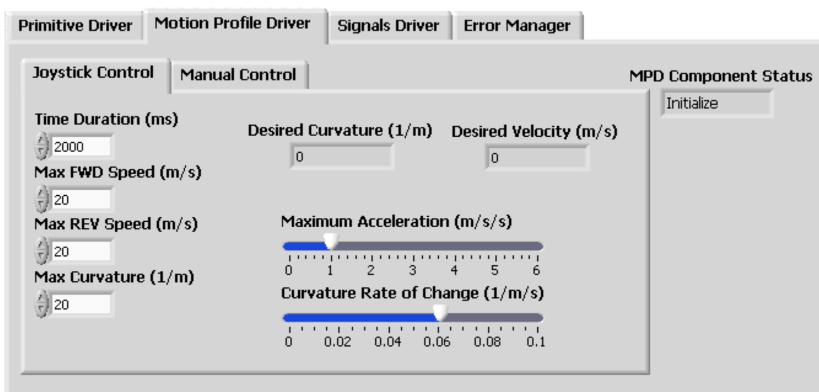


Figure 32: Motion Profile Tab indicates motion profiles mode

When sending motion commands to the XGV the OCU can operate in two modes: Wrenches Mode and Motion Profiles Mode. The mode of the OCU is controlled based on what page of the Controls Tab is currently active. When the user selects the “Primitive Driver” page the OCU will change its mode to Wrenches Mode. Alternately, when the user selects the “Motion Profile Driver” page the OCU will change its mode to Motion Profiles Mode. The other pages have no effect on the mode of the OCU. By changing the mode of the OCU the interpretation of the commands from the joystick are changed. When the OCU is in Wrenches Mode the joystick can be used to wrench efforts to the XGV and when the OCU is in Motion Profiles mode the joystick can be used to send motion profiles to the XGV. It should be noted, however, that the user must have control of the respective component in order to send commands to the Primitive Driver or Motion Profiles Driver components on the XGV.

Additionally, the control mode will also affect what address some JAUS messages are sent to. Based on the control mode of the OCU, certain joystick buttons will send JAUS messages to the Primitive Driver component or the Motion Profile Driver component. These buttons include: Request/Release Control, Set/Clear Emergency, and Resume/Standby. When in Wrenches mode, the messages for these buttons will be sent to the Primitive Driver component and when in Motion Profiles mode the messages will be sent to the Motion Profile Driver Component.

GAMEPAD OR JOYSTICK

Figure 33. Button layout for the gamepad included with the XGV distribution.

Button Descriptions: Below is a table describing the default button map for the gamepad buttons

Button #	Function
1	Gear: Drive
2	Gear: Low
3	Gear: Neutral
4	Gear: Reverse
5	Resume/Standby
6	Set Emergency/Clear Emergency
7	Left Turn Signal Set/Clear
8	Right Turn Signal Set/Clear
9	Horn
10	Hazard Lights
11	Request/Release Component Control
12	Engine On/Off
D-Pad up	Shifts Gear in order: R, N, D, L
D-Pad down	Shifts Gear in reverse order: L, D, N, R

Button Function Descriptions:

Button Function	Functionality Description
Gear: Drive	This function allows the user to control the commanded gear sent to the XGV. When the button is pressed the OCU will send the JAUS message Set Discrete Devices [0x0406] with the gear set to 2.

Gear: LOW	This function allows the user to control the commanded gear sent to the XGV. When the button is pressed the OCU will send the JAUS message Set Discrete Devices [0x0406] with the gear set to 1.
Gear: Reverse	This function allows the user to control the commanded gear sent to the XGV. When the button is pressed the OCU will send the JAUS message Set Discrete Devices [0x0406] with the gear set to 129.
Resume/Standby	Pressing this button will cause the OCU to send the JAUS message Resume [0x0004] or Standby [0x0003] alternately. The component the message is sent to varies depending on the OCU Control Mode. If in Wrenches Mode the message will be sent to the Primitive Driver component and if the OCU is in Motion Profiles Mode the message will be sent to the Motion Profile Driver component.
Set Emergency/Clear Emergency	Pressing this button will cause the OCU to send the JAUS message Set Emergency [0x0006] or Clear Emergency [0x0007] alternately. The component the message is sent to varies depending on the OCU Control Mode. If in Wrenches Mode the message will be sent to the Primitive Driver component and if the OCU is in Motion Profiles Mode the message will be sent to the Motion Profile Driver component.
Left Turn Signal Set/Clear	Pressing this button will cause the OCU to send the JAUS experimental message Set Signals [0xE322] to turn the left turn signal ON. Pressing the button a second time will send a message to turn the left turn signal OFF.
Right Turn Signal Set/Clear	Pressing this button will cause the OCU to send the JAUS experimental message Set Signals [0xE322] to turn the right turn signal ON. Pressing the button a second time will send a message to turn the right turn signal OFF.
Horn	Pressing this button will cause the OCU to send the JAUS experimental message Set Signals [0xE322] to turn the horn ON. Releasing the button will send the message to turn the horn OFF.
Hazard Lights	Pressing this button will cause the OCU to send the JAUS experimental message Set Signals [0xE322] to turn the hazards ON. Pressing the button a second time will send a message to turn the hazards OFF.
Request/Release Component Control	Pressing this button will send the JAUS message Request Control [0x000D] and Release Control [0x000F] alternately. The component the message is sent to varies depending on the OCU Control Mode. If in Wrenches Mode the message will be sent to the Primitive Driver component and if the OCU is in Motion Profiles Mode the message will be sent to the Motion Profile Driver component.
Engine On/Off	Pressing this button will send the JAUS message Set Discrete Devices [0x0406] message to turn the engine on, main energy/fuel on, and begin the auto start sequence. Pressing the button again will send the JAUS message Set Discrete Devices [0x0406] to turn the engine off, main energy/fuel off, and begin the auto shutdown sequence.

NOTE: When using controllers from different manufacturers, the button numbers may change. The user has the ability to remap the controls of each button function to a button of their choosing.

11 BYWIRE XGV SYSTEM SPECIFICATIONS

11.1 Vehicle Platform Specifications

Physical Dimensions

Wheelbase:	103/2.62	inches / meters	
Front Tread:	61 / 1.55	inches / meters	
Rear Tread:	60 / 1.52	inches / meters	
Turning Radius:	18.3 / 5.58	feet / meters	
Exterior Length:	174.7 / 4.44	inches / meters	
Exterior Width:	71.1 / 1.81	inches / meters	
Exterior Height:	67.7 / 1.72	inches / meters	

Vehicle Weight and Ratings

Gross Vehicle Weight Rating:	4,720 / 2,141	pounds / kilograms	Awd
	4,680 / 2,123	pounds / kilograms	Fwd
Curb Weight:	3,794 / 1,721	pounds / kilograms	Awd
	3,638 / 1,650	pounds / kilograms	Fwd
Front Gross Axle Weight Rating:	2,440 / 1,107	pounds / kilograms	Awd
	2,380 / 1,080	pounds / kilograms	Fwd
Rear Gross Axle Weight Rating:	2,255 / 1,023	pounds / kilograms	Awd
	2,175 / 987	pounds / kilograms	Fwd
Payload:	1,000 / 454	pounds / kilograms	Awd
	1,040 / 472	pounds / kilograms	Fwd

Vehicle Mounting Volumes

Interior Cargo Volume:	27.8 / 0.787	$feet^3$ / $meter^3$
Interior Cargo Vol w/ seat folded:	66.0 / 1.869	$feet^3$ / $meter^3$

Vehicle Power Specifications

Front Power Point

Voltage:	12V DC nominal
Fuse Rating:	20 Amps
Switching:	Always on

Rear Power Point

Voltage:	12V DC nominal
Fuse Rating:	20 Amps
Switching:	Always on

A/C Power Point

Voltage:	110V AC nominal
Power Capacity:	150 Watts
Switching:	On in “acc” and “run”

11.2 ByWire XGV Controller Specifications

Steering Control

Closed Loop Control

Max Steering Command (Curvature):	0.20	1/meters
Max Steering Command (Curvature Rate):	0.235	1/meters/second
Steering Command Resolution (Curvature):	0.00005	1/meters
(at wheels, at 0 m/s):	0.0072	degrees
(at wheels, at 46 m/s):	0.030	degrees
Maximum Capable Curvature:	0.22	1/meters

Open Loop Control

Max Steering Command:	100	% Steering Range
Min Steering Command:	-100	% Steering Range
Steering Command Resolution:	0.003	% Steering Range

Speed Control

Closed Loop Control

Maximum Speed in forward direction:	46	meters/second
Maximum Speed in reverse direction:	10	meters/second
Maximum Acceleration in forward direction:	3	meters/second^2
Maximum Deceleration in forward direction:	9	meters/second^2
Maximum Acceleration in reverse direction:	2.7	meters/second^2
Maximum Deceleration in reverse direction:	3.7	meters/second^2

Open Loop Control

Maximum Throttle Command:	100	% Throttle Range
Throttle Command Resolution:	0.5	% Throttle Range
Maximum Brake Command:	100	% Braking Range
Brake Command Resolution:	0.5	% Braking Range
Gear Command:	gear	R, N, D, L

Data Feedback

Throttle Position	
Brake Position	(open & closed loop control)
Brake Master Cylinder Pressure Signal	(manual control)
Steering Angle	
Transmission Gear	
Vehicle Speed	
Individual Wheel Speed	
Parking Brake	
Headlights	
Parking Lights	
Turn signals	
Hazards	
Fog Lights	
Horn	
Door Ajar	
Fuel Level	
12V Battery Voltage	

11.3 JAUS message maximum frequencies and latencies

The messaging rates on the XGV are configurable via the service connections within JAUS, for information on service connections refer to the "How do I Obtain Periodic Information from the XGV" FAQ in Section 8.2. The table below indicates the maximum theoretical amount of latency in the data and the available update rate for the message. For example, when the XGV sends a Report Wheel Speed message, the data is up to 11 ms old.

During operation, latencies actually experienced will vary and will realistically be lower than the maximum values indicated.

Frequency (Hz)	Max Latency (ms)	Message Name	Data Included in Message
20 Hz		**Report Wrench Efforts**	
	50		Current Throttle, Brake
	16		Current Steer
5 Hz		**Report Platform Operational Data**	
	70		Fuel Level
10 Hz		**Report Discrete Devices**	
	50		Engine On/Off (Hybrid Ready-To-Run)
	100		Transmission Gear: Park, Low, Drive, Neutral, Reverse
	50		Parking Brake
on demand		**Report Platform Specifications**	
	n/a		Dimensions/specifications/description of vehicle
50 Hz		**Report Wheel Speeds (Experimental)**	
	11		4x individual wheel speeds in m/s
50 Hz		**Report Velocity State**	
	16		Vehicle velocity in m/s
50 Hz		**Report Curvature (Experimental)**	
	11		Current Curvature Trajectory calculated from steering angle
5 Hz		**Report Signals (Experimental)**	
	50		Turn Signal Status (Off / Left / Right / Flashers)
	50		Horn Status (Off / On)
			Headlights
	50		Off / Parking Lights / On
	50		High beams On/Off
	50		Fog lights On/Off
on demand		**Report Error (Experimental)**	
	n/a		Error Code
	n/a		Error Description
	n/a		Criticality
	n/a		Set/Clear
	n/a		Timestamp
5 Hz		**Report Error Count (Experimental)**	
	50		List of the active error codes

12 APPENDIXES

12.1 JAUS Background Information

For the user without prior knowledge of JAUS, this appendix presents a small amount of background information.

JAUS COMPONENTS

A *component* is the smallest addressable entity in JAUS. Components provide a particular capability, such as positioning (i.e. global pose sensor), and run concurrently on a *node*. Examples of a node would be a computer, a virtual machine, or the processing unit within the ByWire XGV. Each node has a special component referred to as the Node Manager, responsible for routing messages to and from components on that node. Finally, a *subsystem*, shown in Figure 34, is a collection of component software spread across one or more computing nodes. Examples of a subsystem include a manned control station, a vehicle (such as the XGV), or an unattended ground sensor.

Each JAUS component is assigned a 32-bit JAUS Identifier (JAUS ID), unique among the local domain. This JAUS ID comprises four subfields: subsystem, node, component, and instance. The component number in the JAUS ID defines the functionality of the component (i.e. 38 = Global Pose Sensor), and the instance allows for duplication of components.

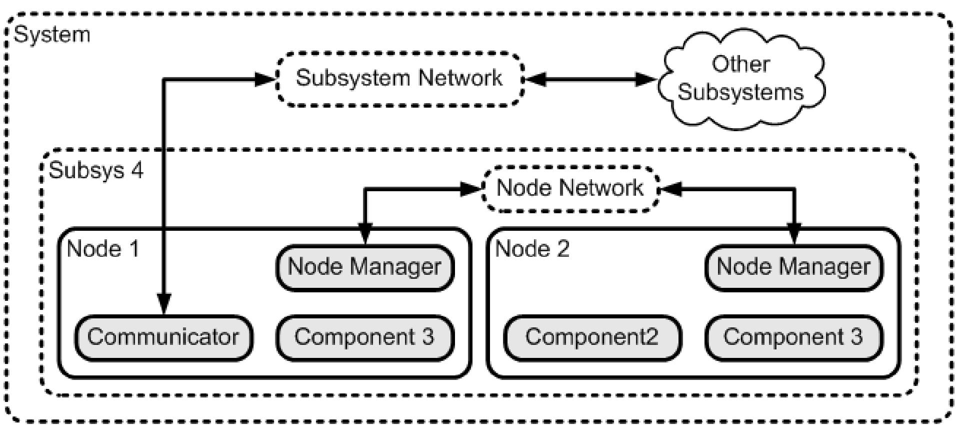


Figure 34. Typical JAUS Communications Topology

The XGV controller operates as node in the vehicle subsystem, running a set of components. Six JAUS components run on the XGV: a Node Manager, a Primitive Driver, a Velocity State Sensor, an experimental Motion Profile Driver, an experimental Signals Driver, and an experimental Error Manager.

JAUS MESSAGES

In JAUS, components interact by passing JAUS messages. All JAUS messages contain a 16-byte header (with a message id, addressing, and other metadata), and may contain additional payload data depending on the message ID. The header also provides provisions for acknowledgement, priority, version checking, multipart messaging for large datasets, and a number of other flags. A simplified version of the header is given in Table 1.

Table 1. JAUS Message Structure

Offset	Length	Field	Interpretation/Use
0 bits	4 bits	Priority Level	Very few JAUS implementers use this. Default should be 6
4	2	Ack/Nak	Used to verify receipt of messages. Leave zero for No-Response-Required
6	1	Service Connection Flag	Indicates periodic data (replacement)
7	1	Experimental Flag	Indicates if message is experimental
8	6	Version	Version of JAUS. Should be set to 0x02 (3.2 and 3.3) to communicate with the XGV
14	2	Reserved Bits	Undefined… set to zero
16	16	Command Code	Globally unique message code, given in the message specification
32	8	Destination JAUS instance	JAUS ID of message recipient
40	8	Destination JAUS component	
48	8	Destination JAUS node	
56	8	Destination JAUS subsystem	
64	8	Source JAUS instance	JAUS ID of message originator
72	8	Source JAUS component	
80	8	Source JAUS node	
88	8	Source JAUS subsystem	
96	12	Data Size	Length of message body, not including header
108	4	Data Control	Used for multi-packet transmissions for large data sets. For single packet transmissions, leave as zero.
112	16	Sequence Number	Use varies according to implementer.
128	---	Message Body	Zero or more subfields, dependent on message code.

There are three types of JAUS messages. **Commands** affect some sort of state change at the receiving component, **Queries** solicit information from a receiver, and **Inform** (aka Report) messages provide information in response to queries.

A small set of generic “core messages” is specified to be supported by all components. Examples of core messages are Standby, Resume, Reset, Request Control, Release Control, Query Identification, etc. The specific JAUS messages supported by the XGV are outlined in Section 8.1.

Endianness, Types, and Scaled Integers

In JAUS, all values are encoded in Little Endian format, and scaled integers are often used instead of floating point numbers. Please see the JAUS Reference Architecture version 3.3, Part 2, for a complete discussion of the commonly used types and scaled integer conversions used in JAUS. A simplified discussion is presented here for convenience.

Table 2. JAUS Data Types

Data Type	Size (bytes)	Representation
Byte	1	8-bit unsigned integer
Short Integer	2	16-bit signed integer
Integer	4	32-bit signed integer
Long Integer	8	64-bit signed integer
Unsigned Short Integer	2	16-bit unsigned integer
Unsigned Integer	4	32-bit unsigned integer
Unsigned Long Integer	8	64-bit unsigned integer
Float	4	IEEE 32-bit floating point number
Long Float	8	IEEE 64-bit floating point number

The formulae used within JAUS for conversion between scaled integers and real numbers are also reproduced here for convenience. *Min* and *Max* refer to the Lower Limit and Upper Limit of the scaled integer, respectively; *I* is the integer, *R* is the real number, and *N* is the number of bits in the integer.

Table 3: Scaled Integer conversion formulae for N-bit scaled integer

Operation	N-bit Unsigned Integer	N-bit Signed Integer
Real to Scaled Integer	$I = (R - Min) * \left(\frac{(2^N - 1)}{(Max - Min)} \right)$	$I = \left(R - \frac{(Max + Min)}{2} \right) * 2 \left(\frac{(2^{N-1} - 1)}{(Max - Min)} \right)$
Scaled Integer to Real	$R = I \left(\frac{(Max - Min)}{(2^N - 1)} \right) + Min$	$R = \frac{I}{2} \left(\frac{(Max - Min)}{(2^{N-1} - 1)} \right) + \frac{(Max + Min)}{2}$

Message Presence Vectors

In JAUS, variable length messages are often controlled by a *presence vector*, an integer for which each bit corresponds to the presence or omission of a particular field. For example, the Set Discrete Devices message controls the multiple fields: engine control, transmission gear, etc; if the control station or planner wanted to only set the transmission gear, the presence vector bit for the engine would be false, and the first field in the message would then be the transmission gear instead of the engine control bytes.

Where the XGV does not support one or more fields in a standard JAUS message (for example, the Transfer Case control in Set Discrete Devices since the Ford Escape has no transfer case), it is noted in the message listing in Section 8.3 (

Message Listing) with a ~~strikethrough~~.

TRANSPORT SPECIFICATION

When JAUS messages are sent over a network, an additional *transport specification* is used to encode additional data specific to the transport medium – such as a CRC block check for serial. The transport specification also outlines guidelines for transmitting JAUS messages over particular medium, such as UDP, TCP, or serial.

The JAUS Transport Specification is available as SAE standard AS5669, and is available for purchase from SAE.

The transport specifications supported by the XGV are outlined in Section 8.1.

OTHER PROTOCOL NOTES

DISCOVERY

In JAUS, discovery is the process of determining what other JAUS entities are on the network, and what their capabilities are, as well as the transport addresses for those JAUS entities. Typically, each Node Manager produces a periodic Report Heartbeat message, sent via UDP broadcast, UDP multicast, or some other sort of broadcast mechanism.

The JAUS messages for Query Identification, Query Services, and Query Configuration can be used to determine the supported messages of software components running on another node or subsystem. Another node receiving the heartbeat could send it a Query Configuration and Query Identification message. Upon receipt of the resulting Report Identification message from the XGV, that node now has a list of the components running on the other node, and can query the individual components for their capabilities using the Query Services message.

These discovery messages enable dynamic configuration in JAUS, where software can, at run-time, determine the JAUS IDs of the components it must communicate with. Since the Report Services message reports the supported messages and capabilities (positioning, signals, etc), a control station or planner can simply search for a component on the XGV which reports the desired capabilities.

In pre-3.3 versions of JAUS, there were no discovery messages, so all IDs were pre-determined. In addition, there was no requirement for a periodic heartbeat pulse.

ACK/NAK

A component can verify that another component received a message, by setting the JAUS Ack/Nak field. For more detail on this, see the JAUS RA version 3.3, Part 2.

Large Data Sets and Multi-part Messages

The maximum size of a JAUS message body is 4080 bytes. For data longer than this, JAUS provides provisions to divide the message into smaller packets and reassemble them at the destination. For more detail on this, see the JAUS RA version 3.3, Part 2.

Component Control

In JAUS, a small level of access control is enforced by requiring that a control station or planner obtain control of a component before certain command messages are accepted by that component. This ensures that only one component has control of a particular message (for example the throttle), at any given time. JAUS uses an 8-bit authority level to arbitrate control, and control is always granted to the highest authority component that requests control using the Request Component Control message.

Service Connections

Service connections in JAUS provide a mechanism for run-time data subscription through latest-data connections. A requestor can establish a service connection for a particular message, at a requestor-specified update rate, and terminate it later when the information is no longer necessary. The primary advantage over repeated queries is a two-fold decrease in total message traffic, making service connections the preferred mechanism for requesting periodic data.

Automated Cleanup during Communication Timeout

Several JAUS implementers have put in place in their software a mechanism to automatically clean up after a communications timeout. Suppose, for example, that an OCU requests control of a vehicle, establishes service connections, and then disappears or goes offline without releasing control or cancelling its service connections. In the development stage, it is often useful for the vehicle to automatically clear its controller and remove any active service connections when the OCU is no longer detected, so that the OCU has a clean slate when restarted. This process is referred to as “automated cleanup”.

12.2 XGV OCU Config File Details

This section describes the various sections and keys included in the OCU configuration file "XGV_OCU_Settings.ini". For proper function of the OCU the file "XGV_OCU_Settings.ini" should be located in the same folder as the TORC OCU executable. If the OCU is unable to find this file the OCU will create the file using the factory default settings. Additionally, the user can edit all these settings from within the OCU by navigating to the Config Tab.

Config File Section Name	Function
[JAUS Core]	**component**: The component address the OCU will request from the Node Manager **instance**: The instance address the OCU will request from the Node Manager **name**: This is the component name of the OCU **authority**: This is the control authority the OCU will have **udp_port**: This is the UDP port used for communication with the Node Manager **hrtbt_freq**: This is the frequency of the heartbeat that the OCU will send out **hrtbt_priority**: This key sets the priority of the heartbeat messages
[Primitive Driver]	**subsystem**: Sets the subsystem address of the Primitive Driver component that the OCU will communicate with. **node**: Sets the node address of the Primitive Driver component that the OCU will communicate with. **component**: Sets the component address of the Primitive Driver component that the OCU will communicate with. **instance**: Sets the instance address of the Primitive Driver component that the OCU will communicate with.
[Velocity State Sensor]	**subsystem**: Sets the subsystem address of the Velocity State Sensor component that the OCU will communicate with. **node**: Sets the node address of the Velocity State Sensor component that the OCU will communicate with. **component**: Sets the component address of the Velocity State Sensor component that the OCU will communicate with. **instance**: Sets the instance address of the Velocity State Sensor component that the OCU will communicate with.
[XGV]	**subsystem**: Sets the subsystem address of the XGV component that the OCU will communicate with. **node**: Sets the node address of the XGV component that the OCU will communicate with. **component**: Sets the component address of the XGV component that the OCU will communicate with. **instance**: Sets the instance address of the XGV component that the OCU will communicate with.
[Signals Driver]	**subsystem**: Sets the subsystem address of the Signals Driver component that the OCU will

	communicate with. **node**: Sets the node address of the Signals Driver component that the OCU will communicate with. **component**: Sets the component address of the Signals Driver component that the OCU will communicate with. **instance**: Sets the instance address of the Signals Driver component that the OCU will communicate with.
[Motion Profile Driver]	**subsystem**: Sets the subsystem address of the Motion Profile Driver component that the OCU will communicate with. **node**: Sets the node address of the Motion Profile Driver component that the OCU will communicate with. **component**: Sets the component address of the Motion Profile Driver component that the OCU will communicate with. **instance**: Sets the instance address of the Motion Profile Driver component that the OCU will communicate with.
[Error Manager]	**subsystem**: Sets the subsystem address of the Error Manager component that the OCU will communicate with. **node**: Sets the node address of the Error Manager component that the OCU will communicate with. **component**: Sets the component address of the Error Manager component that the OCU will communicate with. **instance**: Sets the instance address of the Error Manager component that the OCU will communicate with.
[Signals SC]	**rate**: Sets the rate for the service connection **enable**: Enables (set to TRUE) or disables (set to FALSE) the service connection
[PD Status SC]	**rate**: Sets the rate for the service connection **enable**: Enables (set to TRUE) or disables (set to FALSE) the service connection
[MPD Status SC]	**rate**: Sets the rate for the service connection **enable**: Enables (set to TRUE) or disables (set to FALSE) the service connection
[Steering Angle SC]	**rate**: Sets the rate for the service connection **enable**: Enables (set to TRUE) or disables (set to FALSE) the service connection
[Wheel Speeds SC]	**rate**: Sets the rate for the service connection **enable**: Enables (set to TRUE) or disables (set to FALSE) the service connection
[Wrench Efforts SC]	**rate**: Sets the rate for the service connection **enable**: Enables (set to TRUE) or disables (set to FALSE) the service connection
[Discrete Devices SC]	**rate**: Sets the rate for the service connection **enable**: Enables (set to TRUE) or disables (set to FALSE) the service connection
[Error Count SC]	**rate**: Sets the rate for the service connection **enable**: Enables (set to TRUE) or disables (set to FALSE) the service connection

[Velocity State SC]	**rate**: Sets the rate for the service connection **enable**: Enables (set to TRUE) or disables (set to FALSE) the service connection
[Platform Op Data SC]	**rate**: Sets the rate for the service connection **enable**: Enables (set to TRUE) or disables (set to FALSE) the service connection
[PD Control SC]	**rate**: Sets the rate for the service connection **enable**: Enables (set to TRUE) or disables (set to FALSE) the service connection
[MPD Control SC]	**rate**: Sets the rate for the service connection **enable**: Enables (set to TRUE) or disables (set to FALSE) the service connection
[Throttle Axis]	**throt_axis**: This key is used to set the axis on the joystick used for throttle. Possible values are listed below. **0** – Will use the X axis of the joystick for throttle control **1** – Will use the Y axis of the joystick for throttle control **2** – Will use the Z axis of the joystick for throttle control **3** – Will use the R axis of the joystick for throttle control
[Steering Axis]	**steer_axis**: This key is used to set the axis on the joystick used for throttle. Possible values are listed below **0** – Will use the X axis of the joystick for steering control **1** – Will use the Y axis of the joystick for steering control **2** – Will use the Z axis of the joystick for steering control **3** – Will use the R axis of the joystick for steering control
[X Axis Settings]	**x_min_value**: This represents the minimum raw value for the joystick **x_max_value**: This represents the maximum raw value for the joystick **x_center**: This represents the raw center value to be used for joystick functions **x_axis_invert**: TRUE inverts the X axis values, FALSE does not invert the X axis values **x_deadband**: This value is used to calculate the raw deadband range around the joystick center value.
[Y Axis Settings]	**y_min_value**: This represents the minimum raw value for the joystick **y_max_value**: This represents the maximum raw value for the joystick **y_center**: This represents the raw center value to be used for joystick functions **y_axis_invert**: TRUE inverts the Y axis values, FALSE does not invert the Y axis values **y_deadband**: This value is used to calculate the raw deadband range around the joystick center value.
[Z Axis Settings]	**z_min_value**: This represents the minimum raw value for the joystick **z_max_value**: This represents the maximum raw value for the joystick **z_center**: This represents the raw center value to be used for joystick functions **z_axis_invert**: TRUE inverts the Z axis values, FALSE does not invert the Z axis values **z_deadband**: This value is used to calculate the raw deadband range around the joystick

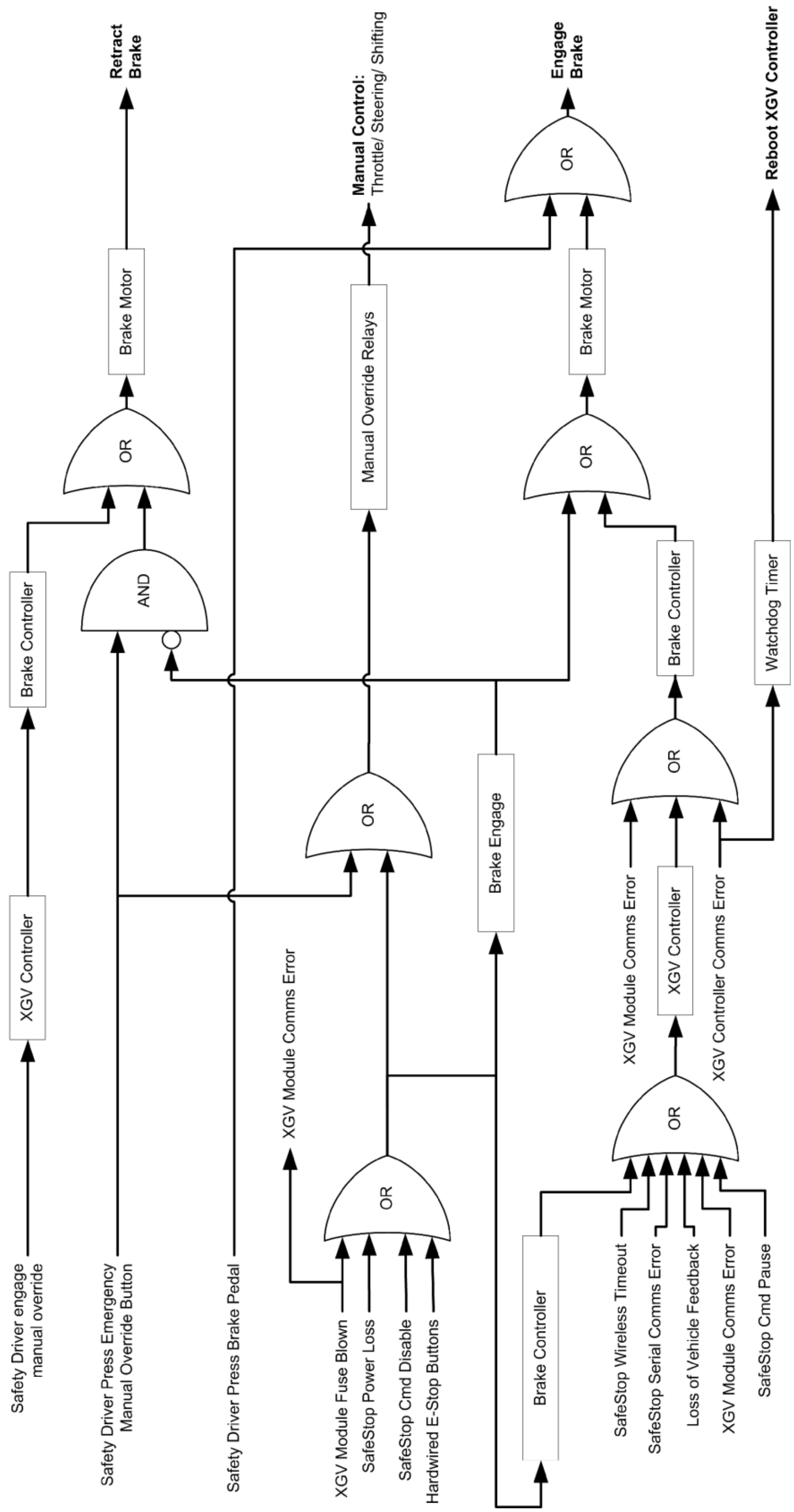
	center value.
[R Axis Settings]	**r_min_value**: This represents the minimum raw value for the joystick **r_max_value**: This represents the maximum raw value for the joystick **r_center**: This represents the raw center value to be used for joystick functions **r_axis_invert**: TRUE inverts the R axis values, FALSE does not invert the R axis values **r_deadband**: This value is used to calculate the raw deadband range around the joystick center value.
[Drive Cntrl]	**button**: Sets the joystick button used to change the XGV's gear to drive
[Low Cntrl]	**button**: Sets the joystick button used to change the XGV's gear to low
[Neutral Cntrl]	**button**: Sets the joystick button used to change the XGV's gear to neutral
[Reverse Cntrl]	**button**: Sets the joystick button used to change the XGV's gear to reverse
[Res Stby Cntrl]	**button**: Sets the joystick button used to send a resume/standby command to the XGV Primitive Driver or Motion Profile Driver component (based on the OCU mode)
[Emergency Cntrl]	**button**: Sets the joystick button used to send a set/clear emergency command to the XGV Primitive Driver or Motion Profile Driver component (based on the OCU mode)
[L Turn Cntrl]	**button**: Sets the joystick button to use for turning the left turn signal on/off
[R Turn Cntrl]	**button**: Sets the joystick button to use for turning the right turn signal on/off
[Horn Cntrl]	**button**: Sets the joystick button used to turn the horn on/off
[Hazard Cntrl]	**button**: Sets the joystick button to use for turning the hazard signals on/off
[Req Rel Cntrl]	**button**: Sets the joystick button used to send a request/release control command to the XGV Primitive Driver or Motion Profile Driver component (based on the OCU mode)
[Engine Cntrl]	**button**: Sets the joystick button to use for turning the engine on/off

12.3 XGV OCU Service Connection Details

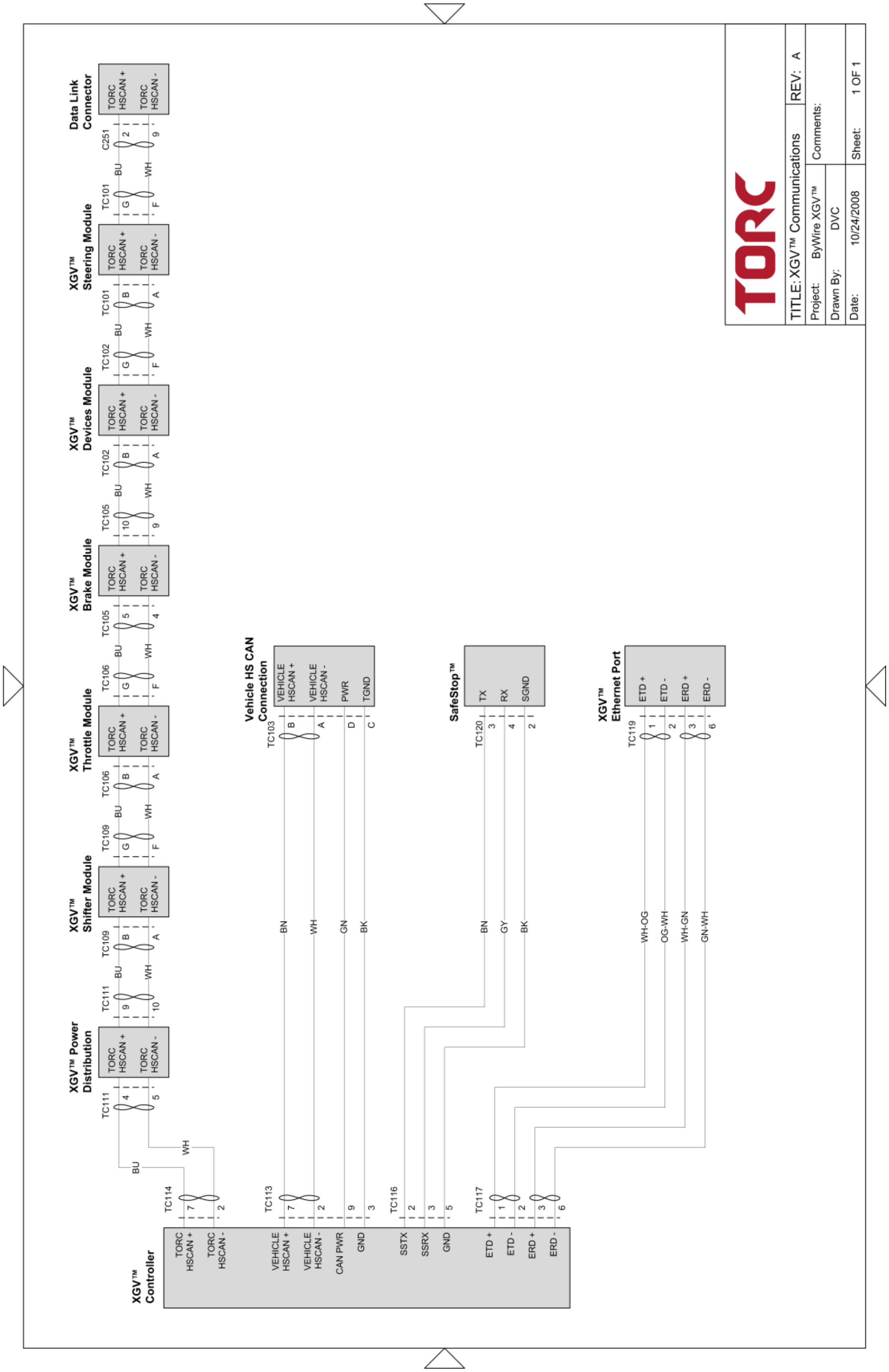
The following section details the service connections used by the OCU to update the information on the OCU.

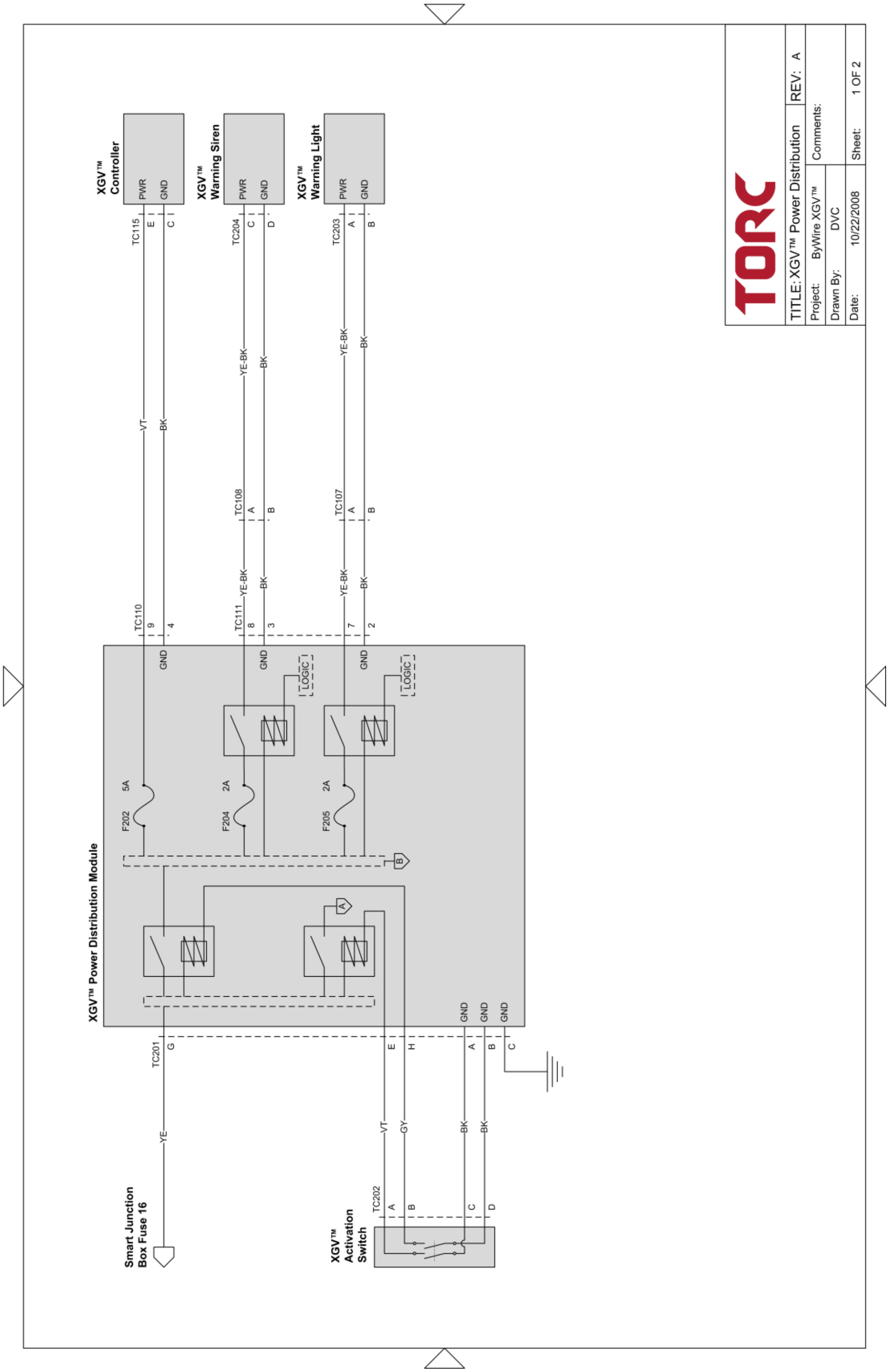
Config File Section Name	Function
[Signals SC]	Used by the XGV OCU to indicate the status of the signals, lights, and horn of XGV.
[PD Status SC]	Used by the XGV OCU to indicate the status of the Primitive Driver component, status of the SafeStop relays, the steering and throttle modes of the XGV, and the vehicle Manual Override state.
[MPD Status SC]	Used by the XGV OCU to indicate the status of the Motion Profile Driver component of the XGV
[Steering Angle SC]	This service connection is currently not used by the ByWire XGV OCU.
[Wheel Speeds SC]	This service connection is currently not used by the ByWire XGV OCU.
[Wrench Efforts SC]	Used by the XGV OCU to indicate the actual wrench efforts of the XGV.
[Discrete Devices SC]	Used by the XGV OCU to indicate the status of the XGV engine, parking brake, and actual transmission gear.
[Error Count SC]	Used by the XGV OCU to list any currently active errors on the XGV.
[Velocity State SC]	Used by the XGV OCU to display the current speed of the vehicle.
[Platform Op Data SC]	Used by the XGV OCU to indicate the fuel level of the vehicle.
[PD Control SC]	Used in conjunction with the MPD Control SC to determine the current mode of the XGV.
[MPD Control SC]	Used in conjunction with the PD Control SC to determine the current mode of the XGV.

12.4 XGV Fault Tree Analysis



12.5 Wiring Diagrams

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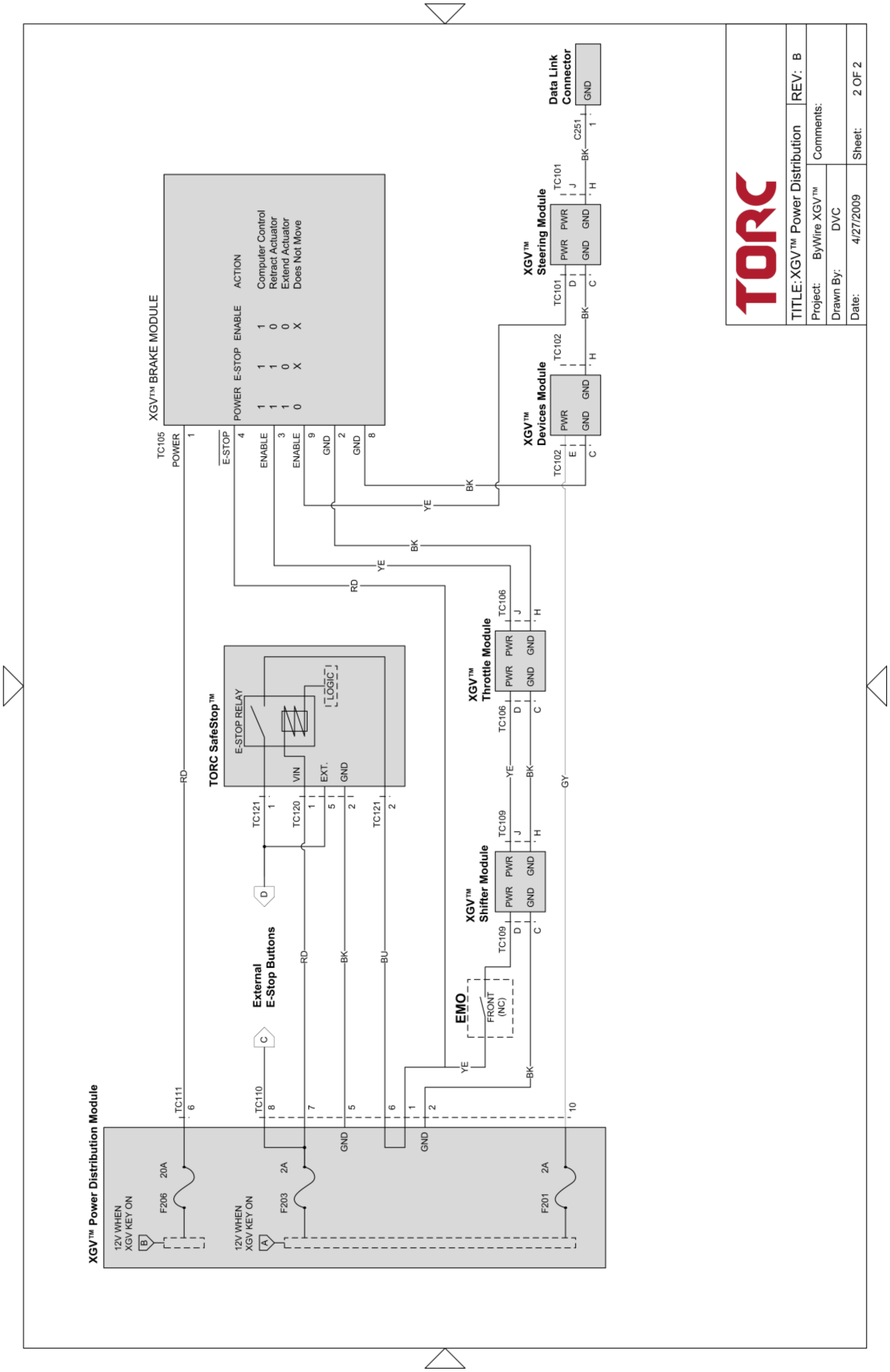
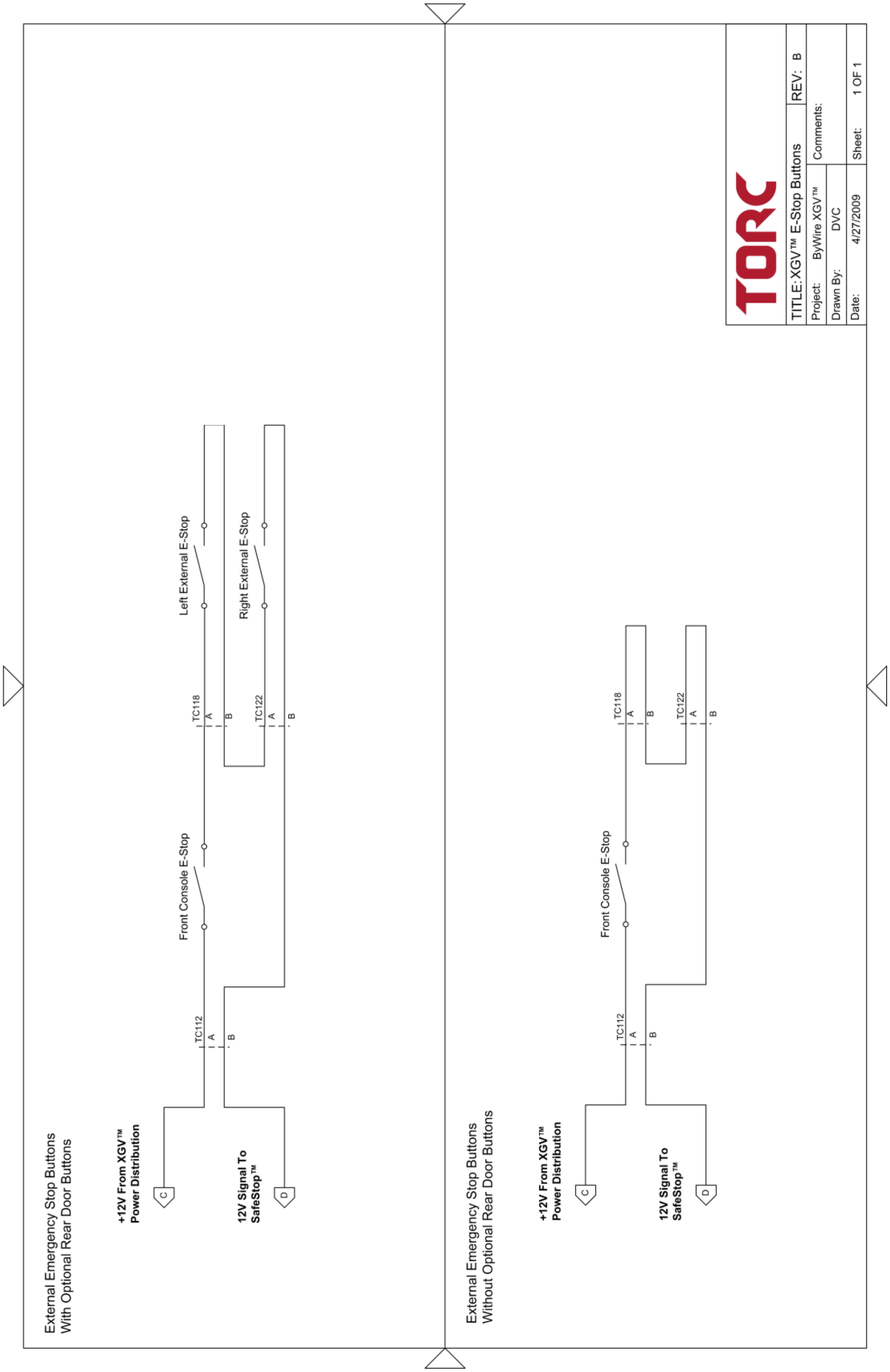
REV: A
Project: ByWire XGV™
Comments:
Drawn By: DVC
Date: 10/22/2008
Sheet: 1 OF 2
XGV™ Controller
XGV™ Warning Siren
XGV™ Warning Light
XGV™ Power Distribution Module
Smart Junction Box Fuse 16
XGV™ Activation Switch
PWR
GND
LOGIC
F202 5A
F204 2A
F205 2A
TC115
TC204
TC203
TC108
TC107
TC110
TC111
TC201
TC202
VT
BK
YE-BK
YE
GY


XGV™ BRAKE MODULE
POWER E-STOP ENABLE ACTION
1 1 1 Computer Control
1 1 0 Retract Actuator
1 0 0 Extend Actuator
0 X X Does Not Move
TORC SafeStop™
E-STOP RELAY
LOGIC
VIN
EXT.
GND
External E-Stop Buttons
EMO
FRONT (NC)
XGV™ Shifter Module
XGV™ Throttle Module
XGV™ Devices Module
XGV™ Steering Module
Data Link Connector
PWR
GND
XGV™ Power Distribution Module
12V WHEN XGV KEY ON
F206 20A
F203 2A
F201 2A
TC105 TC111 TC110 TC120 TC121 TC109 TC106 TC102 TC101 C251
TITLE: XGV™ Power Distribution
REV: B
Project: ByWire XGV™
Comments:
Drawn By: DVC
Date: 4/27/2009
Sheet: 2 OF 2


External Emergency Stop Buttons
With Optional Rear Door Buttons
+12V From XGV™
Power Distribution
12V Signal To
SafeStop™
TC112
Front Console E-Stop
TC118
Left External E-Stop
TC122
Right External E-Stop
External Emergency Stop Buttons
Without Optional Rear Door Buttons
+12V From XGV™
Power Distribution
12V Signal To
SafeStop™
TC112
Front Console E-Stop
TC118
TC122
TITLE: XGV™ E-Stop Buttons
REV: B
Project: ByWire XGV™
Comments:
Drawn By: DVC
Date: 4/27/2009
Sheet: 1 OF 1

12.6 Estimated UPS Run Times

SMART2600RM2U Estimated Runtime

Load in Watts

UPS	Battery Pack	500W	1,000W	1,100W	1,200W	1,300W	1,400W	1,500W	1,600W	1,700W	1,800W	1,900W	2,000W	2,100W
SMART2600RM2U	Internal Batteries	28	12	10	9.0	8.1	7.2	6.6	6.0	5.5	5.0	4.6	4.3	4.0
SMART2600RM2U	1 BP48V24-2U	105	46	40	36	33	30	27	25					
SMART2600RM2U	1 BP48V60RT3U	212	96	85	77	69	63	58	53					
SMART2600RM2U	2 BP48V60RT3U	424	200	179	161	147	134	124	115					
SMART2600RM2U	3 BP48V60RT3U	637	308	277	251	229	210	194	180					
SMART2600RM2U	4 BP48V60RT3U	849	417	376	341	312	287	265	247					
SMART2600RM2U	5 BP48V60RT3U	1,057	526	475	432	396	365	338	314					
SMART2600RM2U	6 BP48V60RT3U	1,263	635	574	523	480	443	411	383					
SMART2600RM2U	7 BP48V60RT3U	1,465	743	673	614	564	521	484	451					
SMART2600RM2U	8 BP48V60RT3U	1,665	851	772	705	648	599	556	519					
SMART2600RM2U	9 BP48V60RT3U	1,862	958	870	795	731	676	629	587					
SMART2600RM2U	10 BP48V60RT3U	2,055	1,065	967	884	814	754	701	655					

All runtime values are in minutes.

12.7 References

TORC SafeStop^{TM} User's Manual
http://www.torctech.com/products/safestop

TORC PowerHUB User's Manual
http://www.torctech.com/products/powerhub

Hybrid Emergency Response Guide
https://www.fleet.ford.com/showroom/2009fleetshowroom/pdfs/2009_Hybrid_ERG_FINAL.pdf

2008 Ford Hybrid Escape Modifier's Guide
https://www.fleet.ford.com/showroom/2008fleetshowroom/pdfs/2008_hybrid_modifiers_guide.pdf

2009 Ford Hybrid Escape Modifier's Guide
https://www.fleet.ford.com/showroom/2009fleetshowroom/pdfs/2009_hybrid_modifiers_guide.pdf

JAUS Reference Architecture, version 3.3
http://www.jauswg.org/baseline/refarch.html

JAUS Transport Specification, SAE AS-5669, version 1
This document must be purchased from SAE. Call SAE customer service at 1-877-606-7323 for purchasing information.

TrippLite SMART2600RM2U User's Manual
http://www.tripplite.com/EN/products/model.cfm?txtModelID=3024