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EMESRT Vehicle Interaction Working group

Part of ACARP C24034 “Proximity Detection Device Open Specification”

On vehicle protocol

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Executive summary

This report presents the strategy for implementation of an industry communications standard for proximity detection and vehicle interaction, as agreed by the EMESRT working group on Vehicle Interaction at a December 2015 workshop in Brisbane, Australia. This document is also a deliverable for ACARP project C24034, “Proximity Detection Device Open Specification”.

The primary outcome of the EMESRT workshop was an agreement by participants, which included representatives from mining companies, OEMs, and Proximity Detection System (PDS) vendors, to establish a common protocol for communications between PDS and OEM devices in the mining industry. Furthermore it was resolved that, due to its familiarity and broad industry acceptance, the preferred basis for the protocol should be the J1939 standards as established by the Society of Automotive Engineers (SAE).

This report provides an overview of the J1939 protocol in light of the vehicle interaction requirements defined by EMESRT. The EMESRT workshop also defined a set of fundamental signals or messages between the PDS and OEM systems that would be required for compliance with the proposed industry standard: these signals, and the J1939 protocol messages necessary to implement them, are documented.

Some key issues remain to be addressed as part of the implementation process, such as the need for an agreed hardwired interface for communication with non-computerised vehicles. Of particular note in this category is the question of the extensibility of the proposed protocol, and the need for an ongoing roadmap to carefully manage the implementation process.

These unresolved issues indicate to CSIRO that the selected protocol is not ideal, and may lead to serious future issues in this space.

1 Revision control

Revision	Date	Details
0	16.02.2016	Initial draft release for comment
1	25.03.2016	Draft following EMESRT VI Workshop 3

2 Introduction

This document has been created as deliverable for the ACARP C24034 project, with a direct connection to the work being undertaken by the EMESRT group on Vehicle Interaction. This document is designed to be a draft for the working group that consists of representatives from Mining companies, Equipment manufacturers (OEMs) and PDS suppliers.

The document addresses the definition of an agreed "on vehicle" protocol for mining industry machinery, and covers the communications channels described in Figure 1 below. Based on the outcomes of the December 2015 workshop organised by the EMESRT working group on Vehicle Interactions, it was agreed that the proposed protocol will be based on the SAE J1939 set of standards. On this basis, relevant information regarding currently used protocols and standards has been accumulated from a wide base of OEMs and PDS suppliers.

The EMESRT working group also established an agreed set of fundamental signals between OEMs and PDSs that would be required for minimum compliance with the proposed protocol. These signals are summarised, and a draft series of J1939 protocol messages that encapsulate the standard signals are presented.

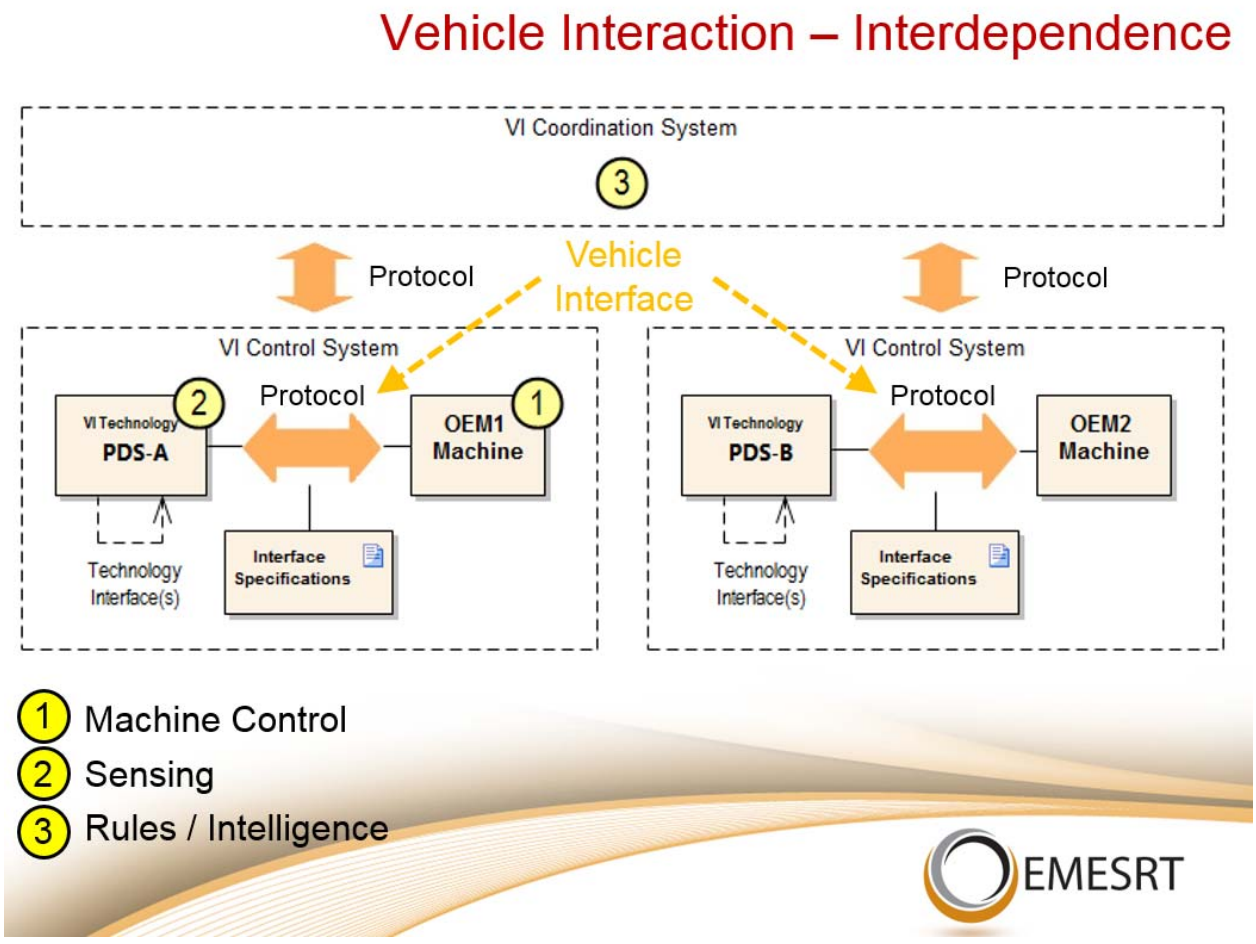


Figure 1 Suggested system architecture

3 Assumptions

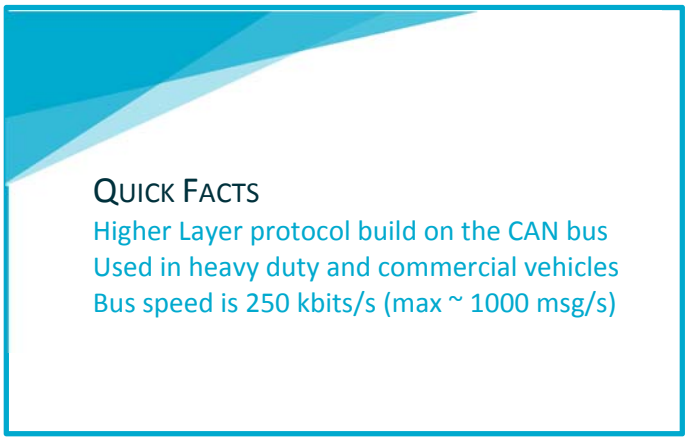
This document makes the following assumptions:

1. This communications protocol defines the transmission between a single PDS and vehicle.
2. This communication protocol uses the J1939 standards.
3. The communications between PDS system and OEM control system may be added on to an existing CANbus, so messages should not conflict with the normal operation of any existing systems utilizing that bus.

4 SAE J1939 overview

J1939 is a set of standards defined by the Society of Automotive Engineers (SAE) for use within heavy-duty vehicles such as trucks, buses, commercial vehicles and mobile hydraulics. It is based upon the CAN protocol and operates at a maximum speed of approximately 250kbps. It describes the physical and data link layers of the OSI model. SAE J1939 is now commonly used in the commercial vehicle area for communication throughout the vehicle, with the physical layer defined in ISO 11898.

The overviews by Kvaser:
https://www.kvaser.com/about-can/higher-layer-protocols/j1939-introduction/)
and Voss:
http://www.esd-electronics-usa.com/Shared/Library/J1939/SAE%20J1939%20Extended.pdf
are highly recommended background reading.



SAE Documents:
The physical layer **(J1939/11)** describes the electrical interface to the bus. The data link layer **(J1939/21)** describes the rules for constructing a message, accessing the bus, and detecting transmission errors. The application layer **(J1939/71 and J1939/73 diagnostics)** defines the specific data contained within each message sent across the network.

J1939/11 Wiring Topology – Physical Layer
The J1939 network is intended to be a single, linear, shielded twisted pair of wires running around the vehicle to each ECU. A short stub is permitted between the ECU and the "bus". This simplifies routing the main bus wiring by not requiring the main bus to connect directly to each ECU. The linear bus is necessary at a data rate of 250 Kbps in order to minimize electrical signal reflections. The termination resistor (typically 120 Ohms) at each end of the bus also reduces reflections.

J1939/21 Data Link Layer
This document describes the data link layer using the CAN protocol with 29-bit Identifiers. For SAE J1939 no alternative data link layers are permitted.

J1939/71 Vehicle Application Layer
This the SAE J1939 reference document for the conventions and notations that specify parameter placement in PGN data fields, the conventions for ASCII parameters, and conventions for PGN transmission rates. This document previously contained the majority of the SAE J1939 data parameters and messages for information

exchange between the ECU applications connected to the SAE J1939 communications network. It also contained reference figures and reference information. The data parameters (SPNs), messages (PGNs) and reference figures and information previously published within this document are now published in **SAE J1939DA.**

CAN Messaging

Every node within the CAN system has access to read and write data on the CAN bus; when sending, a node first checks availability of the bus, then transmits a CAN frame to the network. The CAN protocol is a message based protocol; each individual message is given a predefined unique ID identifying the type of the contents of the message. This means that every node on the bus can receive the message, and then determine whether to accept it or not based on the message ID.

The CAN specification defines several error control mechanisms, ensuring the network is very reliable. All network devices need to be capable of detecting errors and informing other nodes that an error occurred.

J1939 Message Format

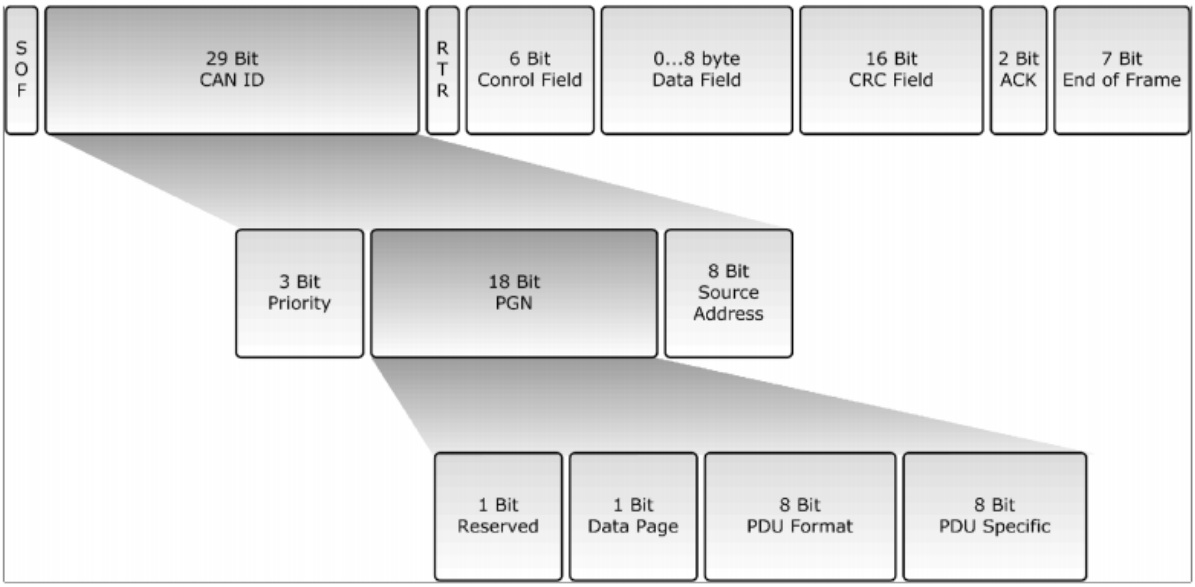


Figure 2 J1939 message format

Each message consists of the format in figure 2. As shown, the maximum size of a message is 128 bits with 8 data bytes. Using a 50% bus utilisation to account for transmission collisions, this results in around 1000 messages per second being transmitted on the bus.

The Parameter Group Number (PGN) identifies the pre-defined Parameter Group, which is made up of individual data items, or “SPN”s.

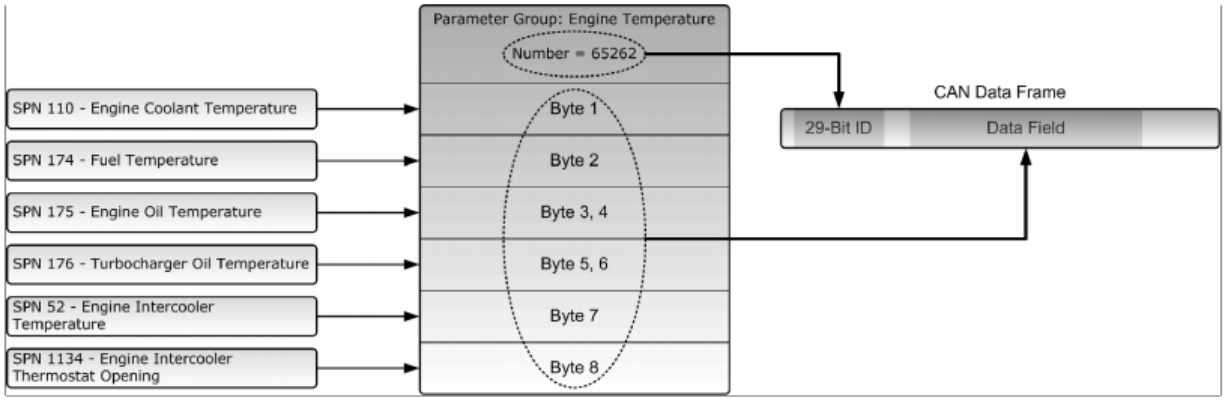


Figure 3 Parameter Group example

The data is contained in the (up to) 8 byte Data field. Within this data field, individual parameters are defined by their offset. Additionally standard data items are predefined as a SPN, and this definition includes:

- Data length
- Resolution
- Value Offset
- Value Range
- Type
- Reference

QUICK FACTS

Each message is 128 bits, with 8 bytes of data
PGNs are pre-defined parameter groups
SPNs are pre-defined data items

J1939 ECU Name

Each device on the CANBus shall have a NAME data item as documented in J1939/81. The Name is a 64 bit (8 bytes) long label which gives every ECU a unique identity. The Name is composed of 10 fields and has the following structure:

1. Arbitrary address bit
2. Industry group, length 3 bits
3. Vehicle system instance, length 4 bits
4. Vehicle system, length 7 bits
5. Reserved bit
6. Function, length 8 bits
7. Function instance, length 5 bits
8. ECU instance, length 3 bits
9. Manufacturer code, length 11 bits
10. Identity number, length 21 bits

Additionally, each physical ECU may incorporate multiple Controller Applications, which may be considered logically independent data sources.

5 Required Data Items

As determined during the EMESRT discussions of December 2015, the following parameters are the high priority data items.

Table 1: High-priority Data Items as Defined by EMESRT (OEM->PDS)

OEM-> PDS	UNIT	RATE	DESCRIPTION
VELOCITY	m/sec pos/neg	4 times/sec	calculated ground speed, suggested resolution +/- 0.1 m/s and precision 0.3
MACHINE TYPE	TBD	on request	Machine ID (type, model, controller…
DIRECTION	+/- (#Gear?)	change of state	We need to know if we are in reverse, neutral, park, or drive… Definition: What direction the operator intended. Should this be called "direction" or "selective direction"
STEERING ANGLE	Degrees (+/- from straight?)	4 times/sec	Intent of this is to provide clarification on direction intent, reduce false positives, prevent a STOP order if it isn't needed … a) currently this is unavailable from the OEM and is a major undertaking to realise if provided by the OEM. b) Other option is PDS seeks 3rd party sensor/interface or builds in this capability. c) From this information the steering angle speed will be derived and reported.
MACHINE STATE	TBD	change of state	Status of subsystems (? traction control system, tramming, slew function, bucket, parking brake, haul truck tray, boom). Can you approach the machine without alarms for both underground and surface? BE CAREFUL not to make all machines OVERLY safe to such an extent that you cannot move/operate the machine. Every function can potentially be a regulatory issue.
SLOPE: ROLL/PITCH	Degrees (+up/-down from level horizon)	TBD	Optimisation of braking distances and alarming uphill or downhill (slope) … and right to left (roll). Coordinate frames TBD
TRACTION CONTROL: SLIP STATUS	TBD	TBD	Optimisation of braking distances and alarming
PAYLOAD	Loaded/unloaded	Change of state	Optimisation of alarming … also for prioritisation when having to decide between stopping a loaded vs. unloaded vehicle - you would 1st stop the loaded vehicle. Different speed limits loaded vs. unloaded

Table 2: High-priority Data Items as Defined by EMESRT (PDS->OEM)

PDS->OEM	UNIT	RATE	DESCRIPTION
EMERGENCY STOP			Stop the machine motion as rapidly as possible. This means an uncontrolled motion stop. NOTE: this has NOTHING to do with an E-Stop
CONTROLLED STOP			Stop machine motion in a conventional manner. NOTE: there is additional work to be done between OEM's and PDS's to get to an understanding and reach agreement… some PPTs from workshop ID different levels of stop - perhaps should be a risk assessment done on site.
SLOW DOWN			Reduce speed of the machine in a conventional/ nominal manner.
HEALTH			Intent behind this is to indicate that the PDS system is right (healthy)

6 Proposed Protocol Messages

The proposed protocol messages are split into 3 separate PGNs. The working group has yet to define whether the data items will be formally defined as SPN.

PGN	Description
65280	PDS-OEM Action
65281	OEM-PDS Reply
65282	OEM-PDS Data

6.1 PDS->OEM Action PGN

Table 3: Proposed PGN(s) – PDS -> OEM Action

PDS -> OEM Action – NEW PGN 65280									
Signal	**PGN**	**Label**	**SPN**	**Offset (byte.bit)**	**SPN length**	**Name**	**Description**	**Update Rate**	**J1939/71 defined**
Status	65280	Proximity Detection System Status/ Command	TBD	1.1	8bits	Status or Command	This is an enumerated table of data items that may be sent from PDS to OEM	TBD	N
Min Braking	65280	Min Braking Request Percent	TBD	2.1	8bits	Min Braking	** 0%-125% encoded on range 0x0-0xf9	TBD	N
Max Throttle	65280	Max Throttle Request Percent	TBD	3.1	8bits	Max Throttle	** 0%-125% encoded on range 0x0-0xf9	TBD	N
Max Velocity	65280	Max Velocuty Request Percent	TBD	4.1	8bits	Max Velocity	** -25m/s-25m/s encoded on range 0x0-0xf9	TBD	N
User Configurable 1	65280	TBD	TBD	5.1	8bits	User Configurable 1	***	TBD	N
User Configurable 2	65280	TBD	TBD	6.1	8bits	User Configurable 2	***	TBD	N
Reserved	65280	TBD	TBD	7.1	8bits	Reserved		TBD	N
Message Counter	65280	Message Counter	TBD	8.1	8bits	Message Counter	Incrementing counter of messages passed between systems to ensure system consistency	TBD	N

Notes

** The resolution and range cannot actually be correct. 0xFA = 250, but the 0xFA cannot be used as it is being used for the **GENERAL FAULT** indication.

*** The use of a ‘user configurable field’ is contrary to the very concept of clear, well defined, open architecture protocol definitions.

PROPOSAL 1

Two new user range PGNs (65280&65281) defined

Eight new SPNs defined

6.2 PDS->OEM Action SPN Details

Table 4: SPN - Status/Command

SPN <TBD>: STATUS/COMMAND	
EDP	0
DP	0
PF	
PS	
PGN	65280 - Proximity Detection System Outputs
TRANSMISSION RATE	TBD
DEFAULT PRIORITY	
SPN POSITION	1.1
SPN LENGTH	8 bit
DESCRIPTION	Status / Command
RESOLUTION	Enumeration
DATA RANGE	0 to 0xff
UNITS	Bit
SPN TYPE	Status/Command

Table 5 Status/Command Enumeration

VALUE	NAME	DESCRIPTION
0X00	Health/No Command	System OK PDS active
0X01	Emergency Stop	Stop the machine motion as rapidly as possible. This means an uncontrolled motion stop. NOTE: this has NOTHING to do with an E-Stop In this case 125% force and service brake.
0X02	Controlled Stop	"Stop machine motion in a conventional manner. NOTE: there is additional work to be done between OEM's and PDS's to get to an understanding and reach agreement… some PPTs from workshop ID different levels of stop - perhaps should be a risk assessment done on site. If no additional information (byte 3/4/5) is provided then it is the OEMs responsibility to define machine response. "

VALUE	NAME	DESCRIPTION
0X03	Slow down	Reduce speed of the machine in a conventional/ nominal manner. If no additional information (byte 3/4/5) is provided then it is the OEMs responsibility to define machine response.
0X04	Bypass	PDS is not active. E.g. Override function for maintenance.
0X81	Emergency Stop Capability Confirmation	Used to confirm the OEM capability to perform an Emergency Stop
0X82	Controlled Stop Capability Confirmation	Used to confirm the OEM capability to perform a Controlled stop
0X83	Slow down Capability Confirmation	Used to confirm the OEM capability to perform a Slow Down
0X84	Bypass Capability Confirmation	Used to confirm the OEM capability to perform a Bypass

Table 6 Additional SPN Definitions

	POSITION	LENGTH	RESOLUTION	RANGE	UNITS
MIN BRAKING	2.1	8	0.5%	0% to 125%	Percent
MAX THROTTLE	3.1	8	0.5%	0% to 125%	Percent
MAX VELOCITY	4.1	8	0.2m/s	-25m/s to 25m/s	m/s
USER CONFIGURABLE 1	5.1	8	N/A	N/A	N/A
USER CONFIGURABLE 2	6.1	8	N/A	N/A	N/A
RESERVED	7.1	8	N/A	N/A	N/A
MESSAGE COUNTER	8.1	8	N/A	0-255	messages

Special cases

In each field, the standard J1939 standard codes may be used to indicate status:

0xFA	**General Fault**
0xFE	General Error
0xFF	Ignore

6.3 OEM->PDS Reply

Table 7 Proposed PGN(s) – OEM -> PDS Reply

OEM -> PDS Reply – NEW PGN 65281									
Signal	**PGN**	**Label**	**SPN**	**Offset (byte.bit)**	**SPN length**	**Name**	**Description**	**Update Rate**	**J1939/71 defined**
Status	65281	Proximity Detection System Status/ Command	TBD	1.1	8bits	Status or Command	This is an enumerated table of data items that may be sent from PDS to OEM	TBD	N
Min Braking	65281	Min Braking Request Percent	TBD	2.1	8bits	Min Braking	** 0%-125% encoded on range 0x0-0xf9	TBD	N
Max Throttle	65281	Max Throttle Request Percent	TBD	3.1	8bits	Max Throttle	** 0%-125% encoded on range 0x0-0xf9	TBD	N
Max Velocity	65281	Max Velocuty Request Percent	TBD	4.1	8bits	Max Velocity	** -25m/s-25m/s encoded on range 0x0-0xf9	TBD	N
User Configurable 1	65281	TBD	TBD	5.1	8bits	User Configurable 1	***	TBD	N
User Configurable 2	65281	TBD	TBD	6.1	8bits	User Configurable 2	***	TBD	N
Reserved	65281	TBD	TBD	7.1	8bits	Reserved		TBD	N
Message Counter	65281	Message Counter	TBD	8.1	8bits	Message Counter	Incrementing counter of messages passed between systems to ensure system consistency	TBD	N
								TBD	N

This message is a **direct** reflection of PGN 65280, and the OEM should send it back to the PDS to indicate the success of the previous action message. Note that data fields may be modified to contain status conditions as per the Special Conditions table. Additionally the OEM may respond with control inputs to what it is capable of enacting, it would be the responsibility of the PDS to react in an appropriate manner.

Notes

** The resolution and range cannot actually be correct. 0xFA = 250, but the 0xFA cannot be used as it is being used for the **GENERAL FAULT** indication.

*** The use of a 'user configurable field' is contrary to the very concept of clear, well defined, open architecture protocol definitions.

6.4 OEM->PDS Data PGN

Table 8 OEM->PDS Data

OEM -> PDS Data – NEW PGN 65282									
Signal	**PGN**	**Label**	**SPN**	**Offset (byte.bit)**	**SPN length**	**Name**	**Description**	**Update Rate**	**J1939/71 defined**
Velocity	65282		TBD	1.1	8bits	Measured Velocity of the vehicle	Speed of the vehicle registered by the tachograph.	TBD	N
Movement/ Intended Direction	65282		TBD	2.1	8bits	Movement/ Intended Direction	Indicates the intended direction of the vehicle: 01 - Forward 02 - Reverse 03 – Neutral 04 – Park 05 – Motion Inhibited 11 – Forward Gear 1 12 - Forward Gear 2 .. 26 - Forward Gear 20 31 – Reverse Gear 1 32 – Reverse Gear 2 .. 46 – Reverse Gear 20	TBD	N
Payload	65282		TBD	3.1	2bits	Payload indication	The current payload of the equipment, indication 00 – Unloaded 01 – Loaded 10 – Reserved 11 – Not Available	TBD	N
Traction Control	65282		TBD	3.3	2 bits	Traction Control indication	The current status of the traction control system: 00 Off 01 On 10 Reserved 11 Not Available		
Vehicle Pitch	65282		TBD	4.1	8bits	Max Velocity	The angle between the vehicle x-axis and the ground plane. -125 degrees to 125 degrees	TBD	N
Vehicle Roll	65282		TBD	5.1	8bits	User Configurable 1	The angle between the vehicle y-axis and the ground plane. -125 degrees to 125 degrees	TBD	N
User Configurable 1	65282		TBD	6.1	8bits	User Configurable 2	***	TBD	N
User Configurable 2	65282		TBD	7.1	8bits	Reserved	***	TBD	N
Message Counter	65282	Message Counter	TBD	8.1	8bits	Message Counter	Incrementing counter of messages passed between systems to ensure system consistency	TBD	N
								TBD	N

Notes

** The resolution and range cannot actually be correct. 0xFA = 250, but the 0xFA cannot be used as it is being used for the **GENERAL FAULT** indication.

*** The use of a 'user configurable field' is contrary to the very concept of clear, well defined, open architecture protocol definitions.

PROPOSAL 2

New user range PGN (65282) defined

Nine new SPNs defined

6.5 OEM->PDS Data SPN Details

Table 9 OEM->PDS Data SPNs

	POSITION	LENGTH	RESOLUTION	RANGE	UNITS
VELOCITY	1.1	8	0.2m/s	-25m/s to 25m/s	m/s
MOVEMENT/ INTENDED DIRECTION	2.1	8	N/A	Enumeration	N/A
PAYLOAD	3.1	2	N/A	Enumeration	N/A
TRACTION CONTROL	3.3	2	N/A	Enumeration	N/A
VEHICLE PITCH	4.1	8	1 degree	-125degrees to 125 degrees	Degrees
VEHICLE ROLL	5.1	8	1 degree	-125degrees to 125 degrees	Degrees
USER CONFIGURABLE 1	6.1	8	N/A	N/A	N/A
USER CONFIGURABLE 2	7.1	8	N/A	N/A	N/A
MESSAGE COUNTER	8.1	8	N/A	0-255	messages

7 Compiled information

Table 10: Compiled PGNs – PDS -> OEM

PDS -> OEM (Outputs)										
Signal	PGN	Label	SPN	Offset (byte.bit)	SPN length	Name	Description	Update Rate	Origin ***	J1939/71 defined?
Emergency Stop*	65282		43	7.3	1	Active Stop	Emergency Condition Stop	100 ms		N
	65440		-	1.5	1	Service Brake Auto-Apply	Full Service Brake Request	10 ms		N
Controlled Stop*										N
Slow Down*	65282		42	7.2	1	Active Slow	Slow Down Signal	100 ms		N
	65440		-	2.1	8	Retarder Application Request (%)	Dynamic Retarder Request (0 to 100 %)	10 ms		N
Health	65280	Heart Beat	1?	1.1	32	Hub ID	32 Bit serial number	100 ms		N
			1?	5.1	16	Unit ID	Unique machine ID	100 ms		N
				7.1	8	System Status	0x00 = System startup 0x01 = Waiting for CWS 0x02 = DownLoad Mode 0x03 = Standby mode 0xFF = System active	100 ms		N
	65440			4.1	1	System Fault	Active PDS Fault	10 ms		N

Table 11: Compiled PGNs – OEM -> PDS

OEM -> PDS (Inputs)										
Signal	PGN	Label	SPN	Offset (byte.bit)	SPN length	Name	Description	Update Rate	Origin ***	J1939/71 defined?
Velocity	65132	Tachograph	1624	7.1	16	Tachograph Vehicle Speed	Speed of the vehicle registered by the tachograph. (0 to 250.996 km/h)	50 ms		Y
	65256	Vehicle Direction/ Speed	517	3.1	16	Navigation-Based Vehicle Speed	Speed of the vehicle as calculated from a device such as a Global Positioning System (GPS). (0 to 250.996 km/h)	On request		Y
	61442	Electronic Transmission Controller 1	191	2.1	16	Transmission Output Shaft Speed	Calculated speed of the transmission output shaft. (0 to 8,031,875 rpm)	50 ms (10ms standard)		Y
	65281	N/A	-	1.1	16	Truck Speed	Local vehicle speed. Tx 0xFFF when data not avail (0 to 6553.5 km/h)	100 ms		N
	65215	Wheel Speed Information	904	1.1	16	Front Axle Speed	The average speed of the two front wheels. (0 to 250.996 km/h)	100 ms		Y
	65135	Adaptive Cruise Control	1586	1.1	8	Speed of forward vehicle	Absolute velocity of the preceding vehicle situated within 250 m in the same lane and moving in the same direction. (0 to 250 km/h)	100 ms		Y
Direction	65132	Tachograph	1619	4.7	2	Direction Indicator	Indicates the direction of the vehicle: 00 - Forward 01 - Reverse 10 - Error 11 - Not available	50 ms		Y
	65256	Vehicle Direction/ Speed	165	1.1	16	Compass Bearing	Present compass bearing of vehicle. (0 to 501.99 deg)	On request		Y
	61445	Electronic Transmission Controller 2	524	1.1	8	Transmission Selected Gear	The gear that the transmission will attempt to achieve during the current shift if a shift is in progress, or the next shift if one is pending (i.e., waiting for torque reduction to initiate the shift). (-125 to 125)	100 ms		Y
	65282	N/A	-	5.1	1	Shifter Forward	Selector Switch - Forward Position	100 ms		N
			-	5.2	1	Shifter Neutral	Selector Switch - Neutral Position	100 ms		N
			-	5.3	1	Shifter Reverse	Selector Switch - Reverse Position	100 ms		N
			-	5.5	1	Park Brake Released	Parking Brake Status	100 ms		N
Slope	61459	Slope Sensor Information	3318	1.1	16	Pitch Angle	The angle between the vehicle x-axis and the ground plane. (-64 to 64.51 deg)	10 ms		Y
			3319	3.1	16	Roll Angle	The angle between the vehicle y-axis and the ground plane. (-64 to 64.51 deg)	10 ms		Y
	65281	N/A	-	5.1	16	Inclination	Fore/Aft Slope. Tx 0x7FFF when data not avail (-3,276.8 to 3276.8 deg)	10 ms		N
Steering Angle	61451	Electronic Steering Control	2927	1.1	16	Actual Inner Wheel Steering Angle	Signal which indicates the actual inner wheel steering angle. See Figure SPN2927_A for explanation of positive and negative angles. (-125 to 125 deg)	20 ms		Y

	65312	N/A	-	3.1	16	Steering Angle	Steering Angle. Tx 0x7FFF when data not avail (-900 to 900)	50 ms		N
Payload	64872	Gross Combined Vehicle Weight	417	1.1	24	Gross Combined Weight	Total weight of the truck and all the trailers with on-board scales. (0 to 32,899,070 kg)	On request		Y
	65281	N/A	-	3.1	16	GVW	Current Estimate of Gross Vehicle Weight. Tx 0xFFFF when data not avail (0 to 6,553.5 mT)	10 ms		N
	64996	Equipment Performance Data	2600	1.1	8	Payload Percentage	The current payload of the equipment, reported as a percentage of the equipment's rated payload limit. (0 to 250 %)	500 ms		Y
			2400?	8.5	2	<PGN-SPN don't match -- typo>	<PGN-SPN don't match -- typo>	As requested		Y
Traction Control Slip Status	61441	Electronic Brake Controller 1	1793	6.7	2	ATC/ASR Information Signal	This parameter commands the ATC/ASR driver information signal, for example a dash lamp: 00 Off 01 On 10 Reserved 11 Take no action	100 ms		Y
	65282	N/A	-	4.1	1	Spin/Slide Enabled	Spin/Slide Feature Enabled	10 ms		N
			-	4.2	1	Spin/Slide Status	Spin/Slide Actively Working	10 ms		N
	61443	Electronic Engine Controller 2	-	N/A	N/A	N/A	N/A	50 ms		Y
	61440	Electronic Retarder Controller 1	-	N/A	N/A	N/A	N/A	100 ms		Y
Machine Type**	65280	N/A	-	2.1	8	Machine Model	Indicates xxx product line (0 to 255)	1 s		N
	65283	N/A	-	N/A	N/A	jNmt Alive & Machine ID	Machine id (type of engine, variant etc …)	1000 ms		N
Machine State**	65281	N/A	-	7.1	8	Accelerator Pedal (%)	Accelerator Pedal Application. Tx '0xFF' when data not available (0 to 100 %)	10 ms		N
		N/A	-	8.1	8	Retarder Application (%)	Dynamic Retarder Application. Tx '0xFF' when data not available (0 to 100 %)	10 ms		N
	65282	N/A	-	8.1	8	Service Brake Application (%)	Service Brake Application. Tx '0xFF' when data not available (0 to 100 %)	10 ms		N
		N/A	-	4.3	1	Forward True	Actual Wheel Direction Forward	10 ms		N
		N/A	-	4.4	1	Reverse True	Actual Wheel Direction Reverse	10 ms		N
		N/A	-	4.5	1	Retard Mode Active	Drive System Retard Mode Active	10 ms		N
		N/A	-	4.6	1	Propel Mode Active	Drive System Propel Mode Active	10 ms		N
		N/A	-	4.7	1	Cruise Control	Cruise Control Engaged	10 ms		N
		N/A	-	5.4	1	Service Brake Set	Service Brake Pressure Switch	10 ms		N
		N/A	-	5.6	1	Brake Lock Set	Rear Wheel Service Brake Lock for Load/Dump	10 ms		N
		N/A	-	5.8	1	Dump Body Down	Dump Body Position Switch	10 ms		N
	61440	Electronic Retarder Controller 1	-	N/A	N/A	<Whole PGN>	<Whole PGN>	100 ms		Y
	TBD	OEM Machine Status	-	N/A	1	Machine Cutter Status	N/A	200 ms		N
			-	N/A	2	Machine Tram Status	N/A	200 ms		N
			-	N/A	1	Machine Pump Status	N/A	200 ms		N
			-	N/A	1	System Override	N/A	200 ms		N
	65274/ 65265	Brakes/ (Cruise Control/ Vehicle Speed	619/70	N/A	2	Park Brake Actuator Or Parking Brake Switch	Signal which indicates the current state of the actuator(s) that control the parking brake (see also SPN 70). 00 - Parking brake actuator inactive 01 - Parking brake actuator active 10 - Error	200 ms		Y

							11 - Not available or Switch signal which indicates when the parking brake is set. In general the switch actuated by the operator's park brake control, whether a pedal, lever or other control mechanism. (See also SPN 619) 00 - Parking brake not set 01 - Parking brake set 10 - Error 11 - Not available			
	65192	Articulation Control	1120	N/A	1	Articulation Angle	Angle of deflection of an articulated transit vehicle. A right turn is indicated with a positive angle and a left turn is indicated with a negative angle. (-125 to 125 deg)	200 ms		Y
	761448	Hydraulic Pressure Governor Info	1762	N/A	2	Hydraulic Pressure	Hydraulic pressure measured at the output of the hydraulic pump. (0 to 128,510 kPa)	200 ms		Y

*J1939-71 defines a number of signals for acceleration/velocity/brake manipulation and status. Further definition of signal propagation and system responsibilities required
**Needs explicit definition
*** Removed proprietary information

8 Proposed Hardware

SAE J1939-19 describes an Off-Board Diagnostics Connector based on a Deutsch HD-10-9-1939.

Figure 4 Deutsch HD10-9-1939 connector

To Be Discussed – is this appropriate or desirable?

9 Unresolved Issues

The following issues are to be resolved by the working group in future iterations of this document. The resolution of these items should be documented, and the issue in question then removed from this section.

1. **Redundant physical wires**
   One issue in the application of this protocol to the general mining industry will be the compatibility with both existing equipment as well as new equipment. On older machines without control systems or CAN bus, consideration should be made for the definition of a hard wired, lower level implementation of the critical components of this data transfer. Considerable effort went into this task in previous ACARP project C22012.

2. **Heartbeat**
   Timing discussions should incorporate the use of the bi-directional transfer of heartbeat, or system health, using the “Machine State” (OEM->PDS) and “Health” (PDS->OEM) messages.

3. **Decision/accountability**
   This protocol in its current state is facilitating the transfer of several critical pieces of information between OEM and PDS. This inherently limits the implementation of the “rules” layer, or decision system, to reside within the PDS system. Referring again back to C22012, there was general agreement that this functionality may be implemented by either PDS, OEM, or indeed a third party, and as such the protocol should define messages between each of these system components.

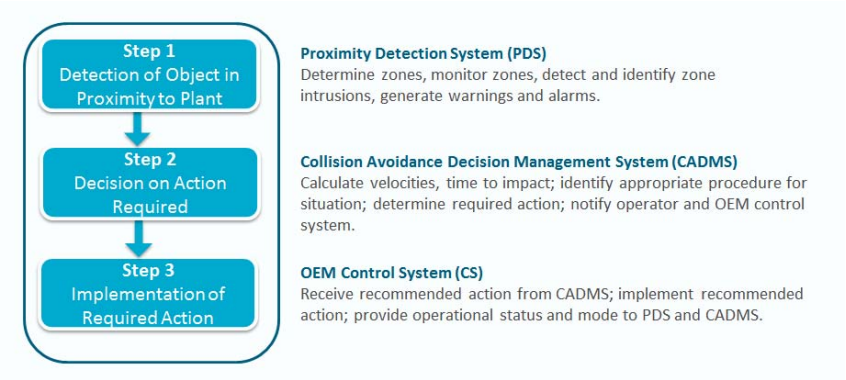


Figure 5 C22012 system analysis

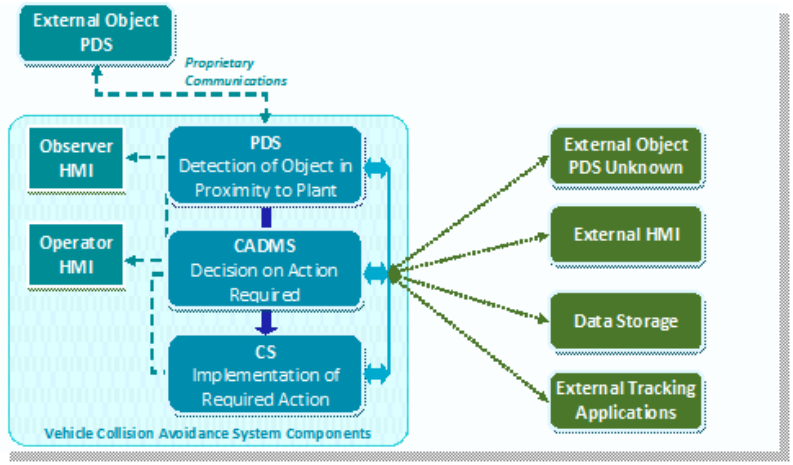


Figure 6 ACARP C22012 system model

4. Data Logging

The data logging requirements for a system do not belong in the communication protocol, however this should be addresses as a part of system requirements.

5. Protocol limitation concerns

The use of J1939 at this time provides short term advantages in the form of ease of implementation, however it is envisaged that there are a number of future scenarios that will be limited by this protocol:

- Off vehicle communications (v2v, back to base)
- Multiple systems on-vehicle
- Sites with a mixed fleet (either different vehicles or different PDS)

This is especially problematic in the assumption that only a single PDS system will be on board any given vehicle. As an example, it was found in the Shovel SLAP project that 3 different technologies with different failure modes were required to raise the system confidence to the appropriate level. This could also be a conceivable outcome with this technology, with multi-vendor solutions required.

6. Protocol standardisation concerns

It is not clear that the request/reply messaging protocol defined in this document fits with the basic definition of J1939. Independent advice will be sought on this issue, however there is a risk that considerable rework will need to be undertaken if this methodology is not consistent with the architecture.

Also, from the definitions in this document:

- The resolution and range cannot actually be correct. 0xFA = 250, but the 0xFA cannot be used as it is being used for the **GENERAL FAULT** indication.
- The use of a 'user configurable field' is contrary to the very concept of clear, well defined, open architecture protocol definitions.

10 Roadmap to Extensibility

This protocol document is defining the “Vehicle Interface” in the diagram below – a method of communicating between the vehicle control system and a proximity detection system. This will be implemented on a single vehicle, between a single PDS technology and the Vehicle control system.

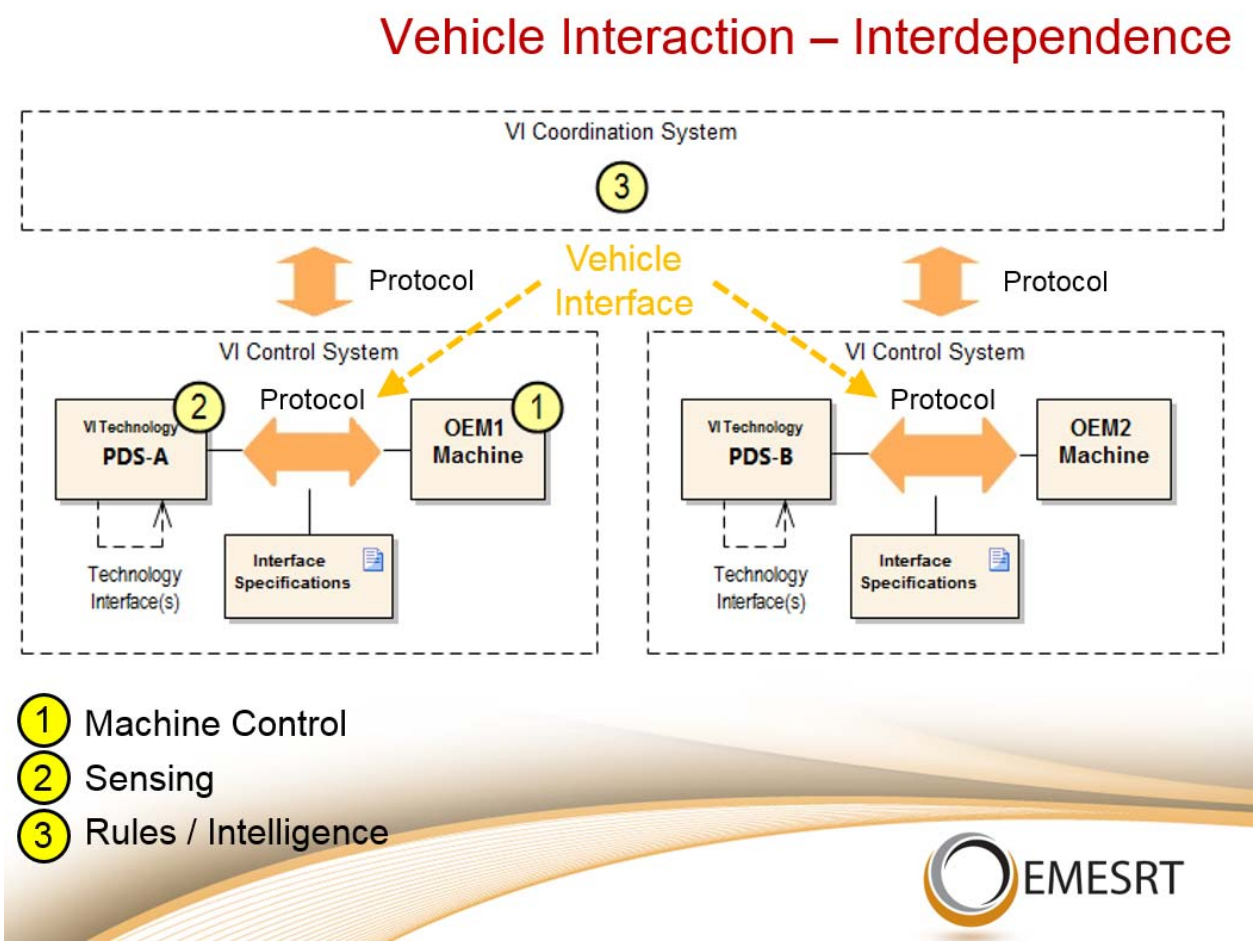


Figure 7 Suggested EMESRT system architecture

Future work will need to be undertaken by the EMESRT group to define the methodology for the higher levels of interfaces required. This in no way implies the need for distribution of commercial or sensitive information from the OEMs or OTMs; it is simply an acknowledgement that there are certain items of information that can be gathered from various sources that will make the system as a whole more efficient and capable of operation at a higher level.

Additionally, the 12 data items that have been identified by the EMESRT group as the high-priority targets will need to be extended to cover the suite of scenarios that have been identified as high-risk for the end users.

11 Conclusions

As of March 2016, there are a number of action items that will be undertaken as part of the EMESRT process:

1) Members to take back this work to the businesses, confirm or suggest changes within 2 weeks
2) Members to submit considerations for a charter paragraph for the group
3) A Webinar in May 2016 to:
    a. Endorse the protocol as it exists at that point
    b. Finalise the charter developed to reflect the intentions of the group
4) Approach SAE contact to initiate discussions on formalising this protocol
5) Independent review of the functional safety aspects, including
    a. Consideration of functions vs residual risk
    b. Definition of a method of assessing functional safety at the system level
    c. Consideration of the abuse cases, i.e. if the operator touches the brake, does it return control from the PDS to the operator?
6) EMESRT will attempt to facilitate beyond bench testing with appropriate minesites where possible
7) An open webinar is scheduled for early April to disseminate progress and directions to the wider community

This ongoing work will be carried out by a subcommittee of the EMESRT representatives.

The EMESRT workshops to date have culminated in the creation of this document, as agreed by representatives from mining companies, OEMs, and Proximity Detection System (PDS) vendors, to establish a common protocol for communications between PDS and OEM devices in the mining industry. Furthermore, it was resolved that, due to its familiarity and broad industry acceptance, the preferred basis for the protocol should be the J1939 standards as established by the Society of Automotive Engineers (SAE).

This report provides an overview of the J1939 protocol in light of the vehicle interaction requirements defined by EMESRT. The EMESRT workshop also defined a set of fundamental signals or messages between the PDS and OEM systems that would be required for compliance with the proposed industry standard: these signals, and the J1939 protocol messages necessary to implement them, are documented.

Some key issues remain to be addressed as part of the implementation process, that indicate serious concerns with the long term viability of the chosen platform

Appendix A J1939 standards list

http://store.sae.org/j1939/contents/

J1939_201308
Serial Control and Communications Heavy Duty Vehicle Network - Top Level Document
J1939/1_201211
On-Highway Equipment Control and Communication Network
J1939/11_201209
Physical Layer, 250 Kbps, Twisted Shielded Pair
J1939/13_201110
Off-Board Diagnostic Connector
J1939/14_201110
Physical Layer, 500 Kbps
J1939/15_201405
Physical Layer, 250 Kbps, Un-Shielded Twisted Pair (UTP)
J1939/15_201508
Physical Layer, 250 Kbps, Un-Shielded Twisted Pair (UTP)
J1939/16_201510
Automatic Baud Rate Detection Process
J1939/2_201303
Agricultural and Forestry Off-Road Machinery Control and Communication Network
J1939/21_201504
Data Link Layer
J1939/3_200812
On Board Diagnostics Implementation Guide
J1939/3_201511
On Board Diagnostics Implementation Guide
J1939/31_201404
Network Layer
J1939/5_201204
Marine Stern Drive and Inboard Spark-Ignition Engine On-Board Diagnostics Implementation Guide
J1939/71_201506
Vehicle Application Layer
J1939/73_201307
Application Layer - Diagnostics
J1939/73_201508
Application Layer - Diagnostics
J1939/73_201601
Application Layer - Diagnostics
J1939/74_201011
Application - Configurable Messaging
J1939/74_201509
Application - Configurable Messaging
J1939/75_201105
Application Layer - Generator Sets and Industrial
J1939/75_201511
Application Layer - Generator Sets and Industrial
J1939/81_201106
Network Management
J1939/82_201506
Compliance
J1939/84_201502
OBD Communications Compliance Test Cases for Heavy Duty Components and Vehicles
J1939/84_201601
OBD Communications Compliance Test Cases for Heavy Duty Components and Vehicles
J1939DA_201505
J1939 Digital Annex
J1939DA_201508
J1939 Digital Annex
J1939DA_201510
J1939 Digital Annex

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