Recommended Practice for a
Serial Control and Communications Vehicle Network

J1939 Committee Draft

October 2, 1999

Table of Contents

Recommended Practice for a
Serial Control and Communications Vehicle Network

J1939

Forward

This series of SAE Recommended Practices has been developed by the Truck & Bus Control and Communications Network Subcommittee of the Truck & Bus Electrical & Electronics Committee. The objectives of the subcommittee are to develop information reports, recommended practices and standards concerned with the requirements, design, and usage of ECUs which transmit electrical signals and control information among vehicle components. The usage of these Recommended Practices is not limited to truck and bus applications; other applications may be accommodated with immediate support being provided for construction and agricultural equipment, and stationary power systems.

These SAE Recommended Practices are intended as a guide toward standard practice and are subject to change so as to keep pace with experience and technical advances.

The Controller Area Network (CAN) protocol described in these Recommended Practices is the intellectual property of Robert Bosch GmbH (Bosch).   Bosch will grant a license to any company which intends to manufacture or design CAN ECUs. ONLY the manufacturer of the integrated circuit containing the CAN protocol or implementers of the CAN protocol in software must deal with the copyright license process. The user of the CAN protocol does not require a license. Licensing information and applications can be obtained at the following address:

> Robert Bosch GmbH
> Attn: Licensing Department
> PO Box 106050
> D-70049 Stuttgart
> Federal Republic of Germany

These Recommended Practices are being generated to continue the work accomplished by the J1708, J1587, and J1922 Recommended Practices. The J1939 series of Recommended Practices will offer a higher performance alternative to these earlier documents.

1. Scope

These Recommended Practices are intended for light, medium, and heavy duty vehicles used on or off road as well as appropriate stationary applications which use vehicle derived components (e.g. generator sets). Vehicles of interest include, but are not limited to: on and off highway trucks and their trailers; construction equipment; and agricultural equipment and implements.

The purpose of these Recommended Practices is to provide an open interconnect system for electronic systems. It is the intention of these Recommended Practices to allow Electronic Control Units to communicate with each other by providing a standard architecture.

1.1   Degree of Openness

A J1939 network is open to the degree that any two ECUs which conform to the same J1939/0*X* document can be connected via the network and communicate with each other without functional interference. The J1939/0X dcouments describe a specific type of application, typically representing a specific industry to which it pertains such as agricultural or heavy duty trucks. ECUs which conform to a different J1939/0*X* document may not be capable of communicating directly with one another and in some cases may cause degradation or complete disruption of the entire network.

1.2   Proof of Compliance

There is no procedure presently in place to test, validate, or provide formal approval for ECUs utilizing the J1939 network. Each developer is expected to design their products to the spirit of, as well as the specific content of, this recommended practice. Provisions are made in J1939/11 and J1939/12 for self certification to these documents. In the future, it is hoped that procedures will be defined and implemented to test new products to ensure full compliance with all appropriate J1939 documents. Until that time, compliance will be honorarily determined. Should questions arise regarding the use or interpretation of any part of these recommended practices they should be directed to the SAE Control and Communications Subcommittee for resolution.

2.   References

2.1   Publications

ISO 7498	Information Processing Systems - Open Systems Interconnection (OSI) - Basic Reference Model.
ISO 11898	Road Vehicles — Interchange of Digital Information — Controller Area Network (CAN) for High Speed Communication, December 1992
ISO 11992	Road Vehicles - Electrical Connections Between Towing and Towed Vehicles - Interchange of Digital Information (Parts 1, 2, 3)
SAE J1213	Glossary of Automotive Electronic Terms
SAE J1708	Recommended Practice for Serial Data Communication Between Microcomputer Systems in Heavy Duty Vehicle Applications.
SAE J1587	Recommended Practice for Electronic Data Interchange Between Microcomputer Systems in Heavy Duty Vehicle Applications
SAE J1922	Powertrain Control Interface for Electronic Controls Used in Medium and Heavy Duty Diesel On-Highway Vehicle Applications

SAE publications are available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001. ISO publications are available from ANSI, 11 West 42nd Street, New York, NY 10036.

2.2   Definitions and Abbreviations

Definitions provided herein will supersede those contained in SAE J1213. SAE J1213 will otherwise apply throughout.

2.2.1   Definitions

Acknowledgment (ACK) — Confirms that the requested action has been understood and performed.

Address — The 8 bit field (or fields) used to define the source (and destination when applicable) of a message (e.g. engine, transmission, etc.).

Arbitration — The process by which one or more ECUs resolve conflicts in obtaining access to a shared network bus.

Bit Stuffing — A procedure used to assure the transmitted and received messages maintain a minimum number of dominant to recessive edges, and vise versa, to maintain the proper resynchronization within the string of bits in a CAN Data Frame. See CAN specification for a more detailed discussion.

Bridge — A device which stores and forwards messages between two J1939 network segments.   This permits changes in the media, the electrical interface, and data rate between segments. The protocol and address space remain the same on both sides of the bridge. Note that a bridge may selectively filter messages going across it so that the bus load is minimized on each segment.

Bus — See Segment.

CAN Data Frame — The ordered bit fields necessary to create a CAN frame used to convey data, beginning with an SOF and ending with an EOF.

Cyclic Redundancy Check (CRC) — An error control mechanism. A 15 bit cyclic redundancy check is performed for detecting transmission errors.   Given a k-bit frame or message, the transmitter generates an n-bit sequence, known as a frame check sequence so that the resulting frame, consisting of $k + n$ bits is exactly divisible by some predefined number. The receiver then divides the incoming frame by the same number and, if there is no remainder, assumes that there was no error.

Data Field — A 0 to 64-bit field normally placed in a CAN data frame which contains the data as defined in the Application Layer (document J1939/7X).

Data Page — One bit in the Identifier portion of the CAN Arbitration Field is used to select one of two pages of Parameter Group Numbers. This provides for the future growth of Parameter Group definitions. It also is one of the fields used to determine the Parameter Group Number which labels the data field of the CAN Data Frame.

Destination Address (DA) — This is a Protocol Data Unit (PDU) specific field in the 29 bit CAN identifier used to indicate the address of the ECU intended to receive the J1939 message.

Device — A physical component with one or more ECUs and network connections.

Electronic Control Unit (ECU) — A computer based electronic assembly from which J1939 messages may be sent or received.

End of Frame (EOF) — A 7 bit field marking the ending of a CAN data frame.

Extended Frame — A CAN data frame using a 29 bit identifier as defined in the CAN 2.0 specification.

Frame — A series of data bits making up a complete message. The frame is subdivided into a number of fields, each field containing a predefined type of data. See CAN Data Frame

Function — A capability of a vehicle system having one or more ECUs that are connected to a J1939 bus segment of a Vehicle System. The function value is used in the 8 bit Function field in the 64 bit NAME entity (See J1939/81, Section 4.1)

Gateway — This device permits data to be transferred between two networks with different protocols or message sets. The gateway provides a means to repackage parameters into new message groups when transferring messages from one segment to another.

Group Extension (GE) — This is a PDU specific field of a J1939 CAN Data Frame that is used as part of the information necessary to determine the Parameter Group Number.

Identifier — The identifier portion of the CAN arbitration field.

Idle — A state on the CAN bus where no node is transmitting or attempting to transmit data.

Implement — A machine consisting of one or more ECUs which may be attached to or detached from the vehicle as a unit.

Media — The physical entity which conveys the electrical transmission (or equivalent means of communication) between ECUs on the network. For J1939/11, the media consists of shielded twisted pair copper wires.

Message — A "message" is equivalent to one or more "CAN Data Frames" that have the same Parameter Group Number. For instance the information related to a single Parameter Group Number to be transferred on the bus may take several CAN data frames.

Multipacket Messages — A type of J1939 message which is used when more than one CAN data frame is required to transmit all data specific to a given Parameter Group Number. Each CAN data frame will have the same identifier but will contain different data in each packet.

NAME - An 8 byte value which uniquely identifies the primary function of an ECU and its instance on the network. A device's NAME must be unique, no two devices may share the same NAME value on a given vehicle network.

Node — A specific hardware connection of an ECU to the physical media. A specific node may have more than one address claimed on the network.

Non-Volatile — Retention of changeable memory values even though power is turned off for any reason. This term is used with respect to data values, such as ECU addresses or NAMEs, that are changed during use. Read Only Memory (ROM) is technically non-volatile, but is not changeable during use and thus not what is referred to in these documents.

Negative-Acknowledgment (NACK) — A response which indicates that a message has not been understood or a requested action could not be performed.

Packet — A single CAN data frame. This can also be a message if the Parameter Group to be transferred can be expressed in one CAN data frame.

Parameter Group (PG) — A collection of parameters that are conveyed in a J1939 message. Parameter Groups include commands, data, requests, acknowledgments, and negative-acknowledgments. The PG identifies the data in a message, regardless of whether it is a single packet or multipacket message. Parameter Groups are not dependent on the source address field thus allowing any source to send any Parameter Group.

Parameter Group Number (PGN) — A three byte, 24 bit, representation of the Reserved Bit, Data Page, PDU Format, and GE fields. The Parameter Group Number uniquely identifies a particular Parameter Group.

PDU Format (PF) — An 8 bit field in the 29 bit identifier that identifies the PDU format and is used in whole or in part to provide a label for a Parameter Group. It also is one of the fields used to determine the Parameter Group Number which labels the data field of the CAN Data Frame.

PDU Specific (PS) — An 8-bit field in the 29 bit identifier whose definition depends upon the value of the PDU Format field. It can be either a destination address (DA) or Group Extension (GE). It also is one of the fields used to determine the Parameter Group Number which labels the data field of the CAN Data Frame.

PDU1 Format — A PDU format used for messages that are to be sent to a destination address (DA). The PS field contains the destination address (specific or global).

PDU2 Format — A PDU format used to send information that has been labeled using the Group Extension technique. This PDU does not contain a destination address. The PS field contains the Group Extension in the case of PDU2 formats.

Preferred Address — The address that an ECU will attempt to use first when claiming an address. Preferred Addresses are assigned by the committee.

Priority — A 3-bit field in an identifier that establishes the arbitration priority of the information communicated. The highest priority is zero and the lowest priority is seven.

Protocol Data Unit (PDU) — A PDU is a J1939 specific CAN Data Frame format.

Remote Transmission Request (RTR) — A feature of the CAN protocol allowing an ECU to request that another ECU or ECUs send a message. This feature of CAN is not used in J1939. An alternate request mechanism is specified for J1939.

Repeater — An ECU which regenerates the bus signal onto another segment of media. This permits the network to connect more electrical loads (ECUs) onto the bus, or to connect to another type of media (Physical Layer Expansion). The speed (data rate), protocol (data link layer), and address space are the same on both sides of the repeater. For J1939, any delays in regenerating the data signal must be kept to a very small fraction of one bit interval.

Reserved Bit —A bit in a J1939 29 bit identifier reserved for future definition by SAE. It also is one of the fields used to determine the Parameter Group Number which labels the data field of the CAN Data Frame.

Router— An ECU which allows segments with independent address spaces, data rates, and media to exchange messages. A router may permit each segment to operate with minimum bus loading yet still obtain critical messages from remote segments. The protocol remains the same across all segments. Note that the router must have look up tables to permit the translation and routing of a message with ID X on segment 1 to ID Y on segment 2.

Segment — The physical media and attached nodes of a network not interconnected by network interconnection ECUs. A single segment of a network is characterized by all of the ECUs "seeing" the signal at the same time (i.e., there is no intermediate ECU between electrical sections of the network). Multiple segments can be connected together by network interconnection ECUs including repeaters, bridges, and routers.

Source Address (SA) — An 8-bit field in the 29 bit identifier which allows for the unique identification of the source of a message. The SA field contains the address of the ECU that is sending the message.

Standard Frame — A CAN data frame using an 11 bit identifier as defined in the CAN 2.0b specification.

Start of Frame (SOF) — The initial bit in a CAN frame serving only to indicate the beginning of the frame.

Subnetwork — This refers to the network activity (message traffic) on a specific J1939 segment when multiple segments are used. Subnetworks may include: Tractor; Trailer, Implement, and Braking System. Note that they may be separated by a bridge or router to minimize total bus loading. Collectively the subnetworks are the J1939 Vehicle Network.

Vehicle — A machine which, in most applications, includes a capability to propel itself and includes one or more J1939 segments. A vehicle may be assembled of one or more Vehicle systems which are connected together to form the whole vehicle.

Vehicle System — A subcomponent of a vehicle, or a component that is analogous to a subcomponent of a vehicle, that includes one or more J1939 segments and may be connected or disconnected from the vehicle. A Vehicle System may be made up of one or more Functions, which have ECU's that are connected to a J1939 segment of the Vehicle System.

2.2.2 Abbreviations

ABS   Antilock Braking System
ACK   Acknowledgment
AP   Accelerator Pedal
ASR   Acceleration Slip Regulation (Traction Control)
ASCII   American Standard Code for Information Interchange
CAN   Controller Area Network
Con-Ag Construction-Agriculture Industry
CRC   Cyclic Redundancy Check
DA   Destination Address
DLC   Data Length Code
DP   Data Page
ECU   Electronic Control Unit
EOF   End of Frame
GE   Group Extension
ID   Identifier
IDE   Identifier Extension Bit
LLC   Logical Link Control
LSB   Least Significant Byte or Least Significant Bit
MAC   Medium Access Control
MID   Message Identifier
MSB   Most Significant Byte or Most Significant Bit
NA   Not Allowed
NA   Not Available
NACK   Negative-Acknowledgment
OSI   Open System Interconnect
P   Priority
PDU   Protocol Data Unit
PF   PDU Format
PG   Parameter Group
PGN   Parameter Group Number
PID   Parameter Identifier
PS   PDU Specific
PS_GE PDU Specific - Group Extension
PS_DA PDU Specific - Destination Address
PTO   Power Take-Off
R   Reserved
RTR   Remote Transmission Request
SA   Source Address
SID   Subsystem Identifier
SLOT   Scaling, Limits, Offset, and Transfer Function
SOF   Start of Frame
SPN   Suspect Parameter Number
SRR   Substitute Remote Request
un   Undefined

2.3   References to the OSI Model:

The Open System Interconnect (OSI) model was developed by the International Organization for Standardization (ISO) in 1984 as a model of a computer communications architecture. There are seven layers to the OSI model as shown in Figure 1. The intent is that protocols be developed to perform the functions of each layer as needed.

J1939 is structured into several parts based on this ISO Model. While there is a J1939 document allocated to each layer, not all of them are explicitly identified by having their own J1939 document. Some of the layers not having their own documents are supported by functionality included within other documents.

OSI NETWORK
MODEL LAYER

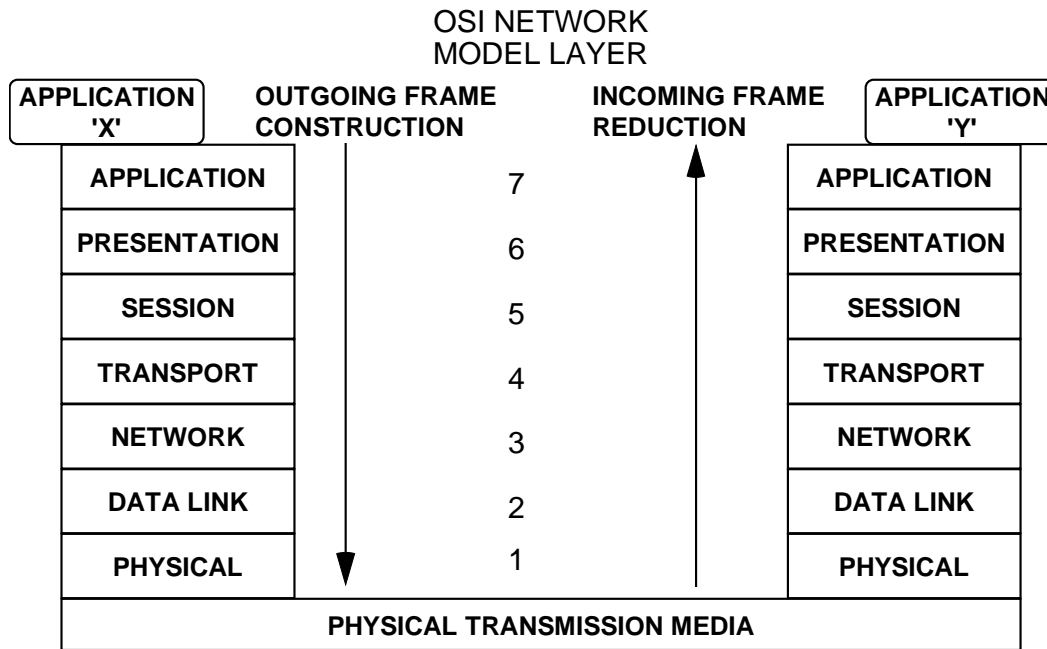| APPLICATION 'X'	OUTGOING FRAME CONSTRUCTION	INCOMING FRAME REDUCTION	APPLICATION 'Y'
APPLICATION	7		APPLICATION
PRESENTATION	6		PRESENTATION
SESSION	5		SESSION
TRANSPORT	4		TRANSPORT
NETWORK	3		NETWORK
DATA LINK	2		DATA LINK
PHYSICAL	1		PHYSICAL
PHYSICAL TRANSMISSION MEDIA			

FIGURE 1 - The OSI Seven Layer Model

The functionality of each layer is:

1. Physical — Concerns the transmission of structured bit stream over physical media; deals with the mechanical, electrical, functional, and procedural characteristics to access the physical media
2. Data Link — Provides the reliable transfer of information across the physical layer; sends blocks of data (frames) with the necessary synchronization, error control, sequence control, and flow control;
3. Network — Provides upper layers with independence from the data transmission and switching technologies used to connect systems; responsible for establishing, maintaining, and terminating connections;
4. Transport — Provides reliable, transparent transfer of data between end points; provides end-to-end error recovery and flow control; provides segmentation and reassembly of very large messages;
5. Session — Provides the control structure for communication between applications; establishes, manages, and terminates connections (sessions) between cooperating applications;
6. Presentation — Provide independence to the application process from differences in data representation (syntax); and
7. Application — Provides access to the OSI environment for users and also provides distributed information services.

The purpose of the OSI model is to provide a common basis for coordinating standards development by placing them within the perspective of the overall model. Any resulting standard, such as J1939, is not required to be explicitly partitioned into these seven layers as long as the fundamental functionality is supported. In addition, the hardware and software which perform the functions of each layer need not be rigidly defined such that each layer is recognizable within the system design. The distinction between layers can become totally obscured upon

allocating these functions to a specific system design. In reviewing the J1939 layer documents, it can be seen that some J1939 layers include some functions normally associated with other OSI layers. This usually occurs when a layer may not require, or justify having, a standalone document of its own.

Because the J1939 network is a specific communications system, supporting specific sets of applications and a specific industry, rather than being generalized, not all of the OSI layers are required. Only those layers which are required for the anticipated J1939 uses will be defined, with a separate document being used for each of these layers.

2.4   Documentation Structure and Guide

This J1939 document is merely the top level of a hierarchy of related documents. A separate document, identified as J1939/*N*, has been defined for each application of the network and for each of the seven OSI model layers. To accommodate multiple versions of any one layer, a second slash digit (*X*) is used to identify the version of a document. Thus to determine the total network definition for a particular application, such as for North American agricultural equipment, one must obtain the top level application document, J1939/02, which identifies all of the layer versions used, and then obtain each of these individual layer documents. The presently defined documents and numbering system are as follows:

J1939   This top level document describes the network in general, the OSI layering structure, the subordinate document structure, and provides control for all preassigned values and names.

J1939/0*X*   An application document, where *X* refers to a specific network/application version of the network. This document will identify the industry or applications for which it pertains and will list the specific versions of each layer that makes up this network.
  J1939/01 (Draft)   Truck and Bus Control and Communications Network.
  J1939/02 (Draft)   Agricultural Equipment Control and Communications Network.

J1939/1*X*   A Physical Layer document, where *X* refers to a specific version of the Physical Layer.
  J1939/11   Physical Layer, 250K Bits/sec, Shielded Twisted Pair.
  J1939/12 (Draft)   Physical Layer, 250K Bits/sec, Twisted Quad.
  J1939/13 (Draft)   Physical Layer, Diagnostic Connector

J1939/21   Data Link Layer (no alternative versions permitted)

J1939/3*X*   Network Layer document, where *X* refers to a specific version of the Network Layer.
  J1939/31   Network Layer,

J1939/4*X*   Transport Layer document, where *X* refers to a specific version of the Transport Layer. No Transport Layer documents are presently defined.

J1939/5*X*   Session Layer document, where *X* refers to a specific version of the Session Layer. No Session Layer documents are presently defined.

J1939/6*X*   Presentation Layer document, where *X* refers to a specific version of the Presentation Layer. No Presentation Layer documents are presently defined.

J1939/7*X*   Applications Layer Document, where *X* refers to a specific version of the Application Layer.
  J1939/71   Vehicle Application Layer.
  J1939/72 (Draft)   Virtual Terminal Application Layer.
  J1939/73   Application Layer - Diagnostics.

J1939/81   J1939 Network Management Protocol (no alternative versions permitted).
J1939/82 (Draft) Compliance

Document numbers have been assigned to all seven of the OSI model layers even though they are not all specifically defined within the present definition of J1939. This was done in part to provide an easily recognizable relationship between the documents and the OSI model and also to provide growth capabilities should it be determined later that such documents are needed. J1939/81, Network Management, is kept separate as it represents a vertical slice through all of the layers and is thus best explained and understood as an individual subject rather than include a subset of network management within each of the affected layers.

Multiple application layer documents may be utilized simultaneously on the same network and thus must maintain compatibility. An example of such a system is a piece of agricultural equipment that utilizes both J1939/71 for the majority of communications and J1939/72 for the display terminal communications, both sets of messages being carried over the exact same network. A single vehicle/application may also utilize different physical layers within the same system but they need not be compatible if on different segments. An example is on-highway trucks where the physical layer used to connect the tractor to the trailer may be different than that used on the tractor itself.

3.   Technical Requirements

Beyond being an introduction to the full set of J1939 documents, this document is meant to aid those unfamiliar with J1939 by answering the most basic questions of:

- · How J1939 is intended to work
- · How to construct and process messages (transmit and receive)
- · How to design an ECU to support J1939
- · How typical control sequences are done (application examples)
- · How a typical network is wired

3.1   J1939 Tutorial

The following tutorial is for the Truck and Bus Control and Communications Network as specified in J1939/01. J1939/01 is used in this tutorial as a typical example, and not to infer that all applications must follow J1939/01. Other applications may elect to utilize alternative versions of one or more layers resulting in corresponding changes to the following discussion. This section is offered as a means of illustrating and clarifying the network, not as a definition of it. See the individual sub documents, J1939/0*X* to J1939/81 for the correct definition and specification of each aspect of the network.

3.1.1   Introduction

J1939 is a high speed communications network designed to support real-time closed loop control functions between ECUs which may be physically distributed throughout the vehicle. J1708/J1587 is an older, widely used low speed network intended to provide simple information exchange, including diagnostic data, between ECUs. J1939 is capable of performing all of the functions of J1708/J1587 as well as the control system support. Any one application may utilize one or the other or both of these networks.

J1939 uses the CAN protocol which permits any ECU to transmit a message on the network when the bus is idle. Every message includes an identifier which defines the message priority, who sent it, and what data is contained within it. Collisions are avoided due to the arbitration process that occurs while the identifier is transmitted (using a non-destructive arbitration scheme). This permits high priority messages to get through with low latency (delay) times because there is equal access on the network for any ECU, but when multiple ECUs are simultaneously attempting to transmit, the highest priority message prevails.

3.1.2 Message Format and Usage (J1939/21 for 29 Bit Identifier)

J1939 provides a complete network definition using the 29 bit identifier (CAN Extended Frame) defined within the CAN protocol shown in Figure 2. J1939/21 enables 11 bit identifier (CAN Standard Frame) devices to be used within the same network, defining all messages as proprietary, permitting both device types to coexist without interference. The 11 bit identifier definition is not directly a part of J1939 but is included to assure that users of it can coexist on the same network without conflict. J1939 will not provide any further definition of the use of the 11 bit identifier. The CAN Data Frame Bits SOF, SRR, IDE, and RTR bits will not be discussed in the following description (see J1939/21 and ISO 11898). The first 3 bits of the 29 bit identifier are used for determining message priority during the arbitration process. A value of 000 has the highest priority. Higher priority messages would typically be used for high speed control messages. An example of this is the torque control message from the transmission to the engine (see J1939/71). A lower priority would be used for data which is not time critical. An example of this is the engine configuration message. The priority field may be programmable for each message type so that network tuning can be performed by an OEM if necessary.

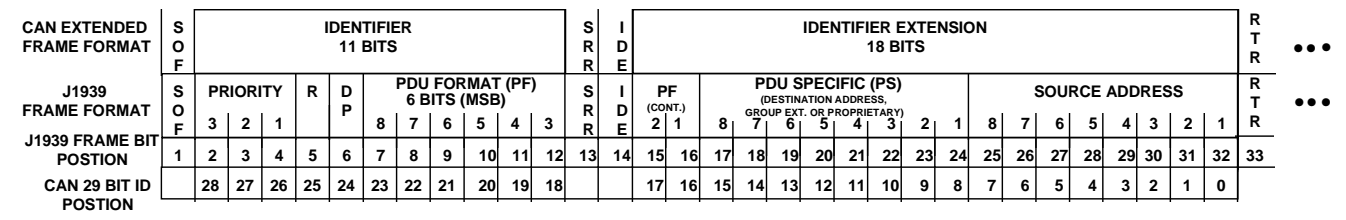|	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	
CAN EXTENDED FRAME FORMAT	SOF	IDENTIFIER 11 BITS											SRR	IDE	IDENTIFIER EXTENSION 18 BITS																		RTR	•••
J1939 FRAME FORMAT	SOF	PRIORITY			R	DP	PDU FORMAT (PF) 6 BITS (MSB)						SRR	IDE	PF (CONT.)		PDU SPECIFIC (PS) (DESTINATION ADDRESS, GROUP EXT. OR PROPRIETARY)								SOURCE ADDRESS								RTR	•••
		3	2	1			8	7	6	5	4	3			2	1	8	7	6	5	4	3	2	1	8	7	6	5	4	3	2	1		
J1939 FRAME BIT POSTION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	
CAN 29 BIT ID POSTION		28	27	26	25	24	23	22	21	20	19	18			17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0		

FIGURE 2, The J1939 29 Bit Identifier.

The next bit of the identifier (R) is reserved. The bit should be set to 0 for transmitted messages. This default will permit future use of the bit for other purposes as defined by the SAE committee.

The next set of 9 bits in the identifier is the Data Page (DP) bit and PDU Format (PF) field. PDU stands for Protocol Data Unit (i.e. Message Format). The DP bit is used as a page selector. Page 0 contains all the messages which are presently being defined. Page 1 provides additional expansion capacity for the future, to be assigned after page 0 has been completed. The PF field identifies one of two PDU formats able to be transmitted. PDU Formats are described in J1939/21, Section 3.3. The SRR and IDE bits are entirely defined and controlled by CAN and therefore not described or modified by J1939.

The next 8 bits of the identifier are PDU Specific (PS), meaning that they are dependent on the value of the PF. If the PF value is between 0 and 239 (PDU1), this PS field contains a destination address. If the PF field is between 240 and 255 (PDU2), the PS field contains a Group Extension (GE) to the PDU Format. The Group Extension provides a larger set of values to identify messages which can be broadcast to all ECUs on the network.

Most messages on J1939 are intended to be broadcast using the PDU2 format. Data transmitted on the network using PDU2 format cannot be directed to a specific destination. When a message must be directed to a particular ECU, it must have been assigned a PGN in the PDU1 format range of numbers so a specific destination address can be included within the identifier of the message. An example of this is the transmission commanding a specific torque value from the engine or a specific torque value from a retarder. Requiring a destination must be considered when the Parameter Group is first defined and published by the SAE committee (see J1939/21).

Collectively, the Reserved bit,Data Page, PF, and PS values define the PG being transmitted. These PGs have definitions which include the parameter assignments within the 8 byte data field of each message as well as the transmission repetition rate and priority. The term "Parameter Group" is used because they are groups of specific parameters. Parameter Groups are identified by a Parameter Group Number (PGN), which uniquely identifies each Parameter Group. The PGN structure permits a total of up to 8672 different Parameter Groups to be defined

per page. Parameter Groups and Parameter Group Numbers are described in J1939/21 and current assignments are listed in Appendix A.

The last 8 bits of the identifier contain the address of the ECU transmitting the message (Source Address). For a given network, every address must be unique (254 available). Two different ECUs cannot use the same address at the same time. The PGNs are independent of the Source Address, thus any ECU can transmit any message.

3.1.3 Addresses and NAME (J1939/81 and Appendix B)

Each ECU on the network will have at least one name and one address associated with it. There are examples, such as an engine and engine retarder residing in a common ECU, wherein multiple names and multiple addresses may coexist within a single electronics unit. The address of an ECU defines a specific communications source or destination for messages, the name includes identification of the primary function performed at that address and adds an indication of the instance of that functionality in the event that multiple ECUs with the same primary function coexist on the same network. As many as 254 different ECUs of the same function can coexist on the network, each identified by their own address and name.

To uniquely name each ECU, J1939 defines a 64 bit NAME consisting of the fields shown in Table 1. The Function Instance, ECU Instance, and Identity Number fields permit multiple ECUs of the same make and model to coexist on the same network but still have unique NAMEs for each. See J1939/81 for a full description of ECU naming and address assignment and Appendix B for current committee assignments.

Table 1. NAME Fields

Arbitrary Address Capable	Industry Group	Vehicle System Instance	Vehicle System	Reserved	Function	Function Instance	ECU Instance	Manufac turer Code	Identity Number
1 bit	3 bit	4 bit	7 bit	1 bit	8 bit	5 bit	3 bit	11 bit	21 bit

NAMEs identify the primary vehicle function or functions which an ECU performs and uniquely identify each ECU, even when there are more than one of the same type on the network. But with a length of 64 bits, a NAME is inconvenient to use in normal communications. Therefore, once the network is fully initialized, each ECU utilizes an 8 bit address as its source identifier or "handle" to provide a way to uniquely access a given ECU on the network. For example, an engine may be assigned address 0, but if a second engine is present, it needs a separate, unique address (e.g. 1) and instance. ECUs that accept destination specific commands may require multiple addresses. This permits distinguishing which action is to occur. For example, if the transmission is commanding a specific torque value from the engine (address 0), this must be differentiated from commanding a specific torque value from the engine brake (retarder)(address 15). As can be seen by this example, a single ECU on the network may have multiple addresses and each address will have an associated NAME. To facilitate the initialization process of determining the address(es) for each ECU on the network, commonly used devices have Preferred Addresses assigned by the committee (Preferred Addresses are listed in Tables B2 - B9). Using the Preferred Addresses minimizes the frequency of multiple devices attempting to claim the same address.

In general, most ECUs will use their Preferred Addresses immediately upon power up. A specific procedure (defined in J1939/81 and elaborated on in J1939/01) for assigning addresses after powerup is used to resolve any conflicts that may occur. Each ECU must be capable of announcing which address(es) it intends to use. This is the address claim feature. Two options are available:

1) Upon power-up and whenever requested, an ECU must send an Address Claimed message to claim an address. When an ECU sends the Address Claimed message, all ECUs record or compare this newly claimed address to their own table of addresses on the network. Not all ECUs are required to maintain such a table, but all must at least compare the newly claimed address with their own. Should multiple ECUs claim the same address, the one having the lowest value NAME uses this address and the other(s) must claim a different address or stop transmitting on the network.

2) An ECU may send a request for Address Claimed message to determine addresses claimed by other ECUs. When an ECU sends a request for Address Claimed, all requested ECUs then send their Address Claimed messages. This permits transitional ECUs (tools, trailers, etc.) or ECUs powering up late to obtain the current address table so that an available address can be found and claimed or to determine which ECUs are currently on the network. This approach permits the option of self-configurable addresses for those ECUs which may need it, but does not make this a requirement for all ECUs. Self-configurable addressing is optional; those ECUs which might be expected to encounter address conflicts are recommended to support this capability.

When an address conflict has been detected, the following four options are available, depending upon the capabilities of the ECU involved:

Self-Configurable ECUs — a self-configurable ECU is capable of dynamically computing and claiming an unused address. Most service tools and bridges will have this capability.

Command Configurable ECUs — A network interconnection ECU, such as a bridge, or a service tool may command another ECU to use a given address. The ECU having the unclaimable address would then issue an Address Claimed message to acknowledge acceptance of this new commanded address. The ECU may be commanded to accept a new address even though it has already claimed a valid address.

Service Configurable ECUs — ECUs which are modifiable by service personnel, usually by the means of DIP switches or a service tool. When "commanded address" messages are used, his option differs from the Command Configurable in that a service tool is required and will often use proprietary techniques.

Non-Configurable ECUs — Those ECUs that are neither self-configurable nor reprogrammable would have to cease transmitting if they fail to claim a valid address.

3.1.4 Communication Methods

Three primary communication methods exist within J1939 and appropriate use of each type allows effective use of the available Parameter Group Numbers. The three communications methods are:

Destination specific communications, using PDU1 (PF values 0 - 239) (includes the use of the global destination address - 255)
Broadcast Communications using PDU2 (PF values 240 - 255)
Proprietary Communications using either PDU1 or PDU2 format

Each of the communications methods has an appropriate use. Destination specific Parameter Group Numbers are needed where the message must be directed to one or another specific destination and not to both. J1939 currently defines a torque control message which may be sent to an engine or retarder. In the case of more than one engine, this message must be sent only to the desired engine and a destination specific Parameter Group Number is needed and has been assigned.

Broadcast Communications apply in several situations, including:

> Messages sent from a single or multiple sources to a single destination
> Messages sent from a single or multiple sources to multiple destinations

Broadcast Communications cannot be used where a message must be sent to one or another destination and not to both.

The third communications method in J1939, proprietary communications, is provided by the use of two proprietary Parameter Group Numbers. A Parameter Group Number has been assigned for broadcast proprietary communications and a Parameter Group Number has been assigned for destination specific proprietary communications. This allows for two functions. One, a specific source can send its proprietary message in a PDU2 type format (broadcast). Two, it allows for situations where a service tool must direct its communication to a specific destination out of a possible group of ECUs. For instance this case arises when an engine uses more than one controller but the service tool must be able to perform calibration/reprogramming while all ECUs are connected to the same network. In this case the proprietary protocol needs to be destination specific. Note that the destination ECU must be capable of properly interpreting the proprietary data.

Proprietary communications are useful in two situations:

> Where it is unnecessary to have standardized communications
> Where it is important to communicate proprietary information

3.1.5 Transmitting Messages (Using J1939/21 and J1939/7X)

In addition to the 29 bit identifier shown in Figure 2, a CAN Data Frame includes a 6 bit control field, a data field which is typically 8 bytes, and terminates with CRC, ACK, and EOF fields. To send a particular data item, a message must be constructed by properly filling each of these fields. This is done by first referencing the applicable J1939 documents. This process will define the Parameter Group Number (PGN) to use, the message update (transmission) rate, and default priority. Since multiple data items are typically packed together within a message, it will also define the data field format. Note that when the ECU does not have data available for a given parameter it sets those bits to "not available" so that a receiver knows that the data is not provided.

Parameter Groups which have more than eight bytes of data must be sent as multipacket messages using the Transport Protocol functions defined in J1939/21 Section 3.10.

3.1.6 Receiving Messages (Using J1939/21 and J1939/7X)

There are various techniques (and electronic ICs) available for capturing selected messages off the network. Several general observations can be made however regarding received messages.

> 1. If it is a destination specific request or command, the ECU must determine if there is an address match between itself and the incoming messages' destination address. If there is, it must process the message and provide some type of acknowledgment.
> 2. If a message is a global request, every ECU, even the originator, must process it and respond if the data is available.
> 3. If a message is broadcast, each ECU must determine if it is relevant or not.

3.1.7 ECU Design (Using J1939/11, J1939/21, and J1939/7X)

Although every manufacturer will have different performance requirements for the ECU contained within their product, several observations should be made regarding the resources needed to support J1939. The current

data rate of J1939/11 is 250 kbps (400µS/bit). A typical message containing 8 data bytes is 128 bits long (excluding bits used for bit stuffing) which is approximately 0.5 ms. The shortest message is 64 bits long. This means that a new message could be present every 250 microseconds. Even though not every message is relevant, nor is the bus loading likely to be above 50%, the receiving processor must still be able to handle (or buffer) multiple back to back messages. This will require some RAM space as well as processor time for the memory transfers. The requirement is that no messages should be lost due to ECU hardware or software design limitations.

3.1.8 Network Topology — J1939/01 Using Physical Layer J1939/11 and Network Layer J1939/31

The J1939/01 network defines a system containing one or more segments connected by network interconnecting ECUs. Each J1939 segment consists of a single, linear, shielded twisted pair of wires running around a section of the vehicle to each ECU. A short stub is permitted to connect this "bus" to each ECU. This simplifies the routing of the main bus wiring by not requiring it to come in direct proximity with each ECU. The linear bus is necessary at a data rate of 250 Kbps in order to minimize reflections of the electrical signals. The termination resistor at each end of the bus also reduces reflections. To support a tractor pulling one or more trailers, and the frequent removal and addition of new trailers, a separate J1939 segment (subnetwork) is used within the tractor and in each trailer or dolly.

The J1939 network may thus be composed of multiple segments, with a network interconnection ECU (bridge) between them. These segments need not be directly compatible with each other, as they may operate at different data rates or use different physical media. For example, a bridge provides electrical isolation between segments, provides initialization support for the subnetwork connected to it, and can provide message filtering to prevent unnecessary message traffic on the subnetworks. In the event of a bus failure on the wires exposed between the tractor and trailer, the main J1939 subnetwork on the tractor will continue to function.

3.2   Preassigned Values

Application specific parameters and Parameter Groups are defined in the J1939/7*X* documents. Parameter Groups that are used for control and management of the network are defined in J1939/21, J1939/31, and J1939/81. Assignments for Preferred Addresses, NAME elements, and Parameter Group Numbers are maintained in the appendices to this document. Each of these items are described in this section. The actual values that have been assigned are listed in the Appendices. If new values are required that are not already assigned, developers may request new values to be assigned by the SAE Control and Communications Network Subcommittee. Request forms are provided for this purpose in Appendix D. Users of the documents should assure that this base document is newer or has the same revision date as the particular application document they are using to avoid making requests that are obsolete at the time of submittal.

3.2.1 Parameter Group Numbers

Parameter Group Numbers are assigned specifically to use either PDU1 format or PDU2 format (PDU types are described in Section 3.1.2 and in J1939/21, Section 3.3). Once assigned to a format the other PDU type is not available for that Parameter Group. The assignment of a Parameter Group Number should be done keeping in mind the following characteristics: priority, update rate, importance of the data in the packet to other ECUs, and length of the data associated with the Parameter Group. Appendix A includes a template for assigning Parameter Group Numbers and the current assignments.

Parameter Group Numbers are assigned linearly to the various sections of the Parameter Group list in Appendix A based on the criteria provided on the Parameter Group Request form (Appendix D).

Much of the communications between ECUs constructed by a single manufacturer do not require standardization. The information that is communicated is not generally useful to other ECUs on the network. In this situation the proprietary Parameter Groups can be used. The use of standardized communications is preferred and should be used whenever practical, however the proprietary option is offered as a means of solving unique problems and situations.

If proprietary information is being communicated, or the information to be communicated is not of general interest, the proprietary method should be used.   If the information is of general interest and does not require direction of the message to a particular ECU, a Parameter Group Number utilizing the PDU2 broadcast format should be sought. Finally, if the information is of general interest but requires direction to one or another ECUs then destination specific addressing is needed and a PDU1 format Parameter Group Number should be sought. Proprietary and PDU1 communications methods should be considered carefully and used sparingly.

3.2.2 Data Field Grouping

Minimizing message overhead with CAN based systems requires full use of the data fields of messages. Except in the case of very time critical messages, parameters should be grouped to fill the 8 byte data field. Following this principle conserves PGNs for future assignment and allows for minimum network loading when all data bytes are known by and sent from the same address. Strong justification is needed to allow definition of Parameter Group Numbers that result in sparsely used data fields.

Parameters should be grouped as follows:

1. By common subsystem (the ECU likely to measure and send the data)
2. With similar update rates (to minimize unnecessary overhead)
3. By function (Oil, Coolant, Fuel, etc.)

It should be recognized that, while these are guidelines, in most cases when parameters are grouped together they will end up violating one or more of the above rules. Since all parameters defined in J1939 have a technique for identifying when they are not available it is not critical that all of the parameters in one Parameter Group come from the same ECU. If a new parameter is defined and there are spare bytes or bits in an existing Parameter Group, then it can be easily added there. When the update rate is fast, it is desirable to make sure that a Parameter Group is as fully utilized as possible (i.e. uses all 8 data bytes) before defining another PG and preferable that all parameters are normally coming from one specific ECU.

For the slower update rate data it is not as critical that all of the parameters in a Parameter Group come from the same ECU. Even though it is desirable to have parameters come from one ECU, the intention of J1939 is to provide a means for communicating the data and not dictating which ECU is to send what data.

3.2.3 NAME Systems and Functions

A Function is a capability of a component or group of components served by one or more ECUs. The Function of each ECU is identified within an 8 bit field of that ECU's NAME. As there may be multiple ECUs which identify themselves with the same Function, the Function Instance field of NAME is used to distinguish between them. The same Function value (upper 128 only) may mean different things for different Industry Groups or Vehicle Systems, therefore the Function (upper 128 only) identification is dependent upon the Industry Group, and the Vehicle System as shown in Figure 3 (see J1939/81 Section 4.1.12).

A Vehicle System is a subcomponent of a vehicle or an analogous component that includes one or more J1939 network segments and may be connected or disconnected from the total vehicle. A Vehicle System may be made up of one or more Functions, which have ECUs that are connected to a J1939 network segment of that Vehicle System. A typical on-highway Vehicle System is a tractor or trailer. Because the definition of Vehicle Systems will

vary from one industry to another, the System definition is dependent upon the Industry Group as shown in Figure 3 (see J1939/81 Section 4.1.12).
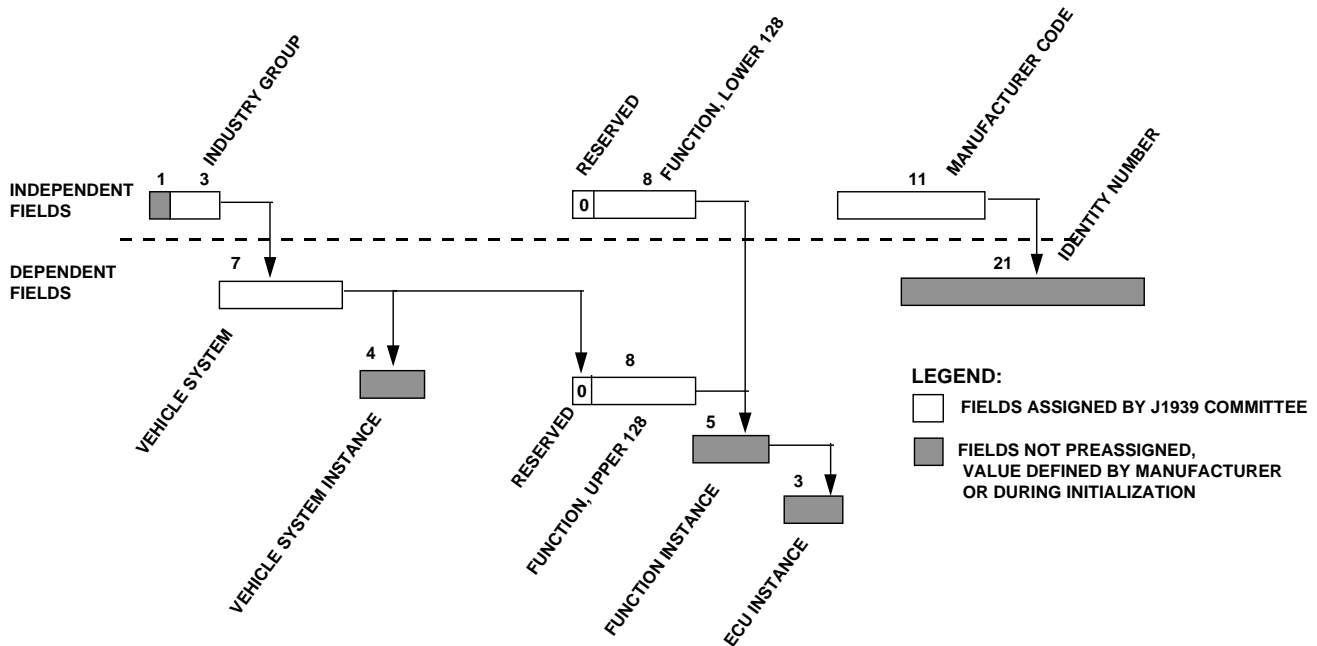

Figure 3. Dependencies in the NAME Fields.

A single ECU on the network may combine multiple Functions, and would then have the option to claim a separate address for each supported function. The assigned Vehicle System and Function values are listed in Appendix B, Tables B11 and B12.

3.2.4 Industry Group

To permit multiple industries to use J1939, an Industry Group code is used to identify the industry to which the ECU is associated. Code 0 is a special category of Industry Group in that it identifies Preferred Addresses and NAMEs that are common to all industries. Any ECU which may be used in more than one industry application, such as diesel engines, should have NAMEs and Preferred Addresses within this global group. It is the responsibility of those requesting new definitions to consider if this may be the case, and to request the new definition in the correct group. To avoid running out of NAME or address values, it is requested that global values be used only when truly applicable, if an ECU may exist in only one group, such as agricultural equipment, it would be preferable to add the definition to the applicable group rather than to use a global value. Industry Group codes are listed in Appendix B, Table B1.

3.2.5 Manufacturer Code

As defined in J1939/81, the NAME convention includes a Manufacturer Code, permitting a unique Identity Number to be a part of the full name. This Identity Number is assigned by the manufacturer and can be an individual ECU's serial number if desired. To enable the Identity Numbers to be unique to a given manufacturer, all manufacturers using J1939 are assigned a code. The Manufacturer's Code numbers are listed in Appendix B, Table B10. A manufacturer is permitted to have multiple codes, such as when there are multiple divisions or major product lines. Having a unique Manufacturer Code for each individual product would be discouraged as this

would quickly exhaust the range of available codes. There are 21 bits available in the Identity Number field of NAME, permitting the manufacturer to include a reference to each particular product if desired.

3.2.6 Preferred Address

The number of addresses within a given system cannot exceed 254 (null and global cannot be claimed by devices). Most ECUs that operate on a J1939 network will have an assigned Preferred Address that the ECU may use. If the ECU's Preferred Address has been claimed or is in use by another ECU on the network, the conflict will be resolved using the procedures outlined in Section 3.1.3 and detailed in J1939/81 Sections 4.2 and 5. There may be additional contraints or procedures defined in the applicable J1939/0X document. For instance, on-highway trailer bridges and devices have address claiming constraints that differ from Con-Ag systems. A supplier of a Self Configurable ECU may provide any strategy for selecting an address to attempt to claim. However, if an alternative approach is not defined, it should attempt to claim an address in the range 128 - 247, starting at 128. Individual reserved Preferred Address assignments begin at zero and are assigned in a linear fashion as follows:

0 to 127	Reserved for most conventional ECUs in Industry Group 0 - Global
128 to 247	Reserved for Industry Specific assignments
248 to 253	Reserved for special ECUs
254	Null Address
255	Global Address

The current Preferred Address assignments are provided in Appendix B and the forms for requesting new assignments are provided in Appendix D. For further information, see J1939/81.

3.2.7 Suspect Parameter Number (SPN)

A Suspect Parameter Number (SPN) is a 19 bit number used to identify a particular element, component, or parameter associated with an ECU. This capability is especially useful for diagnostics, permitting an ECU which has detected a fault associated with a particular component, such as a sensor, to transmit a fault message identifying the faulty component. SPNs are assigned by the Committee and are listed in Appendix C. The first 511 SPNs are reserved and will be assigned, when possible, to the exact same number as the Parameter Identifier (PID) of J1587. For example, J1587 PID 91 is "Percent Accelerator Pedal Position" and an accelerator pedal position parameter fault could be reported in J1939 by using SPN 91. All following SPNs will be assigned in order as they are received.

Due to the very large number of SPNs which may ultimately be assigned, and their assignment in order of request, it will be very difficult for one interested in finding the SPN value of a particular component of interest simply by looking through the table. To facilitate the verification that new SPN requests are not duplications of existing assignments, the committee retains this table as an MS Excel™ spreadsheet, with additional data beyond that shown in Table C1. This permits sorting based upon SPN number, name, description, attribute (actuator, pressure, temperature, solenoid, etc.), J1587 attributes (MID, PID, SID), J1939 document paragraph, source name, and source address. It would be desirable for those developing J1939 applications or wishing to request the assignment of a new SPN to have access to an up-to-date version of this spreadsheet so that they can perform various sorts and searches of the data. At the time of publication, the SAE has not yet determined how this data can best be made available to the users of J1939 who are not committee participants.

3.3   Application Examples

A typical shift sequence consists of a series of commands from the transmission to the engine for controlling engine RPM and torque. Messages from the engine provide status and information which is used to determine when a particular condition has occurred. Other messages may also be sent regularly to disable the engine

retarder at the proper time interval, or to inhibit ASR functions which might effect engine demand during portions of the shift sequence.

Parameter Group	Msg. Type	Sender	Using ECU	Action/Function
ETC1	Info	Trans	Eng, ASR	Transmission decision to shift (Shift in progress)
TSC1	Cmd	Trans	Eng.	Override Priority bits set for Trans. (01 priority) Torque control, Torque = 0
TSC1	Cmd	Trans	Retarder (Eng.)	Disable Mode, Torque = 0
EEC1	Info	Eng.	Trans	Torque = 0 (Clutch may be disengaged)
TSC1	Cmd	Trans	Eng	Speed Control Mode, Requested Speed = X
EEC1	Info	Eng	Trans	Speed = X (Clutch may be engaged)
TSC1	Cmd	Trans	Eng	Speed/Torque Limit Mode (11 priority)
ETC1	Info	Trans	ASR	Allow ASR (11 priority)
TSC1	Cmd	Trans	Ret (Eng)	Enable Mode
TSC1	Cmd	Trans	Eng	Override Disable
ETC1	Info	Trans	Eng, ASR	Shift complete

A typical ABS sequence will cause a message to be transmitted which indicates that the engine should reduce torque and the driveline (transmission) to remain in its existing (stable) state. If the ABS condition is "significant" (i.e. not just bouncing tires), it may request that the driveline also be disengaged. Note that this message must be sent at regular intervals to maintain the condition. Once the event is over, the ABS inactive indicates that the transmission and engine may return to "normal" operation

Parameter Group	Msg. Type	Sender	Using ECU	Action/Function
				ABS decision to modulate brakes
EBC1	Cmd	ABS	Eng, Trans	ABS active
TSC1	Cmd	ABS	Retarder (Eng.)	Disable Mode, Torque = 0 (Prevent engine stall)
TC1	Cmd	ABS	Trans	Disengage Driveline
				ABS event over
EBC1	Cmd	ABS	Eng, Trans	ABS inactive

A typical ASR sequence will attempt to reduce torque by sending torque limit messages to the engine. Torque can also be reduced by requesting more driveline retardation or permitting some clutch slip. Ultimately an upshift may be requested in order to achieve acceptable torque values. Note that the transmission takes over engine control during the shift.

Parameter Group	Msg. Type	Sender	Using ECU	Action/Function
				ASR Torque Reduction Decision
EBC1	Cmd	ASR	Eng, Trans, Retarder (Drvl)	ASR Torque control active
TSC1	Cmd	ASR	Eng	Torque Limit
TSC1	Cmd	ASR	Retarder (Drvl.)	Request more retardation
TC1	Cmd	ASR	Trans	Request more clutch slip
TC1	Cmd	ASR	Trans	Request new gear selection,
				No clutch slip request
				Shift if possible
				Shift complete, ASR continues torque limit
				ASR event over
EBC1	Cmd	ASR	Eng, Trans, Retarder (Drvl)	ASR inactive, disable override

Prepared by the SAE Truck and Bus Control and Communications Subcommittee of the SAE Truck and Bus Electrical and Electronics Committee.