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SURFACE VEHICLE RECOMMENDED PRACTICE

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Agricultural and Forestry Off-Road Machinery Control and Communication Network

RATIONALE

This is the initial publication of the SAE J1939 application layer intended for use in Agricultural and Forestry equipment applications.

FOREWORD

This series of SAE Recommended Practices has been developed by the Truck and Bus Control and Communications Network Subcommittee of the Truck and Bus Electrical and 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 electronic 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 to keep pace with experience and technical advances.

INTRODUCTION

As described in the parent document, SAE J1939, there is a minimum of five documents required to fully define a complete version of this network. This particular document, SAE J1939-02, identifies one such complete network by specifying the particular set of SAE J1939 and ISO 11783 documents which define the Truck and Bus Control and Communications Vehicle Network as it applies to Off-Road equipment.

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1. SCOPE

These Recommended Practices are intended for light and heavy duty agricultural and forestry vehicles used primarily off-road as well as appropriate stationary applications which use vehicle derived components. Vehicles of interest include, but are not limited to: agricultural equipment and implements and forestry harvesting equipment.

1.1 Purpose

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.

This document is intended to specify the requirements for application of SAE J1939 in agricultural and forestry equipment. This document specifies the series of documents within the set of SAE J1939 documents that are applicable to agricultural and forestry equipment and provides further requirements for this industry.

A primary intent of this document is to point out areas where there may be differences between SAE J1939 and ISO 11783 as applied to off-road machinery such as agricultural and forestry machines.

2. REFERENCES

2.1 Related Publications

The following publications are provided for information purposes only and are not a required part of this document.

2.1.1 ISO Publications

Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

ISO 11783 Tractors and Machinery for Agriculture and Forestry—Serial Control and Communications Data Network

2.1.2 NMEA Publications

Available from National Marine Electronics Association, 7 Riggs Ave., Severna Park, MD 21146, 410-975-9425, www.nmea.org.

NMEA 2000 National Marine Electronics Association Standard for Serial-Data Networking of Marine Electronic Devices

3. DEFINITIONS

Terms and abbreviations are defined in SAE J1939 Top Level for use in the context of this document. Additional terms are defined below.

3.1 Terms

Controller Application	The software within an Electronic Control Unit (ECU) that performs a particular control function. More than one Controller Application may reside within an ECU.
Configurable Messages	A set of message PGNs that can be configured to contain any desired combination of a set of parameters (SPNs) that are designated to be configurable.
Farm Management Information System	The office computer system for the farmer or contractor. It includes the software for farm management such as book keeping, payroll, resource management for machines, products, workers, field management, GIS, decision support systems and task management.
Fast Packet	A transport protocol method employing broadcast messages with no minimum separation between packets.
Implement Bus	Bus segment that connects agricultural implement ECUs as well as some tractor ECUs such as Virtual Terminal.
ISOBUS	Standardization of the agricultural implement bus.
Management Computer Interface	The method of exchanging information between the FMIS and the vehicle Task Controllers using XML data format. A physical interface is not specified.
Network Interconnection ECU	A device that exists primarily for interconnecting networks or sub networks. Specific implementations for “forwarding” messages include: Repeater, Bridge, Router, and Gateway.
Process Data	A message that is used for the transmission of measured data and/or set point commands to one or more controllers.
Task Controller	An electronic unit on the mobile implement control system that is responsible for the sending, receiving and logging of Process Data. A Task Controller may have an operator interface.
Termination Bias Circuit	A circuit required at each end of a bus segment that provides bias voltages for the CAN High and CAN Low signals and the common mode impedance termination for the respective conductors.
Tractor Bus	Bus segment that connects mainly tractor mounted ECUs including power train modules.
Tractor ECU	Standardized network interconnect device between tractor bus and implement bus.
Virtual Terminal	An ECU, consisting of a graphical display and input functions, which provides the capability to display information to and retrieve data from an operator for a connected implement or Working Set.

3.2 Abbreviations

Abbreviations are defined in SAE J1939 for use in the context of this document.

CA Controller Application
ECU Electronic Control Unit. Any of a number of electronic modules contained in a machine that communicates with other ECU's via the SAE J1939 network standard.
ETP Extended Transport Protocol
FMIS Farm Management Information System
ISO International Organization for Standardization
NMEA National Marine Electronics Association
SAE Society of Automotive Engineers
SPN Suspect Parameter Number
TBC Termination Bias Circuit
VT Virtual Terminal
XML eXtensible Markup Language

3.3 Documentation Structure

General information regarding this series of recommended practices is found in SAE J1939.

By mutual agreement between SAE and ISO standards groups, ISO 11783 addresses all aspects of a communication standard relevant to agricultural and forestry industries. These standards are harmonized with the SAE J1939 Control and Communications standard. ISO 11783 has approval authority over all issues of message definition and parameter definitions for agricultural and forestry applications. These approved items are then assigned numbers by SAE J1939 and listed with all other such items in the SAE J1939 documents and database. One exception is that Agricultural NAMES are assigned numbers by ISO 11783.

A subset of the SAE J1939 documents is applicable for forestry and agricultural equipment. A combination of the SAE J1939 and ISO 11783 documents is needed to completely specify the agricultural or off-road control and communications standard. The series of documents applicable for agricultural and forestry equipment are listed in Table 1.

TABLE 1 - APPLICABLE DOCUMENTS

SAE Document	ISO Document	Summary
SAE J1939 Top Level Document	N/A	This top-level document describes the network in general and its appendices include pre-assigned NAMES, preferred addresses, and suspect parameters.
↓	ISO 11783 Part 1 General Standard	This standard specifies a serial data network for control and communications on forestry or agricultural tractors, mounted, semi-mounted, towed or self-propelled implements. Its purpose is to standardize the method and format of transfer of data between sensors, actuators, control elements, information storage and display units whether mounted on or part of the tractor, or any implements.
SAE J1939-02 Agricultural and Forestry Off-Road Machinery Control and Communication Network	↑	The application layer for off-road equipment being described in this document. A primary intent of this document is to point out areas where there may be differences between SAE J1939 and ISO 11783.
No SAE equivalent. See ISO Document. →	ISO 11783 Part 2 Physical Layer	The agricultural implement bus physical layer consists of a 250K bit/s, twisted, non-shielded, quad-cable physical layer and active terminators.
SAE J1939-13 Diagnostics Connector	Included in ISO 11783 Part 2	The Off-Board Diagnostic connector used on the vehicle to get access to the vehicle communication links.
SAE J1939-21 Data Link Layer	ISO 11783 Part 3 Data Link Layer	These documents describe the use of the CAN 29 bit identifier and the basic transport protocol mechanism.

TABLE 1 - APPLICABLE DOCUMENTS (CONTINUED)

SAE Document	ISO Document	Summary
SAE J1939-31 Network Layer	ISO 11783 Part 4 Network Layer	These documents describe the network layer, which defines the requirements and services needed for communication between electronic control units in different segments of the off-road network. The various types of network interconnection unit are defined.
SAE J1939-71 Application Layer	ISO 11783 Part 8 Powertrain Messages	These particular standards contain the Messages required by tractors and self-propelled implements on the powertrain or tractor bus.
No SAE equivalent. See ISO Document. →	ISO 11783 Part 7 Implement Messages Application Layer for Agriculture	This part of ISO 11783 describes the implement messages application layer of the network, specifying the message set and defining the messages used for communication with and between tractors and connected implements.
No SAE equivalent. See ISO Document. →	ISO 11783 Part 6 Virtual Terminal	This part of ISO 11783 describes a universal Virtual Terminal that can be used by an operator to interface with both tractors and implements.
SAE J1939-73 Diagnostics Application	ISO 11783 Part 12	The diagnostics application layer.
No SAE equivalent. See ISO Document. →	ISO 11783 Part 9 Tractor ECU	This part of ISO 11783 describes the tractor ECU, the electronic control unit that provides the gateway between the network's tractor and implement buses, as well as performing other functions.
No SAE equivalent. See ISO Document. →	ISO 11783 Part 10 Task Controller	This particular standard describes the Task Controller Applications Layer, which defines the requirements and services needed for communicating between the task controller and electronic control units. The data format to communicate with the farm management computer, the calculations required for control and the message format sent to the ECU are defined in this document.
No SAE equivalent. See ISO Document. →	ISO 11783 Part 11 Mobile Data Element Dictionary	This particular standard describes the Data Elements that are used by the Process Data Messages as defined in Part 7 of this standard.
No SAE equivalent. See ISO Document. →	ISO 11783 Part 13 File Server	This particular document section describes a File Server capability for use by tractors and self-propelled implements for storage of large amounts of data for other devices on the network.
SAE J1939-74 Application Layer – Configurable Messages	← No ISO equivalent. See SAE Document.	An application layer that allows users to use parameters that have previously been identified as configurable to be packed into messages in a proprietary manner for optimizing network performance. Parameters from other SAE J1939 documents are not to be sent via the configurable messages. Configurable messaging is not allowed on ISOBUS (implement bus) but could potentially be used on the tractor bus or on a closed system bus.
SAE J1939-75 – Generator Sets and Industrial	← No ISO equivalent. See SAE Document	An application layer with messages dealing with stationary equipment and generator sets.
SAE J1939-81 Network Management	ISO 11783 Part 5 Network Management	These documents describe the management of source addresses for electronic control units, the association of addresses with the functional initialization and response to brief power outages, and minimum requirements for network-connected electronic control units
SAE J1939-82 – Compliance	← No ISO equivalent. See SAE Document	A testing plan and a set of requirements that need to be met for each SAE J1939 document or layer.

4. TECHNICAL REQUIREMENTS

4.1 Network Description

Networks may consist of one or more connected bus segments based on the SAE J1939 component documents specified in Table 1. Figure 1 depicts a typical network that may be found on a tractor and connected implements. This particular network has three bus segments, the tractor bus segment interconnecting components on the tractor, the implement bus segment interconnecting the implement and tractor, and an implement sub-network segment connected to the implement bus by a bridge. At least one of the bus segments shown is required to form a network, but in most systems, at least the tractor and implement bus will exist.

Each of the boxes depicted in Figure 1 represents an ECU. Several of the ECUs in Figure 1 require significant standardization and are described further in documents that are a part of this series. Those ECUs include

1. The virtual terminal described in ISO 11783 Part 6
2. The tractor ECU described in ISO 11783 Part 9
3. The task controller described in ISO 11783 Part 10
4. The engine controller as described in SAE J1939-71.

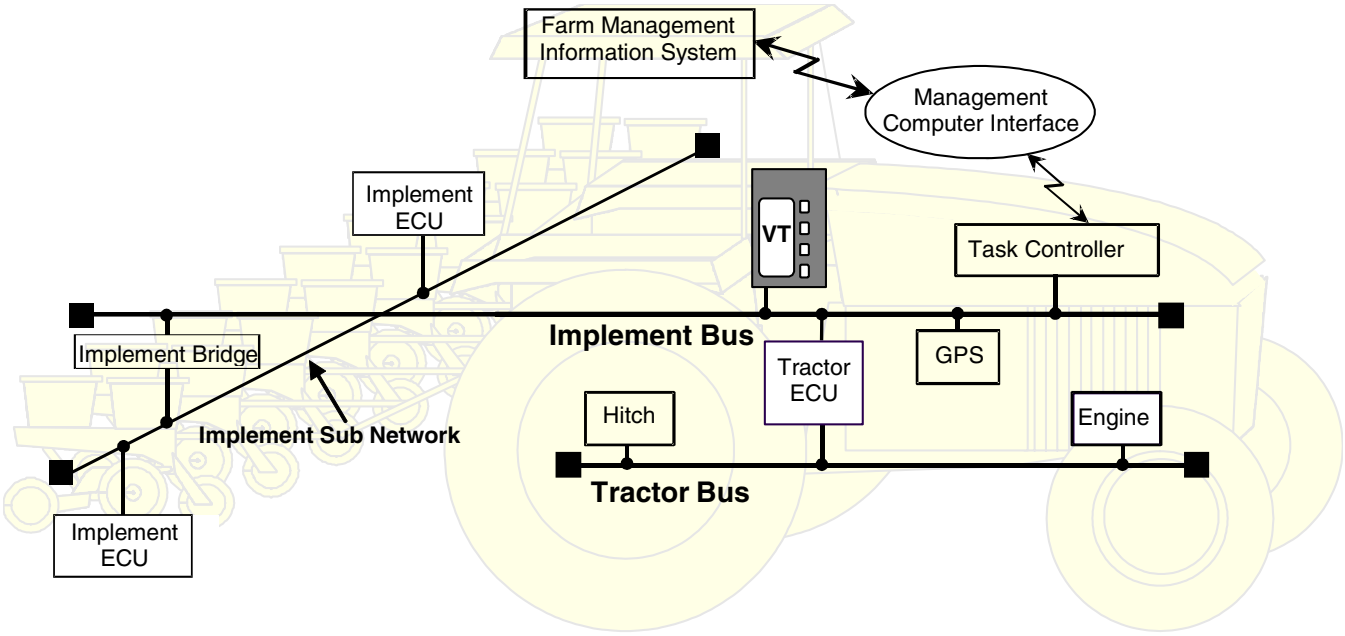

FIGURE 1 - A TYPICAL NETWORK TRACTOR BUS, IMPLEMENT BUS AND IMPLEMENT SUB-NETWORK

4.2 Physical Layer

ISO 11783 Part 2 describes the physical layer intended for use in this network. The document identifies the media as an unshielded twisted quad cable as well as the connectors and signaling for the network. Users should refer to ISO 11783 Part 2 for required connectors and placement. A diagnostic connector is required as a part of the network. The required diagnostic connector is defined in SAE J1939-13. Required placement for the diagnostic connector is provided in ISO 11783 Part 2. Both Tractor Bus and Implement Bus network segments are present in the diagnostic connector.

This physical layer design is not shielded but instead requires that signal transition times on the CAN lines be controlled to limit radiated emissions. The slope on bit rise and fall times of 200 ns nominal are required.

This network requires active termination. These Termination Bias Circuits (TBCs) are required at each physical end of the network to provide the electrical bias and common mode termination needed to suppress reflections.

The CAN bit sample point for ISO 11783 is ”80% ± 3% of the bit time, referenced to the start of the bit time”. This differs from the Truck and Bus standard of SAE SAE J1939-11 whose sample point is “as close to but not greater than 7/8 (87.5%) of a bit time”.

When a network is extended, for instance by connecting an implement to a tractor, the TBC in the breakaway (implement) connector must be removed since the connector is no longer the physical end of the network. The implement now provides the TBC at the end of the network, which may be another breakaway connector at the back of the implement.

4.3 Data Link Layer

SAE J1939-21 describes the data link layer intended for use in this network. Major items include:

- The use of the 29-bit identifier, the protocol data units, message priority and source address fields are described.
- The transport protocol method for handling messages with more than 8 bytes is defined. Both broadcast and connection management forms of transport protocol are supported. These mechanisms are limited to transporting data objects between 9 and 1785 bytes.

Additional data link features supported in this Off Road Machinery Control and Communications Network are:

- NMEA messages that carry GPS information are used in some off-road machines to enable navigation features. For NMEA navigation messages on the implement bus, the Fast Packet method may be used so as to reduce the inter-frame time. The definition of Fast Packet is found in the NMEA2000 Standard. This mechanism is limited to transporting data objects between 9 and 223 bytes.
- An additional “extended” transport protocol (ETP) mechanism is prescribed in ISO 11783 Part 6. This ETP allows ECUs to transport data objects up to 117M bytes in size. This capability is often needed to handle the Virtual Terminal data objects.

ISO 11783 Part 3 is harmonized with SAE J1939-21.

4.4 Network Layer

SAE J1939-31 and ISO 11783 Part 4 are harmonized and describe the network layer intended for use in this network. Various types of network interconnect units are possible. Filtering, forwarding and repackaging of messages are possible. There is also a means of node identification for units connected on another port of the network interconnect unit.

Messages exist to allow the filter database for a network interconnect unit to be configured for different types of message passing and for performance metrics to be accessed.

The physical layer timing requirements of ISO 11783 Part 2 prevent the effective use of repeaters. Since the ISO 11783 network has a sample point of 80 % of the bit time and allows a transition time equal to ¼ bit time, true repeaters cannot be used. Repeaters should not be used to extend the implement bus in this network.

4.5 Application Layers

Several application layers are defined for use in this network. SAE J1939-71 describes messages for general-purpose use and messages for use on the tractor bus. SAE J1939-73 defines diagnostics for the network. Additional application layers for Virtual Terminal, Task Controller, and Management Computer are defined in ISO 11783 and described further below.

4.6 Network Management

SAE J1939-81 describes the management layer intended for use in these networks. A more rigorous requirement for survival of power glitches is imposed for agricultural and forestry vehicles and implements beyond that existing in SAE J1939-81. These requirements are defined in ISO 11783 Part 5 and summarized in the following paragraphs.

4.6.1 Power Supply Disturbances

ECUs on an ISO 11783 network should be able to handle voltage transients and interruptions. Reactions to voltage disturbances of different durations should be processed as detailed in the following clauses. The times are defined for transients and interruptions that occur from the nominal specified supply voltage for the ECU.

4.6.1.1 Ten milliseconds or Less Transients and Interruptions

If normal power (ECU_PWR) is restored within 10 milliseconds and if interruptions are spaced at least 100 milliseconds apart then the ECU should have no occurrences of:

- Loss of normal network communications nor loss of in-process messages.
- Processor reset.
- Loss of data in volatile memory, including network configuration information and/or messages in progress over the network.

4.6.1.2 Greater Than One Second Transients and Interruptions

If normal power is not restored within 1 second then the ECU must reset and complete a Power On Self Test (POST).

4.6.1.3 Greater Than Ten milliseconds and Less Than One Second Transients and Interruptions

If power is disrupted for greater than 10 milliseconds but less that 1 second, internal requirements of the ECU will determine if a reset is required or is not required.

4.6.2 Working Sets

Groupings of ECUs, called working sets, as described in SAE J1939-81 Network Management, are likely to be used extensively in Agricultural networks in order to create distributed control over agricultural implements connected to tractors.

4.6.3 NAME Assignment

The use of NAMEs and Source Addresses described in SAE J1939-81 applies to SAE J1939-02 networks.

On the implement bus (ISOBUS) arbitrary address capability is required. Implement control functions are required to be self-configuring because they can be attached to an already operating network. Presently, the Ag/Forestry Preferred Source Address table (SAE J1939, Table B4) is controlled by ISO 11783 and no additions are allowed.

- The NAMES for Agricultural and Forestry devices are selected from tables maintained by ISO 11783 in an appendix and are referred to as the B tables. These names are mirrored in SAE J1939 Appendix B12, Industry Group 2.

4.6.4 Initialization Processes

Due to the potentially high number of ECUs present on agricultural systems, two initialization items are emphasized here:

1. Multiple identical CAs are possible on an implement, for instance for “per row” monitors or controllers. This possibility creates the potential for destructive message collisions during the address claim process. To remedy this situation, special processing rules during power up initialization are outlined in SAE J1939-81 section 4.4.3.3. The processing includes delaying any retries of any failed address claim messages by a pseudo random delay of between 0 and 153 ms.

2. Since arbitrary address capability is required on the implement bus, it is also a requirement for the CAs to maintain a table correlating NAMEs to source addresses and to use this table to associate transmitted and received messages with the correct CA. See SAE J1939-81 section 4.4.6.

4.6.5 Implement Instance Initialization Processes

When assigning instances to implements to precisely specify an implement location, the rule is to number from left to right followed by front to rear followed by bottom to top. See ISO 11783 Part 7 section A.25.6.

4.7 Virtual Terminal.

A standard for a virtual terminal is provided in ISO 11783 Part 6. The VT is an electronic unit that provides a standardized operator interface to a system. The VT provides operator input and output capabilities in a single electronic unit. The VT is shown in Figure 1 attached to the implement bus. Tractor ECUs or other ECUs within the tractor connected to the implement bus may utilize the VT in the same method as an implement ECU.

4.8 Tractor ECU

The Tractor ECU provides a communications link between the Implement Bus and the Tractor Bus and acts as a network interconnection unit to assure both electrical and message isolation.

This ECU is used to represent the tractor in communications on the Implement Bus. Messages sent from any ECU on the Implement Bus that may need to be directed to an ECU residing on the tractor should be sent to the Tractor ECU and any messages sent to ECUs on the Implement Bus from Tractor ECUs must use the source address of the Tractor ECU. The network interconnection unit must provide appropriate acknowledgments or responses to the requesting or commanding ECU.

Three classes of Tractor ECU capability have been defined. Each class must support a minimum set of messages including all the messages of the next lower class. Details of the Tractor ECU and lists of the required messages for each class are found in ISO 11783 Part 9. The required messages are described in detail in ISO 11783 part 7.

4.9 Task Controller

Task controllers provide control via the ISO 11783 network. Task data received via the Management Computer Interface is stored in the task controllers. These tasks are scheduled by the task controller, which sends control messages to the appropriate ECUs for execution. The task controllers can also record data received from ECU as tasks are being completed. This data can be transferred to the Management Computer through the Management Computer Interface. The operation of the task controller and the format of messages sent and received from ECUs is detailed in ISO 11783 Part 10.

4.9.1 Object Reference Structure

The object reference structure describes the method that a task controller uses to refer to a particular controlled section of an implement. This structure is used not only to allow set points to be sent to objects on an implement but also to allow objects to send actual values back to the task controller.

4.10 Management Computer Interface

Though the physical interface between the Farm Management Information System and the vehicle is not specified in this standard, the messaging is defined in ISO 11783 Part 10 Task Controller. Information about tasks to be performed by the vehicles' ECUs is transferred in XML format from the farm management system to the task controllers. The task controllers then parse the information using the Process Data message described in ISO 11783 Part 7 Implement Messages Application Layer for Agriculture and whose elements are described in ISO11783 Part 11 Mobile Data Element Dictionary.

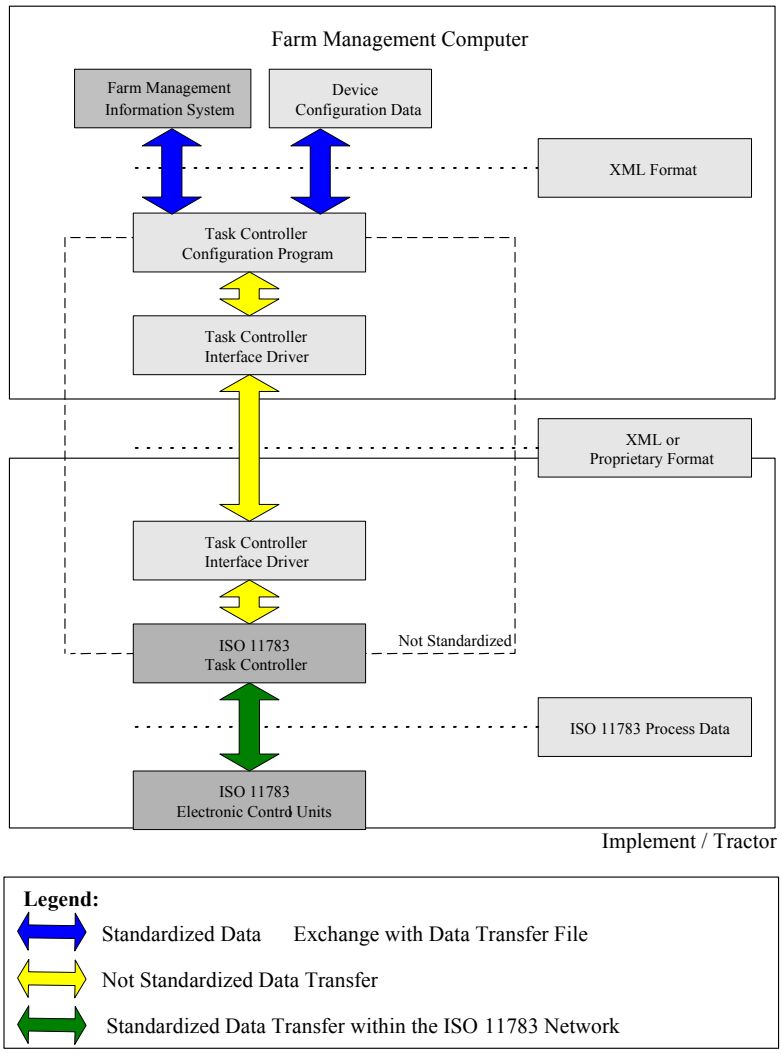

FIGURE 2 - MANAGEMENT COMPUTER INTERFACE

PREPARED BY THE SAE J1939 TRUCK AND BUS CONTROL AND COMMUNICATIONS SUBCOMMITTEE
OF THE SAE TRUCK AND BUS ELECTRICAL AND ELECTRONICS COMMITTEE