Standardized Tool Components for NRMM-Diagnostics

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In the past, passenger car manufacturers have learned the lesson that competition on the level of bits and bytes, proprietary bus systems, data communication and diagnostic protocols is unrewarding. As a result, too much time and money has been spent on the development of proprietary diagnostic tools.
Standardization serves the price, the quality, and the maintainability via scale and training curve effects. Standardization of tools is an advantage for both the machine manufacturer and the tool supplier.
In addition to SAE J1939, which is a widely employed set of CAN-based communication protocols, both the passenger car and truck industry offer a diagnostic technology that is internationally standardized by ISO. State-of-the-art components can be reused by manufacturers of non-road mobile machinery (NRMM). The central software module for the development, testing, validation, production and service of electronically controlled vehicles and machines is the D-Server (ISO 22900). The D-Server processes data in ODX format (ISO 22901), and supports the processing of sequences and routines (e.g. for flash-programming or guided fault finding) that are described in OTX (ISO 13209).

Electronic Control Units (ECUs) in non-road mobile machinery (NRMM) improve performance, comfort and safety. In addition, the fuel consumption and the emission of noise and pollutants can be reduced.

Although new powertrain technologies, such as hybrid and electrical drives are being introduced for mobile machinery, most machines are still powered by heavy-duty diesel engines, often equipped with electronically controlled emission control systems such as SCR (Selective Catalytic Reduction), DPF (Diesel Particulate Filter), and EGR (Exhaust Gas Recirculation).

Today, many ECUs in NRMM are interconnected by CAN. Construction and mining machines are equipped with CANopen devices. CANopen is standardized in EN 50325-4 and specifies the communication services and protocols for configuration, real-time control, and diagnostics. Agricultural and forestry machines use ISOBUS, which is another communication protocol on CAN. ISOBUS is standardized in ISO 11783, a set of documents that is based on SAE J1939.

SAE J1939 is widely used in vehicles and machines that are equipped with diesel engines.

The employment of ECUs enable the capability of controlling and last but not least monitoring functions. A system on-board a vehicle which has the capability of detecting malfunctions is called on-board diagnostic (OBD) system. In the context of this paper, OBD includes but is not limited to monitoring the functions of the engine and the emission control system. An OBD system contains the capability of indicating the occurrence of a malfunction, storing diagnostic trouble codes (DTCs) and communicating with external test equipment.

A diagnostic system assists the service technician in the identification and repair of a malfunction. It significantly reduces the overall repair time and increases service quality and customer satisfaction. State-of-the-art diagnostic systems also provide the capability to reprogram the ECUs by flash-download.

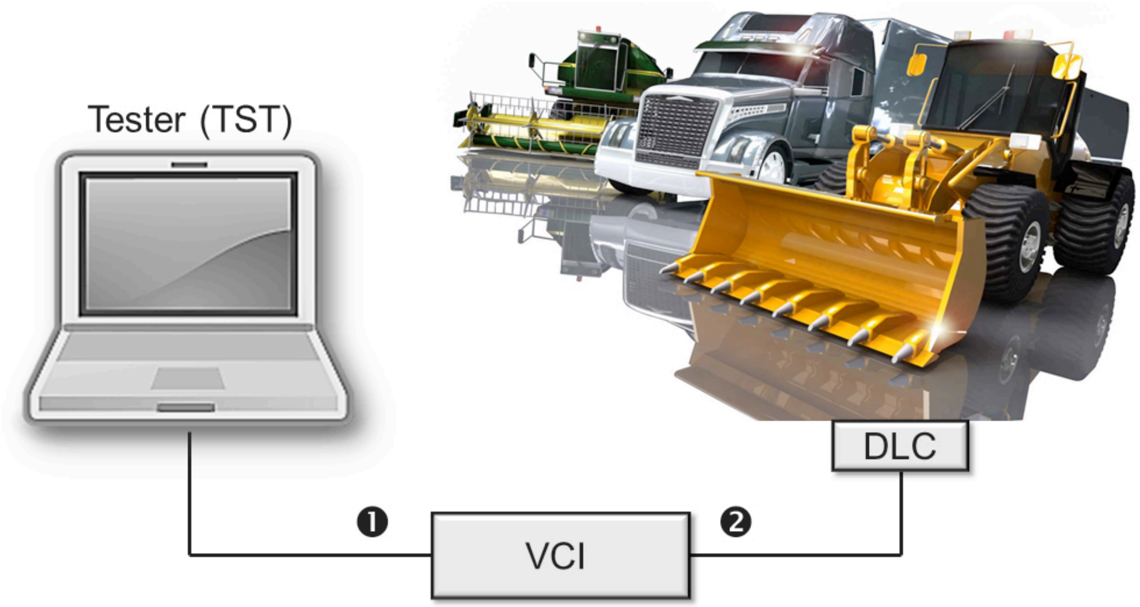

Figure 1: Components of a diagnostic system

Figure 1 illustrates a diagnostic system that consists of the machine´s OBD system with a DLC (Data Link Connector) and a PC-based external test equipment, usually referred to as the “Tester” (TST). The VCI (Vehicle Communication Interface) connects the Tester and the DLC via a TST-to-VCI ❶ and a VCI-to-DLC ❷ connection. Generally, the TST-to-VCI connection is USB or WLAN, and the VCI-to-DLC connection is CAN.

Figure 2 illustrates the components of the TST software. The main part of the TST software is the MVCI D-Server (MVCI = Modular Vehicle Communication Interface). The components of the D-Server are internationally standardized in ISO 22900. ISO 22900-2 specifies the D-PDU API, which is a software interface for the connection between the D-Server and any VCI that is delivered with D-PDU API software.

The D-Server API is standardized in ISO 22900-3. The D-Server API is an object-oriented API based on Microsoft´s COM technology. The application programmer can set up his tester application either with C/C++ or Java. For processing JAVA byte code, the D-Server is equipped with a JAVA Virtual Machine (Java VM).

The D-Server processes data that is stored in ODX format. ODX is short for Open Diagnostic Data eXchange, which is an XML based data format being standardized in ISO 22901. The ODX database contains the description of the diagnostic capabilities of either one or more than one ECUs or the entire NRMM. That includes but is not limited to the communication parameters of one or more CAN buses, the DTCs and the diagnostic protocols. Diagnostic protocols are based on the Open Systems Interconnection (OSI) Basic Reference Model, which structures communication systems into seven layers.

In many NRMM, the CAN communication between the ECUs is based on SAE J1939. SAE J1939-73 specifies the diagnostic communication on the OSI model application layer. As an alternative to SAE J1939-73, *DoCAN* (ISO 15765) can be implemented. DoCAN is short for Diagnostics on CAN.

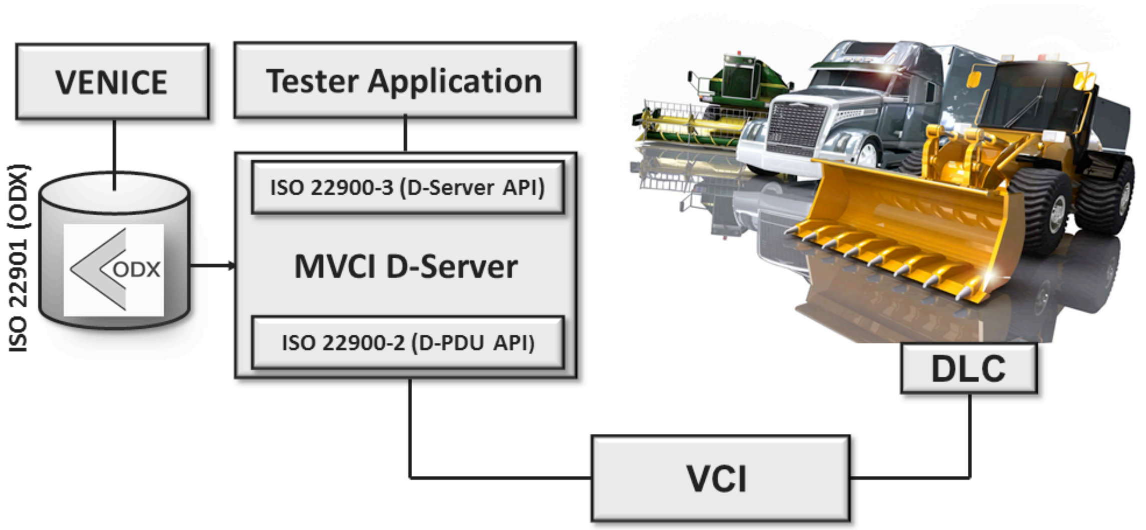

Figure 2: Components of the diagnostic tester

ISO 15765-3 contains the Implementation of *Unified Diagnostic Services* (UDS) on CAN. UDS (ISO 14229-1) is based on the OSI application layer and contains a set of 25 service requests and the related responses. Most of the services are parameterizable. Today, *UDS on CAN* is widely used in road vehicles for service diagnostic tasks. As an alternative to DoCAN, DoIP (Diagnostic over IP, ISO 13400) is applicable.

ISO 15765-4 contains the requirements for emissions-related systems and references WWH-OBD (ISO 27145). WWH-OBD is short for *World-wide Harmonized On-Board Diagnostics*. It is recommended by the World Forum for Harmonization of Vehicle Regulations (WP.29) and intended to become the one and only diagnostic communication standard. As of today it specifies the access to emissions-related information (legislated WWH-OBD), but it will be extended in the direction of non-emissions-related diagnostics.

With the introduction of MVCI D-Server based diagnostic test systems, the passenger car and truck industry started the development of diagnostic sequences in JAVA. A typical example of such a sequence includes the sequence for reprogramming ECUs via flash download.

Since there is no guarantee that successive versions of java runtime environments (JRE) used by the D-Server support java byte code generated for previous JRE versions, long-time compatibility of java job code is not assured.

To solve that problem, the automotive industry created a standardized, machine-readable format for the description of diagnostic test sequences. The format is OTX, which is short for *Open Test sequence eXchange* format. OTX is standardized in ISO 13209 and intended to replace the JAVA jobs (Figure 3).

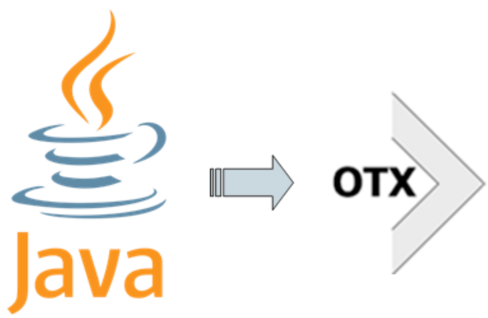

Figure 3: OTX replaces JAVA Jobs

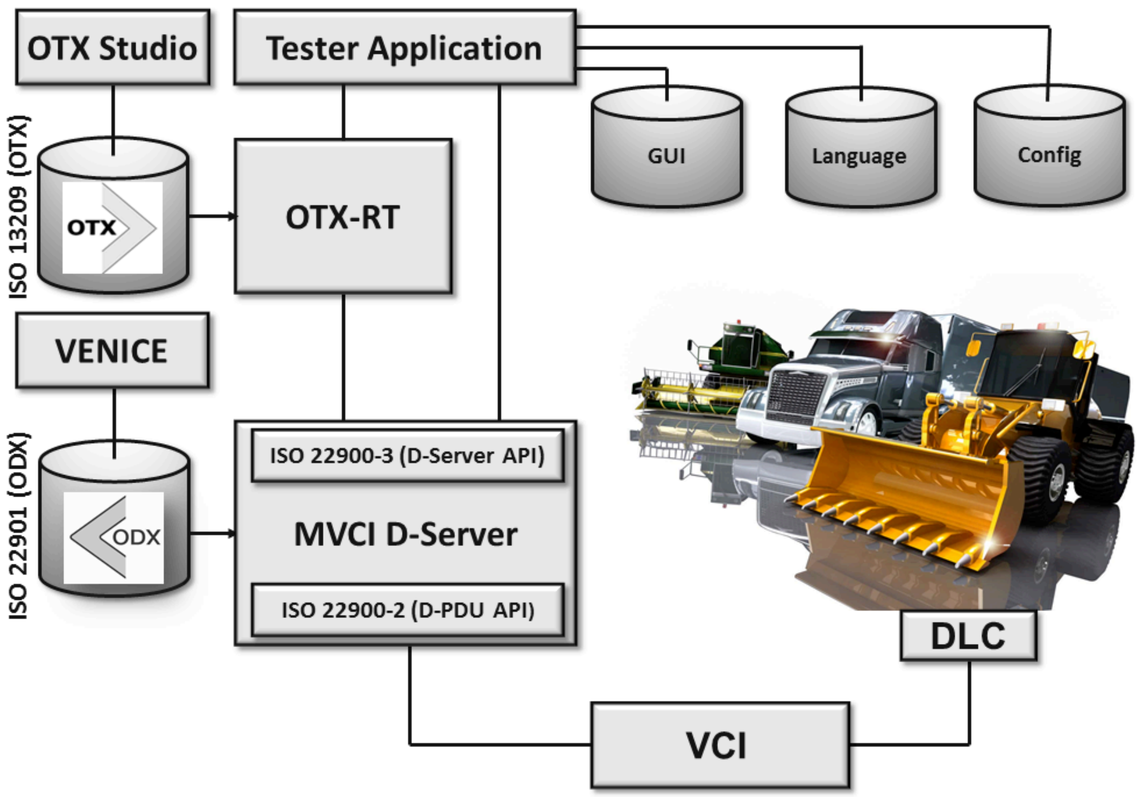

Figure 4: Structure of a diagnostic system with internationally standardized components

Once created, OTX sequences can be reused in the entire process chain (development, production, service), and in various use case, such as

- Diagnostic Tester
- Validation & Verification (e.g. in combination with HiL)
- Error Memory Management
- EOL Programming and Testing
- Reprogramming
- Guided Fault Finding

Figure 4 shows the structure of a diagnostic system with internationally standardized components. Besides the D-Server with D-Server API and D-PDU API, the ODX-based diagnostic data, the OTX-Runtime (OTX-RT) that processes OTX sequences and the on-board diagnostic system of the machine with the DLC, and finally the interconnecting VCI, the system needs a Graphical User Interface (GUI), a container with different languages (LANGUAGE) and a configuration capability (CONFIG).

Table 1 summarizes the international standards for the specification of diagnostic tools.

ISO 11783	**Tractors and machinery for agriculture and forestry-Serial control and communications network**
Part 12 (2009)	Diagnostic services
ISO 13209	**Open Test sequence eXchange format (OTX)**
Part 1 (2011)	General information and use cases
Part 2 (2012)	Core data model specification and requirements
Part 3 (2012)	Standard extensions and requirements

ISO 13400	**Diagnostic communication over Internet Protocol (DoIP)**
Part 1 (2011)	General information and use case definition
Part 2 (2012)	Transport protocol and network layer services
Part 3 (2011)	Wired vehicle interface based on IEEE 802.3
ISO 14229	**Unified diagnostic services (UDS)**
Part 2 (2013)	Session layer services
ISO 15765	**Diagnostic communication over Controller Area Network (DoCAN)**
Part 1 (2011)	General information and use case definition
Part 2 (2011)	Transport protocol and network layer services
Part 3 (2004)	Implementation of unified diagnostic services
Part 4 (2011)	Requirements for emissions-related systems
ISO 22900	**Modular vehicle communication interface (MVCI)**
Part 2 (2009)	Diagnostic protocol data unit application programming interface (D-PDU API)
Part 3 (2012)	Diagnostic server application programming interface (D-Server API)
ISO 22901	**Open Diagnostic data exchange**
Part 1 (2008)	Data model specification
Part 2 (2011)	Emissions-related diagnostic data
ISO 27145	**Implementation of World-Wide Harmonized On-Board Diagnostics (WWH-OBD) communication requirements**
Part 1 (2012)	General information and use case definition
Part 2 (2012)	Common data dictionary
Part 3 (2012)	Common message dictionary
Part 4 (2012)	Connection between vehicle and test equipment
SAE J1939	**Serial Control and Communications Heavy Duty Vehicle Network**
Part 73 (2010)	Application layer - Diagnostics
Part 02 (2013)	Agricultural and Forestry Off-Road Machinery Control and Communication Network.
EN 50325	**Industrial communications subsystem based on ISO 11898 (CAN) for controller-device interfaces**
Part 4 (2003)	CANopen

Table 1: International standards for the specification of diagnostic tools

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