Ford Motor Company

Electrical Electronic Systems Engineering (EESE)

Amendment to Hardware in the loop (HIL) Statement of Work [2]

Table of Content

1. Introduction

1.1 Scope

The requirements in this document are valid for two parties: The ECU supplier also called “the supplier” and Ford also known as Ford Motor Company.

This document is an amendment to the HIL statement of work (SOW) [2] between Ford Motor Company and the supplier. It outlines the expectations of Ford Motor Company, with respect to the supplier’s support of Ford Motor Companies’ HIL testing requirement, and defines the responsibilities between Ford Motor Company and the supplier.

It is a joint responsibility to review and update this document through contract initiation date.

Project content and timing assumptions cited in this document are Ford Motor Company Secret and for reference only.

1.2 Documents Structure

The structure of this document is explained below:

Section 1	Introduction to this document including revision history
Section 2	List of contact persons
Section 3	Describes the objectives
Section 4	Description of Ford Motor Company’s HIL system
Section 5	Tables, that contain the requirements
Section 6	List of acronyms
Section 7	List of attachments
Section 8	The section where the agreement is signed by both parties

1.3 Use of ‘shall’ and ‘should’

The use of the word ‘shall’ in this document denote a mandatory requirement.

The use of the word ‘should’ in this document represent a desired, but not mandatory requirement.

1.4 How to receive more Information

In case you have question please contact either the person responsible for this document (ldrews@ford.com), the author (twulf@ford.com) or Ford Motor Company’s champion defined in 2. ‘Contacts’.

1.5 Document Retention

The supplier shall ensure that all documentation and material pertaining to the project is retained and maintained for a period that satisfies both GIS1 [1] and all applicable legal requirements.

1.6 Applicable Documents

Note: It is the responsibility of the supplier to ensure that the latest revisions of the documents listed in this section are used. This should be achieved either by checking with Ford Motor Company, or by checking the listed reference as appropriate.

Ref.	Document Title	Location
[1]	Global Information Standard 1 (GIS1) Standard for creation, publication and management, including retention and disposal, of company records	Ford Motor Company, (Specific Project Management) on request
[2]	Hardware in the Loop Testing (HIL) STATEMENT OF WORK Revision 2009.1	Ford Motor Company, (Specific Project Management) on request

1.7 Revision History

Version	Date	Description	Author	Approved by
000	2014-03-20	Draft issue	twulf	
001	2014-04-09	Initial release	twulf	ldrews
002	2014-04-17	Review	wchahine twulf	wchahine
003	2014-04-17	2nd review	wchahine	wchahine
004	2017-03-24	Chapter moved: 5.11 -> 5.12, 5.10 -> 5.11, 5.9 -> 5.10 Chapter added: 5.1.3, 5.4.4, 5.9 Chapter modified: 1.7, 5.1.1, 5.1.2.1, 5.1.2.2, 5.2.1, 5.2.5.1, 5.3, 5.4.1, 5.4.2, 5.5.1, 5.5.1.1, 5.5.1.2, 5.5.3, 5.9.1	twulf	ldrews
005	2017-05-08	Chapter number changed: 5.9 -> 5.9.1 Chapter moved: 5.12 -> 5.13 Chapter added: 5.12 Chapter modified: 1.2, 1.7, 2, 5.2.2, 5.2.5, 5.2.6, 5.3.2, 5.3.3, 5.4.1, 5.5.1.1, 5.8.4, 5.10.1, 5.11.1, 8, Footer	twulf	ldrews

2. Contacts

The key contacts of the project need to be established at the commencement of the project and it is expected that there will be one champion identified at suppliers' company and one champion identified at Ford Motor Company. These champions will be responsible for the communication between the two parties.

Consider that the Ford champion is as per the region the ESOW is applied.

Role	**Contact Details (Name, email, etc.)**
Ford Motor Company Lead	
FAPA, Australia	Andy Tuck, atuck5@ford.com
FAPA, China	Evan Sun, ysun15@ford.com
FAPA, India	TBD
FNA EESE HIL	Miguel Mancilla, mmancil1@ford.com
FoE	Lothar Drews, ldrews@ford.com
FSAO	TBD
Supplier Lead/Single Point of Contact	

3. Objectives

Ford Motor Company requires the usage of HIL simulator to validate vehicle's functionality against a set of requirements. Using vehicle simulation and real ECUs in the loop, the purpose is to provide all electrical stimuli needed to fully exercise the ECUs and test its functionality.

The Supplier has to provide all necessary information, data, parts,… which are needed to operate the HIL simulator as per Ford Motor Company's requirements (see detailed lists in section 5 'Requirements' on p. 10 ff.).

4. Description of the Test System

EESE operates one or more HIL test systems per carline (project).
Each HIL is a virtual vehicle setup. Simulations are used to pretend that the ECU is part of a real vehicle. Examples for simulations: Engine, Vehicle, Road, Driver, Environment (Rain, Sun, Humidity), Manoeuvre, Sensors
The tests of a predefined number of functions are supported by each HIL, e.g.:

- Keyless Start
- Locking
- Driver assistant (Lane keep assist, Semi-automatic parallel parking, Traffic sign recognition)
- Stop-Start
- Operation mode management
- Network management

4.1 Advantages using the HIL in Comparison to other Test Methods

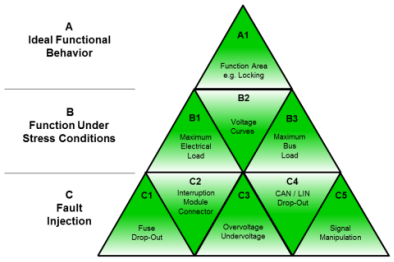
The HIL has some advantages compared with other test methods used at Ford Motor Company like Test Boards or Prototype Vehicle. Examples:

- The HIL is able to set stress conditions, e.g. setting battery voltage near to it specified limits or increasing the CAN bus load.
- Failure insertion testing is much easier and less dangerous as at the real vehicle, e.g. disconnecting wheel speed sensors.
- Missing ECUs, functions or devices can be simulated, e.g. simulation of a rain sensor to stimulate falling rain or using a functional locking model before ECU is possible.
- Real time testing like replaying battery cranking curves is possible.
- Driving manoeuvre automatically is possible. This is very helpful for dangerous manoeuvre or supporting driver assistance functional tests.
- Every test is able run automatically 7x24, which is perfect for a short termed regression testing.

4.2 Testing Tasks

The following testing tasks are conducted at the HILs:

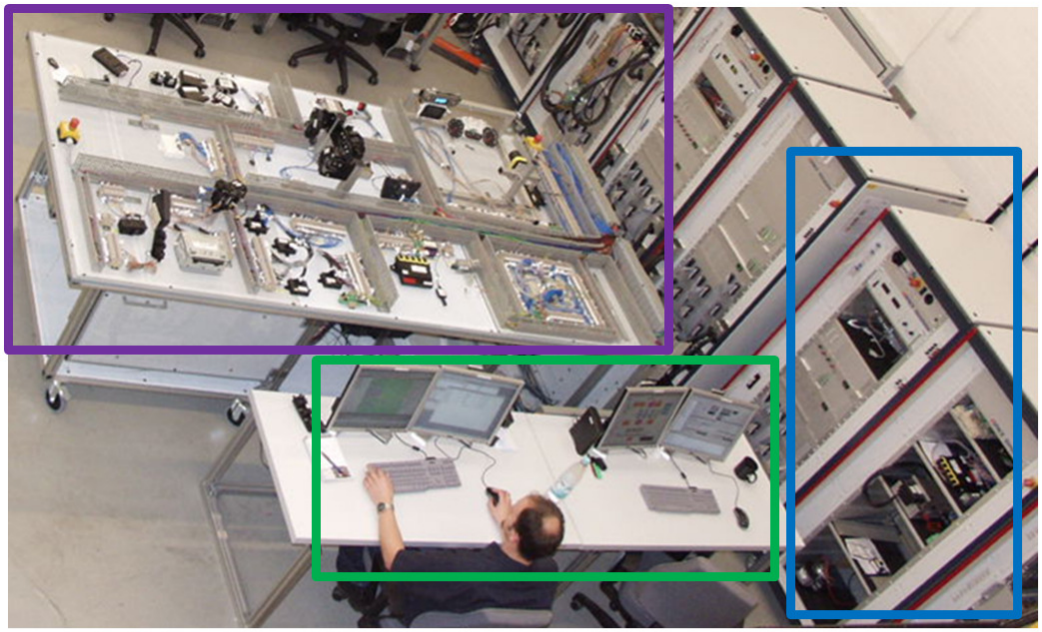
1. Performing the following types of tests:
    - Integration tests
    - Function and system level tests
    - Acceptance tests
    - Stress and failure tests
    - Regression tests



2. The HILs provide a valid test environment before vehicles are available and/or usable to support the function development. The early test results guarantee the prototype vehicle usability.
3. The high sophisticated HIL test environment will be used to support cause identification activities when a quick issue resolution is needed.

4.3 Setup of the HiL

Each HIL is divided into a simulator and a lab vehicle.



Lab-Vehicle
Real ECUs and actuators mounted on Lab Vehicle

Host-PC
Host PC used for test automation, modeling & control of HiL

HiL-Simulator
HiL Rig contains real time processor with I/O

4.3.1 Simulator

The simulator Hard- and Software is off-the-shelf and state-off-the-art.

- The main HIL supplier are dSPACE and NI. Others are e.g. The Mathworks, Vector and Cognex.
- Variety of different I/O boards are used at each system
  - LIN/CAN/Serial busses
  - DIO, DAC, ADC, PWM, Frequency, Current Measurement, Engine specific IO, Signal processor

4.3.2 Lab Vehicle

The lab vehicle contains:

- All the real parts, e.g. ECUs, Window lifter, Engine parts, latches, Remote Keys
- Simulation boxes, e.g. VSD (Valve simulation for ABS/ESP hydraulic simulation), parking aid sensors, tire pressure measuring sensors
- Camera and sound recognition devices (Cognex, NI)

The HILs are designed to contain as many real parts as possible. E.g. instead of using a window switch matrix simulation (which is easy and quick to setup), the real HW part will be instrumented to remotely control the switches.
But there are a lot of limitations and constraints, which makes it necessary to use simulations instead. This is for example:

- Implementability
- Parts delivery timing
- Stimulation capability
- Budget and space limitations

To create a valid setup there are different degrees of functional implementation used at the HiL, e.g.:

- All real parts, e.g. Heated steering wheel
- Sensor simulation:
    - Without additional HW: e.g. front looking radar sensor (adaptive cruise control)
    - With additional HW ('Simulation boxes'): e.g. Parking sensors (Parking aid, Ultrasonic): Sensor box, Pressure sensors (Tire pressure monitoring)
- Actuator simulation: Hydraulic pump (ABS/ESP)
- Stimulus simulation: Road and sign visualization to stimulate the front looking camera (e.g. traffic sign recognition)
- Plant simulation: Brake Hydraulics (ABS/ESP)

5. Requirements

This section lists Ford Motor Company's requirements regarding the supplier's test support of Ford Motor Company's HIL tests.

If the requirement is not applicable for the supplier, check the box (N/A) of the same row.

A modification of any content of the table besides the checking of check-boxes is not allowed. If an additional description or clarification of a requirement is necessary, check the 'Supplement is existing' box of the same row and use the section '5.13 Supplements' p. 18 to write it down. Use the requirements number (#) for reference.

The following list of requirements is a comprehensive one and covers all options of HIL integration designs of suppliers' deliverables. However, Ford Motor Company has in most of the cases a design proposal for the dedicated ECU available. If this is the case, you will find the design in the attached document [A].

5.1 Parts Delivery

#	N/A	Supplement is existing	Topic	Content
5.1.1	☐	☐	Number of items to deliver and timing	The supplier shall provide a set of ECU, sensors, switches, actuators and harnesses for each HIL. The parts shall be delivered two month before the material release date (MRD) without any dedicated order needed. The same timing is valid for any kind of part substitute that is provided instead of the original parts, e.g. as described in the subsequent sections ('5.2 Sensors and Switches', '5.3 Actuators', '5.4 Additional HW and SW')
5.1.2.1	☐	☐	HW changes	If the supplier did any kind of change of one of the in '5.1.1' mentioned parts, he shall provide a new part. Any parts modification will result in part replacement.
5.1.2.2	☐	☐	HW changes	Supplier part modification is acceptable as long as the part remains representative of the original design intent and functionality as well as compatibility to latest SW.
5.1.3	☐	☐	HW type	The minimum requirement for the delivered HW is that at least a functional PCB with design intended content is delivered.
5.1.4	☐	☐	SW changes	New or updated SW shall be provided as per Ford Motor Company's specified SW change processes.
5.1.5	☐	☐	SW changes	All SW shall be flashable with Ford Motor Company's tools (see '5.10.1').
5.1.6	☐	☐	Update timing	All updates shall be delivered within one day after their availability.

5.2 Sensors and Switches

Hereafter ‘Sensor’ is used for both ‘Sensor’ and ‘Switch’.

#	N/A	Supplement is existing	Topic	Content
5.2.1	☐	☐	Info needed to instrument sensor	The supplier shall provide all information that are needed to instrument the sensors, e.g. wiring schematics, PCB layouts and transfer functions.
5.2.2	☐	☐	Providing instrumented sensor	As an alternative to the provision of the information that are needed to instrument the sensors, the supplier can also provide already instrumented sensors as per the HIL’s need, e.g. the interface shall be compatible to the HILs interface, see ‘5.11 Simulator Interfaces’ and all sensor functions shall be controllable.
5.2.3	☐	☐	Bypassing sensor-ECU communication	If it is not possible to instrument the sensor, because it is for instance built in the ECU itself, the supplier shall provide a method to stimulate it. This could be for example a test bus, compliant to ‘5.11 Simulator Interfaces’, which bypasses the deactivated communication between sensor and ECU to allow an external stimulation.
5.2.4	☐	☐	Sensor simulation	If it is not possible to stimulate the physically present sensor with the HILs interface options (see 5.11 ‘Simulator Interfaces’), the supplier shall provide a Matlab/Simulink blockset as per the following requirements.
5.2.4.1	☐	☐	Sensor simulation	The 'Matlab/Simulink' blockset shall meet the requirements as per chapter ‘5.8 Matlab/Simulink blocksets’.
5.2.4.2	☐	☐	Sensor simulation	The supplier shall deliver Matlab/Simulink blocksets of complex transfer functions and communication protocols including any initialization algorithms that are required to enable full function of the delivered device.
5.2.4.3	☐	☐	Sensor simulation	All parameter and controls shall be provided, which are required to enable full function of the physical sensor.
5.2.4.4	☐	☐	Sensor simulation	All parameter and controls, mentioned in ‘5.2.4.3’, shall be fully documented, e.g. min/max values and units.
5.2.4.5	☐	☐	Sensor simulation	If any routine is executed between the ECU and the physical sensor, e.g. calibration-, initialization-, wake-up- or sleep-routines, they shall be implemented in the blockset and shall run automatically.
5.2.5	☐	☐	Sensor simulation box	As an alternative to the provision of a blockset, the supplier can also provide a sensor-simulation-box (SSB), which fully takes over the sensor simulation. In this case the following requirements shall be met.
5.2.5.1	☐	☐	Sensor simulation box	The supplier shall assure that the SSB is accepted by the provided ECU as a physical sensor, i.e. there is no DTC to be provoked by the simulation. If this is not the case because for instance the ECU HW/SW got an update, the supplier shall update the SSB as well.
5.2.5.2	☐	☐	Sensor simulation box	The control of the SSB shall be feasible with the HIL’s interface described in ‘5.11 Simulator Interfaces’.
5.2.5.3	☐	☐	Sensor simulation box	All parameter and controls shall be provided, which are required to enable full function of the physical sensor.
5.2.5.4	☐	☐	Sensor simulation box	All parameter and controls, mentioned in ‘5.2.5.3’, shall be fully documented, e.g. min/max values and units.
5.2.5.5	☐	☐	Sensor simulation box	If any routine is executed between the ECU and SSB, e.g. calibration-, initialization-, wake-up- or sleep-routines, they shall be implemented in the blockset and run automatically.
5.2.6	☐	☐	Connectivity	If a part that is provided by the supplier is not connectable by using the original vehicle harness and connectors, the supplier shall provide fully populated connector/s with 1,5m flying lead with each cable labelled.

5.3 Actuators

#	N/A	Supplement is existing	Topic	Content
5.3.1	☐	☐	Instrumentation of actuators	If a physically present load needs to be instrumented to enable data capturing relative to current status (like position or activation), the supplier shall provide all necessary information that are needed to instrument the actuator, e.g. geometries or physical characteristics (e.g. temperature, acceleration, velocity).
5.3.2	☐	☐	Dummy loads	If Ford Motor Company decides to use dummy instead of physical loads, the supplier shall provide all information that are needed for the design and setup of the dummy load. As an alternative the supplier shall provide dummy loads, with characteristics that are identical to physical load/actuator.
5.3.3	☐	☐	Connectivity	If a part that is provided by the supplier is not connectable by using the original vehicle harness and connectors, the supplier shall provide fully populated connector/s with 1,5m flying lead with each cable labelled.

5.4 Additional HW and SW

#	N/A	Supplement is existing	Topic	Content
5.4.1	☐	☐	Mountings and brackets	If special ECU, sensor or actuator mountings or brackets are needed for correct functionality, the supplier shall provide all necessary information for the build and setup, e.g. drawings. As an alternative the supplier shall provide the mountings and/or brackets.
5.4.2	☐	☐	Flash, diagnostic and calibration tools	The diagnostics, flashing and the calibration of vehicle SW shall be feasible with the tools described in '5.10 Tool Compatibilities'. In the event that these activities are necessary to perform at non-vehicle items, like SSBs, the supplier shall provide the necessary tool. The supplier shall provide flash instructions and necessary key files.
5.4.3	☐	☐	Connectors, terminals and cable	The EDS harness supplier shall provide assembled connectors with terminals included for each ECU, component, sensor, and/or actuator to be used by the HILs, fully populated with 1,5m flying lead.
5.4.4	☐	☐	Modified Calibrations	To assure the testability the supplier shall provide special calibrations, e.g. calibration files with modified limit stop coordinates because of a test setup that is different to the original vehicle setup.

5.5 Functionality

#	N/A	Supplement is existing	Topic	Content
5.5.1	☐	☐	Providing non-standard interface signals	If data is required and cannot be obtained by capturing IO, bus signal, or instrumentation, alternative methods shall be provided. The data provided by the alternative methods shall be capturable with the tools described in in '5.10 Tool Compatibilities'.
5.5.1.1	☐	☐	Providing non-standard interface signals	If the ECU uses internal buzzer or speaker to replay sounds, development frames or readable and well documented DIDs shall be provided and shall contain the type and timing of the sound.
5.5.1.2	☐	☐	Providing non-standard interface signals	For displays connected to ECUs, to recognize which frame, window or pop-up is currently displayed, a unique identifier of the currently displayed item shall be provided, e.g. DID read.
5.5.1.3	☐	☐	Providing non-standard interface signals	If other module internal data is required, it shall be provided as a DID or signal within a development frame, e.g. interface signals of different function modules within an ECU.
5.5.3	☐	☐	Deactivation of internal diagnostics	If the ECU does diagnostic IO checks, that verifies the existence of physically present HW, it shall be possible to deactivate these checks by ISO14229 diagnostic commands.
5.5.4	☐	☐	Storing ECU ID in ECU	To identify a LIN or CAN node, it is necessary to store an identification number (ID) in the ECU (Length shall be 15 bytes). This ID shall be manageable by ISO14229 DID read/write mechanism.
5.5.5	☐	☐	Encrypted Communication Keys	Any keys, which are exchanged between 2 or more ECUs to enable encrypted communication between them, shall be writeable to the module that distributes the key to other modules. This writing may be protected by any Ford-specified security access, depending on the functional specification. If this requirement is contradictory to any applicable Ford specification, this specification shall stay valid. Otherwise, supplier shall write a key, specified by Ford Motor Company, to every ECU that is delivered for HiL testing purposes.

5.6 Commissioning and Operation Support

#	N/A	Supplement is existing	Topic	Content
5.6.1	☐	☐	Setup support	The supplier shall support the integration of the subject components into Ford Motor Company's HIL environment, e.g. assist with the calibration of the subject system. The assistance required could be either on-site or by telephone. This support will be required until the setup is running error free on the HiL. This could be necessary at each SW/HW delivery
5.6.2	☐	☐	Problem resolving	The supplier shall support the issue finding and removal process during the projects' lifecycle.
5.6.3	☐	☐	Range	All supporting activities shall be performed for all existing instances of the parts described in this document. E.g.: If there is HW updates necessary, this update shall be performed by the supplier for all parts that have been delivered.

5.7 Documentation

#	N/A	Supplement is existing	Topic	Content
5.7.1	☐	☐	Interface description	The supplier shall provide a full and detailed electrical and physical description of all interface signals of each delivered item.
5.7.2	☐	☐	Bus signals description	If the interface port is a bus, the signal description shall be provided as a signal database file, e.g. *.dbc or *.ldf, which are compatible with 'Tool Compatibilities' (chapter 5.10).

5.8 Matlab/Simulink blocksets

#	N/A	Supplement is existing	Topic	Content
5.8.1	☐	☐	Target compatibility	The provided blocksets shall be compatible with and compilable on target, see '5.10 Tool Compatibilities'. The compatibility list may change during the projects lifecycle, e.g. migration to a new Matlab/Simulink version. In this case the supplier has to deliver a re-compiled update.
5.8.2	☐	☐	Target compatibility	The delivered blockset shall meet the HILs real time performance requirements; see ‘'5.10 Tool Compatibilities’.
5.8.3	☐	☐	Integration assistance	Supplier shall assist to integrate blockset into HIL RT model.
5.8.4	☐	☐	Target compatibility	The blocksets shall be delivered in compiled form to preserve supplier’s intellectual property. In this case the compiled system shall be verified in the defined Matlab/Simulink environment and shall not cause any simulation issues. E.g. it shall not cause any memory problem. The simulation shall be reliable and reproducible.
5.8.5	☐	☐	IO access	All parameters accessible to the Ford engineer shall be modifiable by using accessible parameters within Matlab/Simulink constant blocks, gains, variables or m-files.
5.8.6	☐	☐	IO documentation	All conversions shall be documented (from physical value to electrical signal and from electrical signal to physical value).

5.9 Costs

#	N/A	Supplement is existing	Topic	Content
5.9.1	☐	☐		All parts and services described in this document shall be provided without any order necessary, i.e. no additional costs.

5.10 Tool Compatibilities

#	N/A	Supplement is existing	Topic	Content
5.10.1	☐	☐	Compatibility list	The subsequent list is an overview of tools and parameter used in the HIL test environment. The tool's version is not necessarily the latest release, is not equal at all HIL test facilities and could change over the lifetime of the project. All SW provided by the supplier shall be compatible to the version of the tool that is used at the HIL test facility at the point of time when the SW is needed. Simulator: • Matlab/Simulink • Solver options • Type: Fixed-Step with cycle time of 1ms • Solver: ode1 (Euler) • dSPACE RT Boards and HW • Diagnostic Interface: ISO14229, 11Bit, max. 1MBaud Diagnostic, Flashing and Calibration Tools: • Ford DET • ATI Vision • Vector CANalyzer

5.11 Simulator Interfaces

#	N/A	Supplement is existing	Topic	Content
5.11.1	☐	☐	Interface list	The interfaces of the simulator are as per the subsequent list. The ECU, SSB and load simulations shall support only these. Inputs: • Digital: Threshold 7.5V, max. ±60V • Differential Digital: Threshold 2.5V • Analogue: ±25V, max. ±75V • PWM: between 2.5 and 7.5V, 16bit, 0.01Hz-100kHz Outputs: • Digital: Push-Pull Output with references VBatt, 5V or GND, max.150mA per channel, 5-60V • Differential Digital: Max. 50V, 250mA per channel • Analogue: ±10V, 12bit, 5mA per channel • PWM: High 5V, 16bit, 0.01Hz-100kHz • R-Sim: 15.8Ω-2MΩ Busses: • LIN • CAN • Serial (RS232/485)

5.12 Supplier's Single Point of Contact

#	N/A	Supplement is existing	Topic	Content
5.12.1	-	☐		The supplier shall provide a name of a single point of contact in their organisation to be responsible for communication with the Ford HIL team. Ideally, this would not be the supplier side project manager, preferred it would be a HIL or software equivalent from the supplier's organisation. The name and contact details shall be entered into the table at chapter 2. 'Contacts'.

5.13 Supplements

Use this sheet to write down supplements to the requirements. If this page is not enough, create copies of it and attach it to the SOW document.

Before signing the SOW, empty rows and areas of the supplement section needed to be strike out.

#	Supplement content

6. List of Acronyms and Abbreviation

Acronym/Abb.	Description
ECU	Electronic Control Unit
EESE	Electrical Electronic Systems Engineering
HIL	Hardware in the Loop
HW	Hardware
ID	Identification Number
MRD	Material Release Date
N/A	Not applicable
PCB	Panel Control Board
SOW	Statement of Work
SSB	Sensor Simulation Box
SW	Software

7. Amendments

#	Description
[A]	Design proposal of the integrate of supplier's deliverables into Ford Motor Company's HIL environment

8. Agreement

Ford Motor Company and supplier jointly agree upon this level of SOW.

Please check before signing:

- All requirements, which are not applicable, are checked ('N/A' checkbox of requirement lists): page 7 ff.
- All empty rows and areas of the supplement section needed to be strike out: page 17

_____

Name, Position

Ford Motor Company

_____

Name, Position

Supplier