# Electronic Systems for Data Transfer and Command

Area 2 – **Technologies**

Lesson 9 – **Communications**

Sequence ID – **29**

**UPM**

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# Who am I?

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I work and teach on sensorics applied to farm machinery, mechatronics, data analysis, robotics, and precision agriculture in general

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The information presented in this topic has been prepared by the full professor Pilar Barreiro, Constantino Valero, and other members of the “LPF_Tagralia” research group at UPM.

# DISCLAIMER

# A2.L9.T1 Electronic systems for data transfer and command

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# What is ISOBUS ?

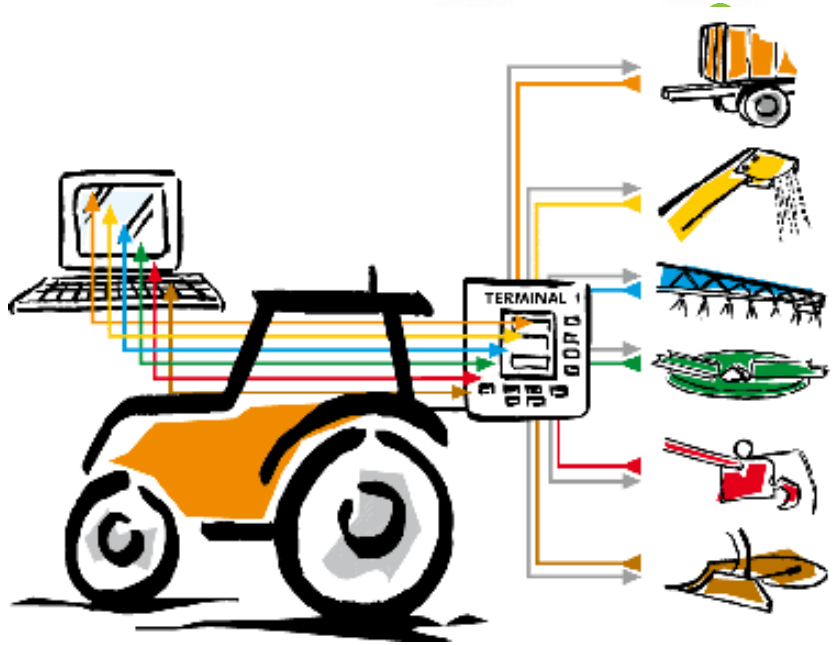
- It's an **international standard** published by the ISO organization www.iso.org
- It's the **universal language** for the exchange of data and machine control commands between tractors, farm machinery, and electronic equipment
- It's an **agreement** between the main manufacturers of farm machinery and electronics
- Currently, it is a *wired* standard, but a *wireless* version is being prepared

# Is ISOBUS new?

- The technical development of the standard (ISO 11783) ISOBUS began in 1992: the ISO organization started a working group devoted to *Agricultural Electronics*.
- It is based on previous standards: SAE J1939 and the bus CAN 2.0B
- It is commonly called “ISOBUS” (in capital letters)
- The first version of the ISOBUS standard was published in 2001; some parts have 2 or 3 updated versions
- In 2008, the AEF (Agricultural Industry Electronics Foundation) was created, to promote the practical implementation of ISOBUS www.aef-online.org

AEF
AGRICULTURAL INDUSTRY ELECTRONICS FOUNDATION

# What is ISOBUS for?




- To be able to connect any machine to any compatible tractor
- To recognize each other automatically
- To be able to exchange information
- To avoid duplicities in electronic systems
- To exchange orders between machines
- To be able to control from a single monitor several implements
- To reduce costs
- To increase safety and performance of farm machinery

# Who designs the ISOBUS standard?

- Specialised technicians of many countries

- At periodical meetings (every 6 months) of the ISO Technical Committee 23 , Sub-Committee 19, Working Group 1&5 for “Agricultural Electronics”
- National Standard organisations send delegates. Example: Spanish UNE (AENOR) participates via CTN 68, represented by ANSEMAT (association of manufacturers)

AENOR

ANSEMAT

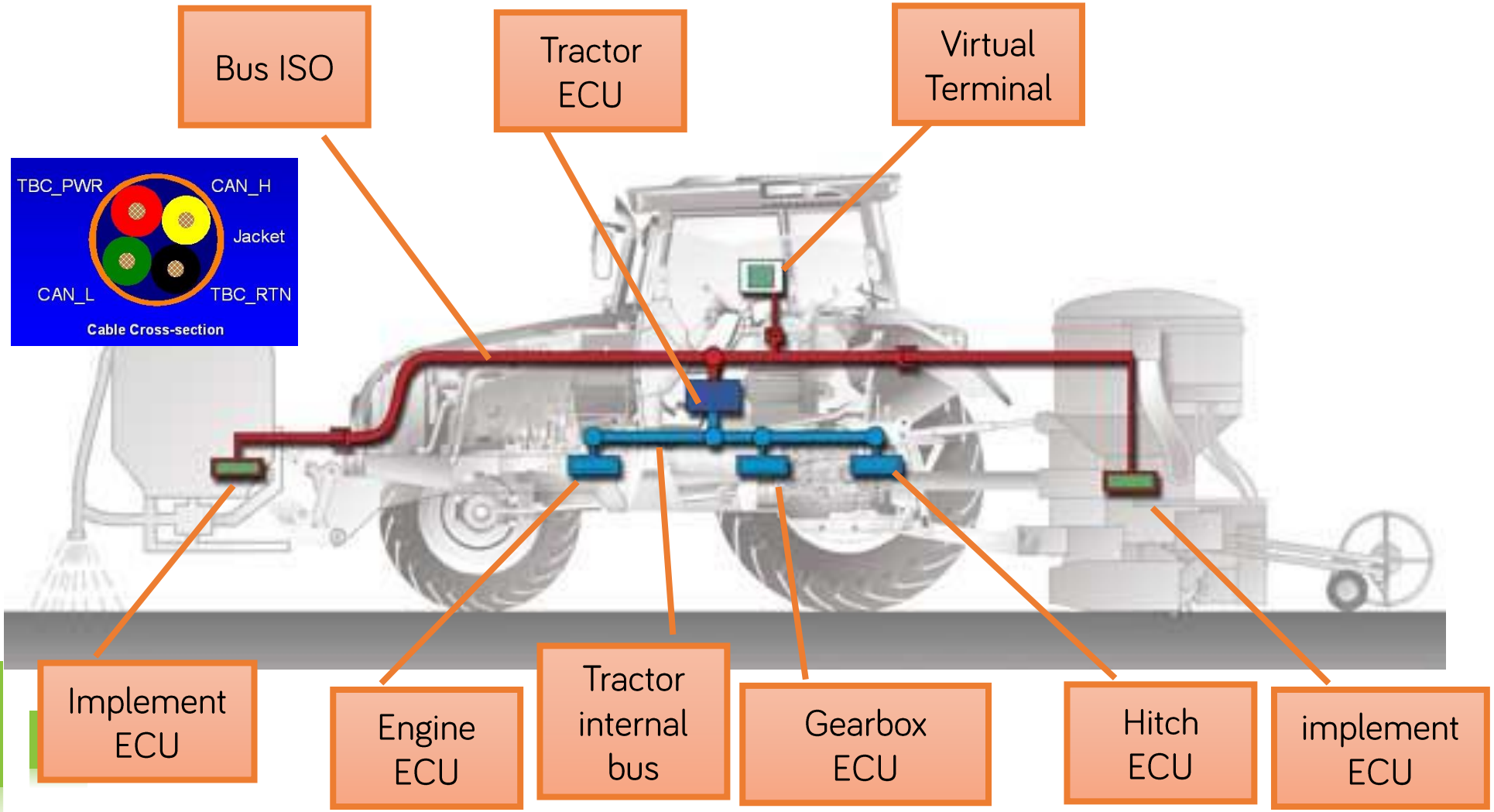
# Parts of the ISO 11783 standard


The standard has 14 published parts, some of them currently in 2nd or 3rd versions

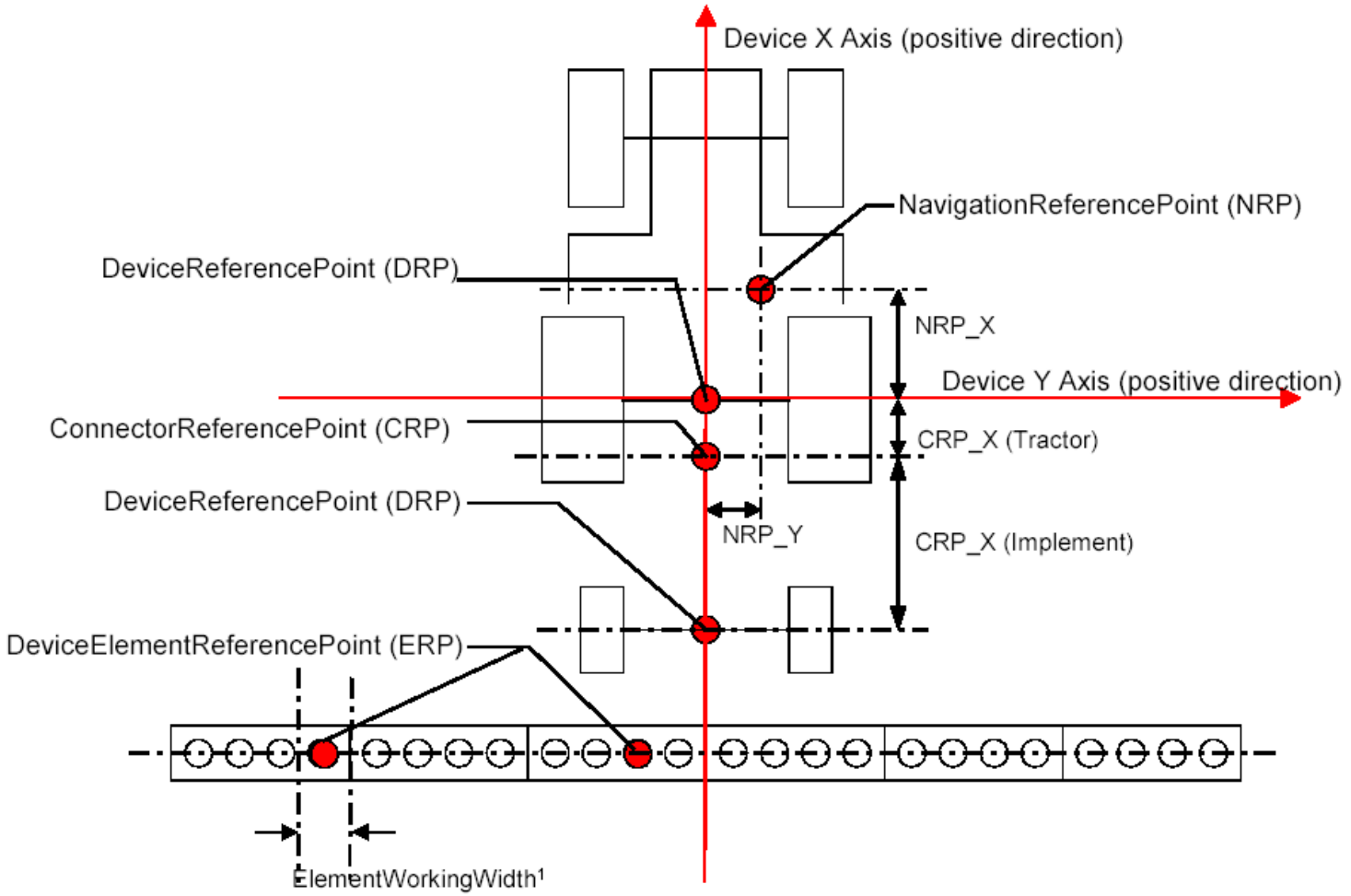
1. General
2. Physical layer: cables comprising the bus, connectors
3. Data layer: messages sent through the data bus
4. Network layer: how subnetworks are connected
5. Network management: how the ECUs are named
6. Virtual Terminal: characteristics and functions
7. Basic messages among implements
8. Power train: tractor control (engine, gear box, CVT, electronic management, hitch point, …)
9. Tractor-ECU: specific tractor functions
10. Task Control / Communication with computer: data logging, **precision farming**, fleet management
11. Dictionary of messages
12. Diagnosis & maintenance
13. File Server: **storing information** about the field work
14. Sequence control: headland management, automatic sequences

# PART 1: General Description

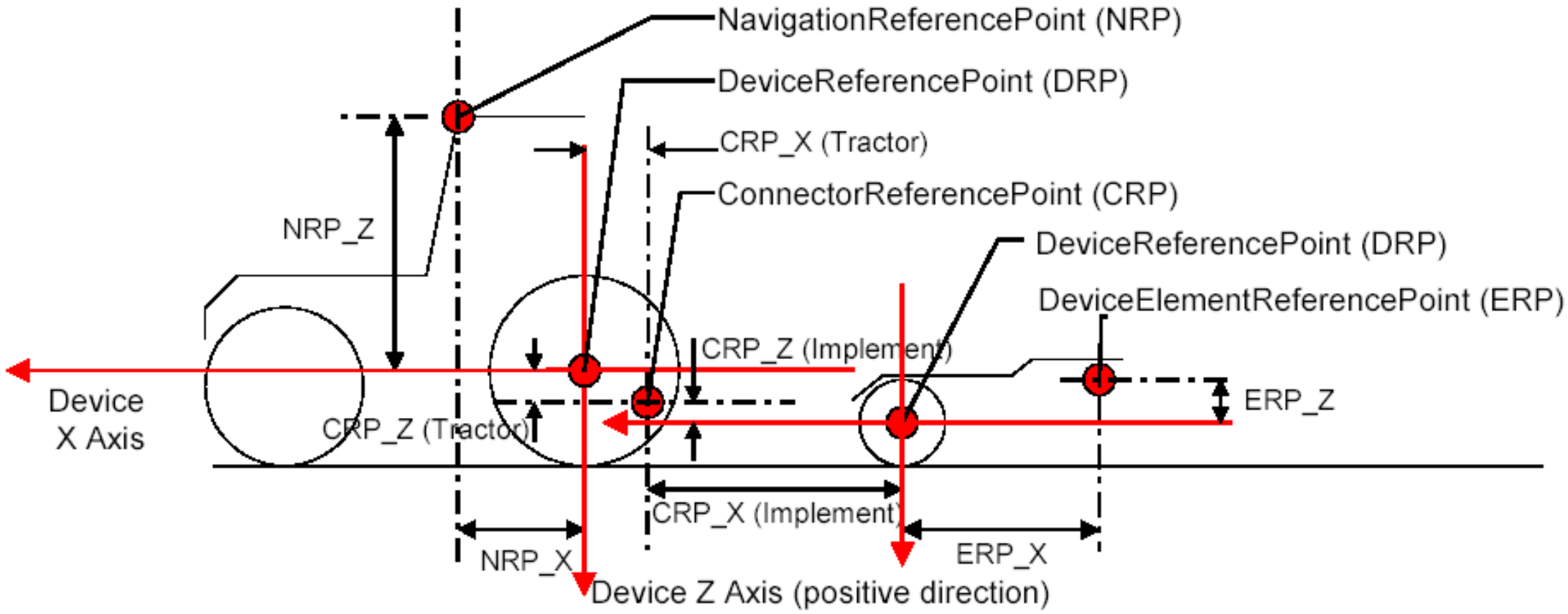
## Main components of ISOBUS equipment



# Detailed spatial location of every tractor & machine component is essential



# Detailed spatial location
# ...from other point of view



# PART 2: Physical Layer

Defines the wires and connectors of ISOBUS devices:

- Communication Bus = the “ISOBUS main cable”
- TBC (Terminating Bias Circuit): a “cap” needed at the end of the Bus, in both ends, for electronic stability
- Nodes: every single junction of the Bus
- Connectors: standard plugs / sockets to connect wires, ECUs, screens…
- Tractor ECU: the most important ECU in the Bus, with the highest level
- All the other control boxes are “normal” ECUs (electronic control units) controlling a portion of the machine or a subsystem of the tractor

# CAN Bus Wiring on Ag Equipment

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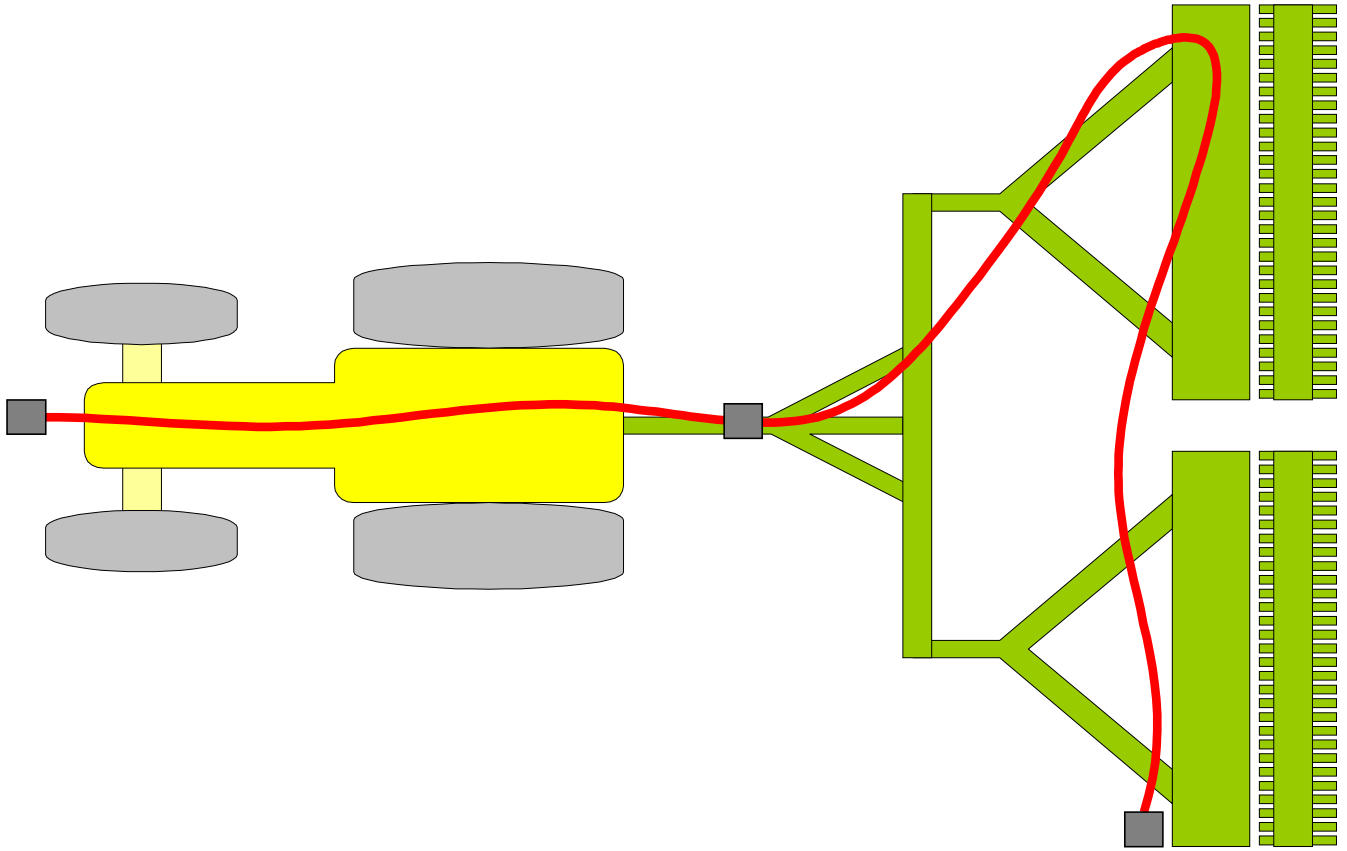
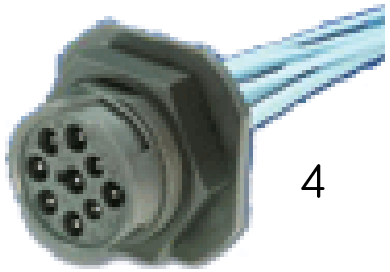


# Main Connectors

1

1. Implement Connector
2. Connector for ISOBUS box
3. Terminator connector
4. Diagnosis connector

1

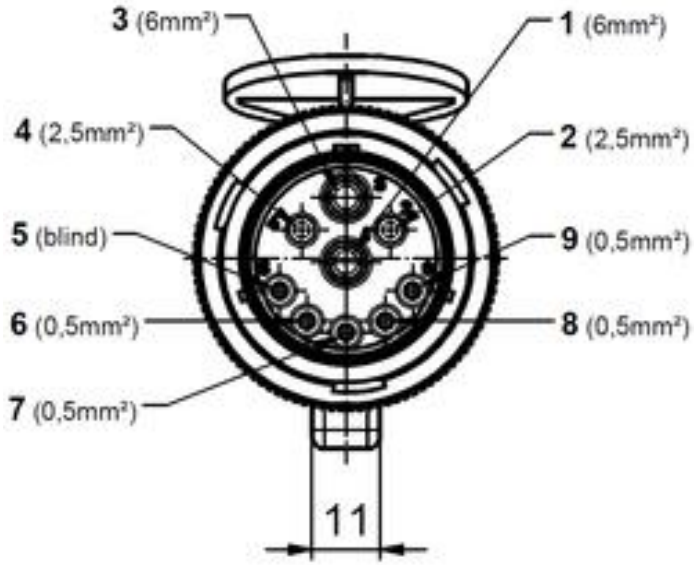


4

3

2

# Pinout of Main Implement Connector

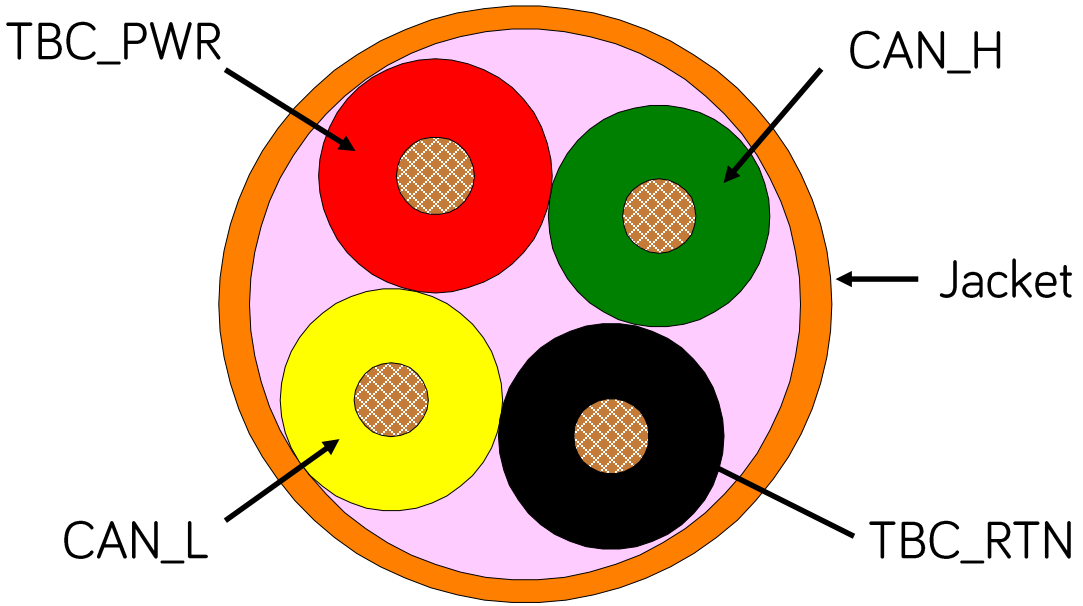



| PIN | Contact | Wire cross section | Wire color | Name |
|---|---|---|---|---|
| 1 | A | 2,5 / 6 / 10 mm² | Black | GND |
| 2 | B | 2,5 mm² | Black | ECU_GND |
| 3 | A | 2,5 / 6 / 10 mm² | Red | PWR |
| 4 | B | 2,5 mm² | Red | ECU_PWR |
| 5 | C | n.c. | | TBC_DIS |
| 6 | C | 0,5 mm² | Red | TBC_PWR |
| 7 | C | 0,5 mm² | Black | TBC_RTN |
| 8 | C | 0,5 mm² | Yellow | CAN_H |
| 9 | C | 0,5 mm² | Green | CAN_L |

# Main Bus cable: a twisted quad cable

Transversal section:

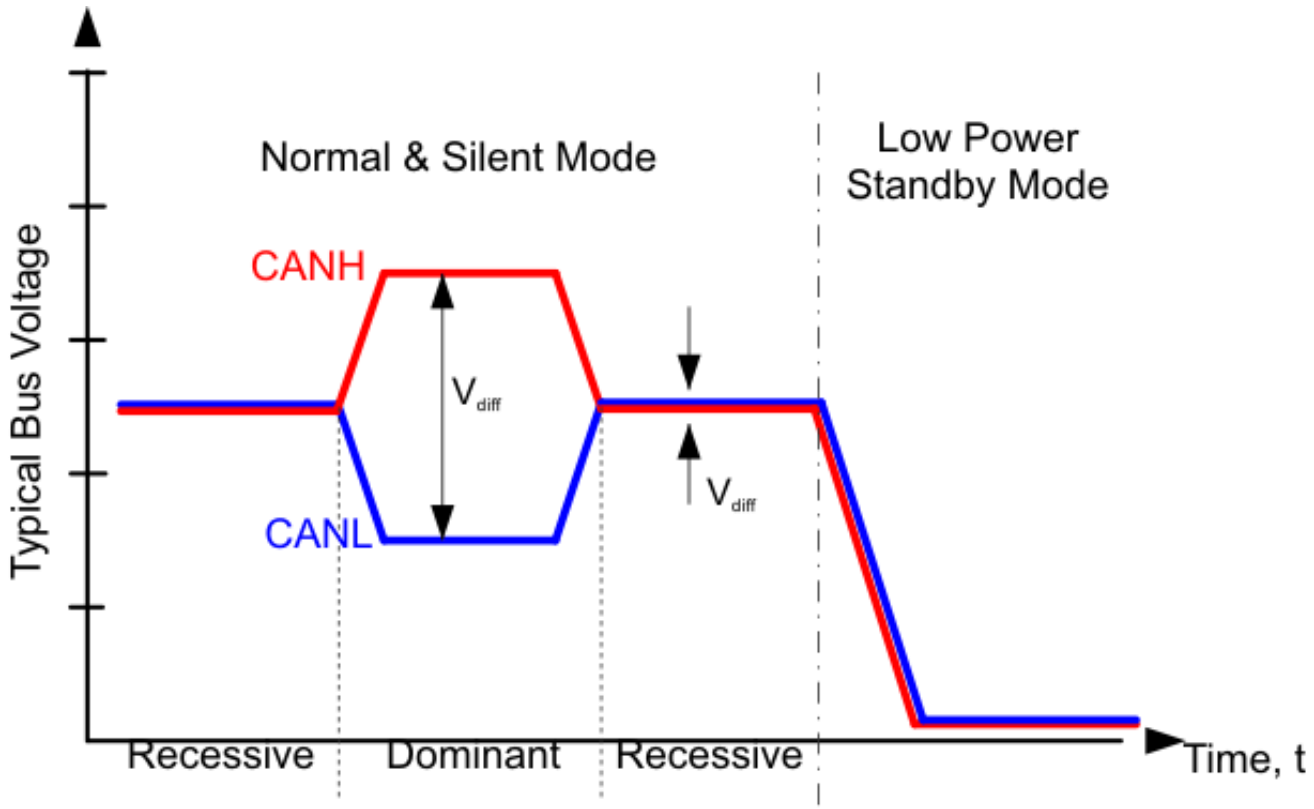
- CAN-High & CAN-Low transmit the Bus messages
- TBC-Power & TBC-RTN (ground) provide electrical power supply (12V) to ECUs and connected devices

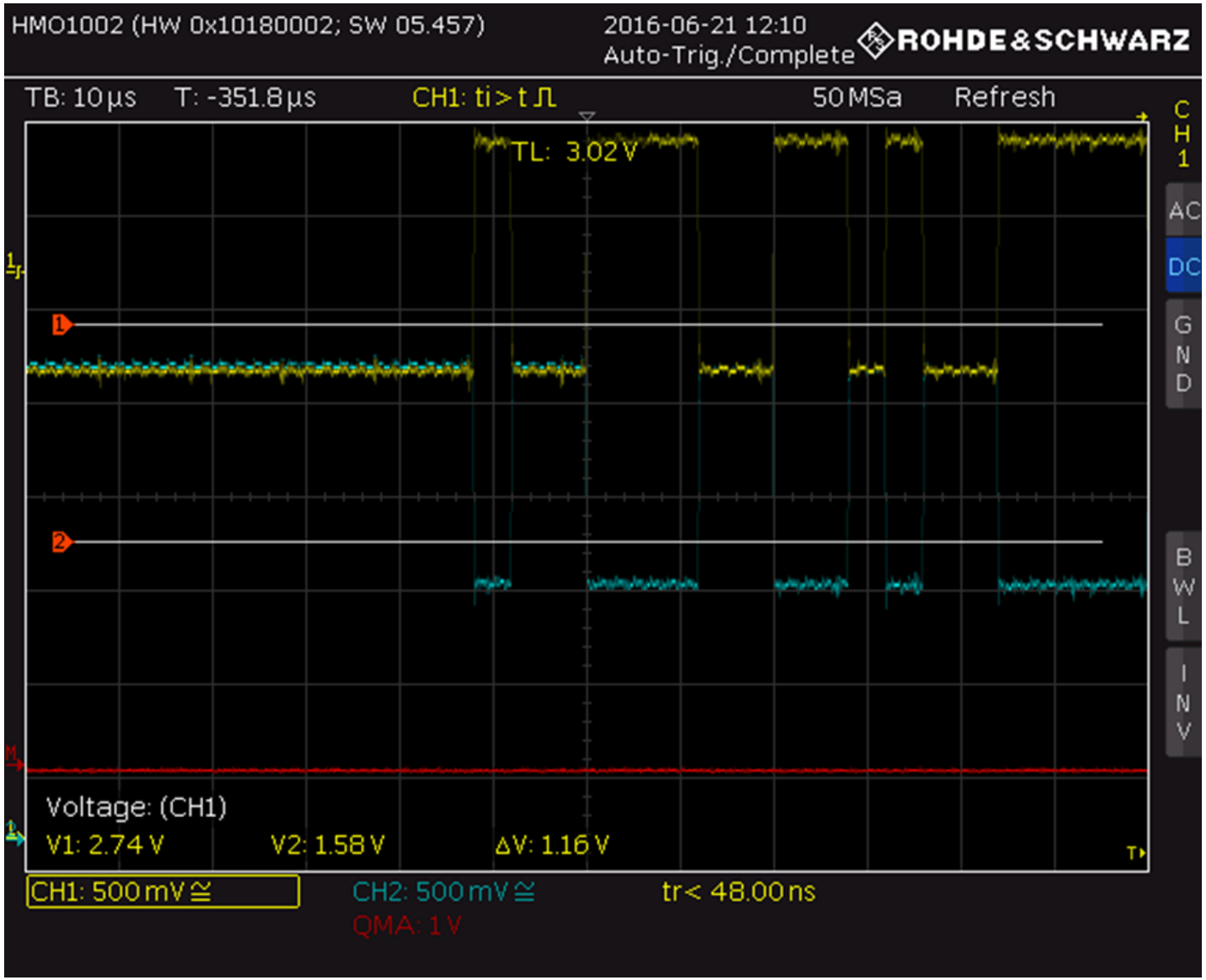


# Voltage of CAN-H and CAN-L wires

Digital messages are transmitted through both wires simultaneously, with a difference in voltage, in order to have redundancy:

- If the devices are ON
  - And no message is being transmitted, both CANH & CANL are at 2.5V (in “recessive mode” = silent)
  - And a message is being transmitted (in “dominant mode”) :
    - CANH is at 3.5V
    - CANL is at 1.5V
- If the devices are OFF (or low power mode) the wires are at 0V




HMO1002 (HW 0x10180002; SW 05.457)
2016-06-21 12:10
Auto-Trig./Complete
ROHDE&SCHWARZ
TB: 10 µs
T: -351.8 µs
CH1: ti > t
50 MSa
Refresh
TL: 3.02 V
CH 1
AC
DC
GND
BWL
INV
Voltage: (CH1)
V1: 2.74 V
V2: 1.58 V
ΔV: 1.16 V
CH1: 500 mV
CH2: 500 mV
tr < 48.00 ns
QMA: 1 V

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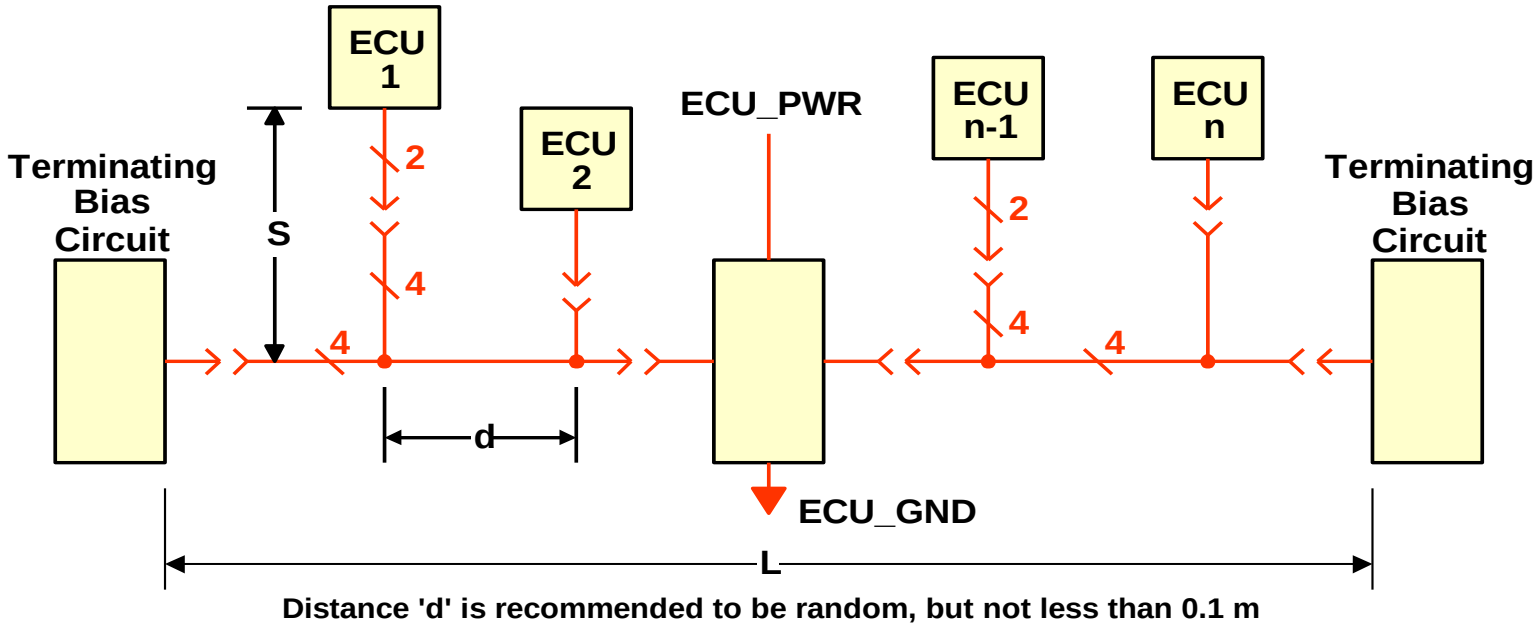
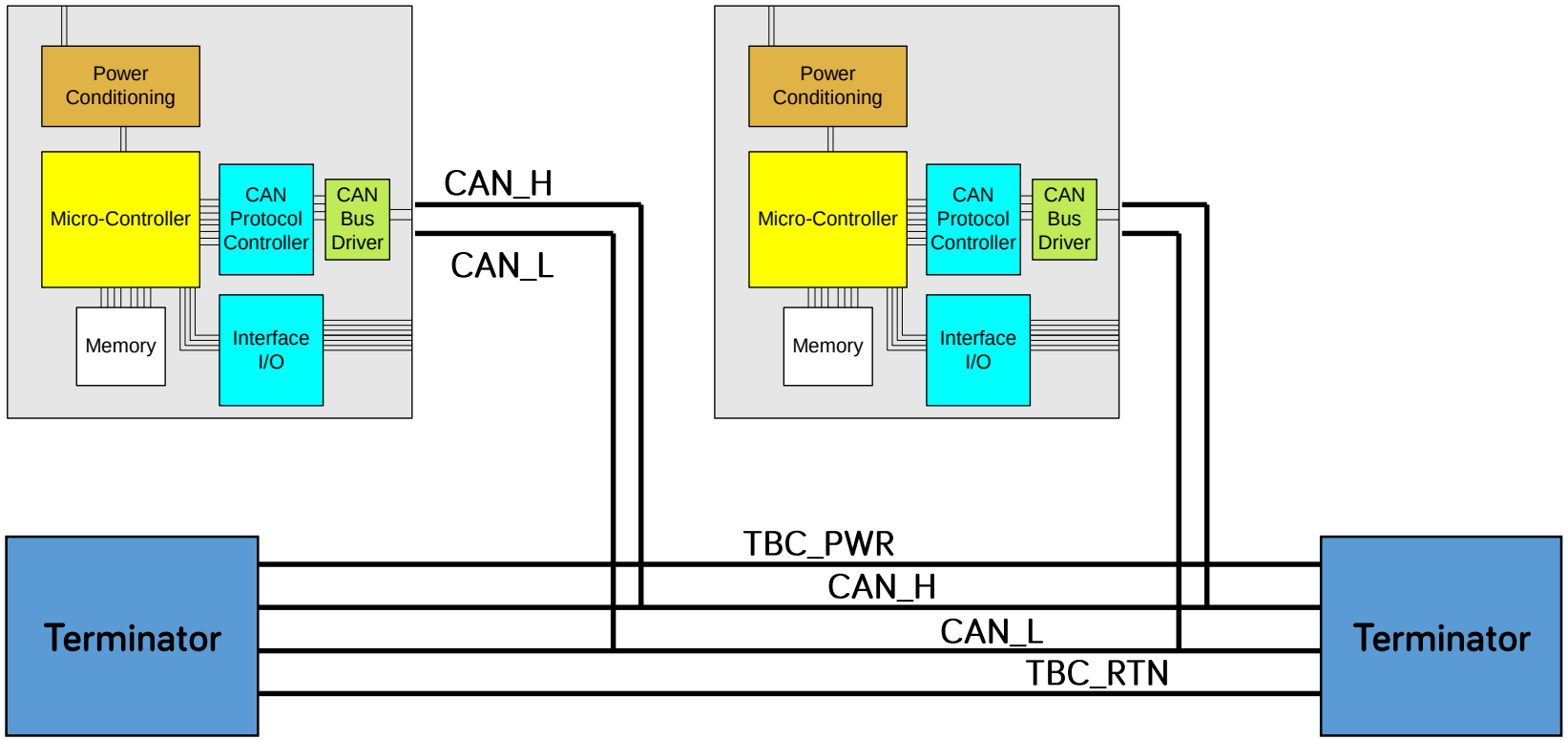
# Physical Layer:

- Maximum dimensions and connections are defined in ISO 11783



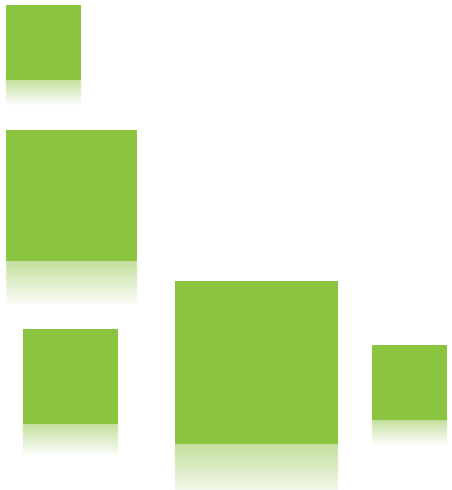

| | |
|---|---|
| Maximum length of a segment (L): | 40 m |
| Maximum length of a branch (S): | 0.3 m |
| Minimum distance between nodes (d): | 0.1 m |

# How each ECU is connected to the Bus



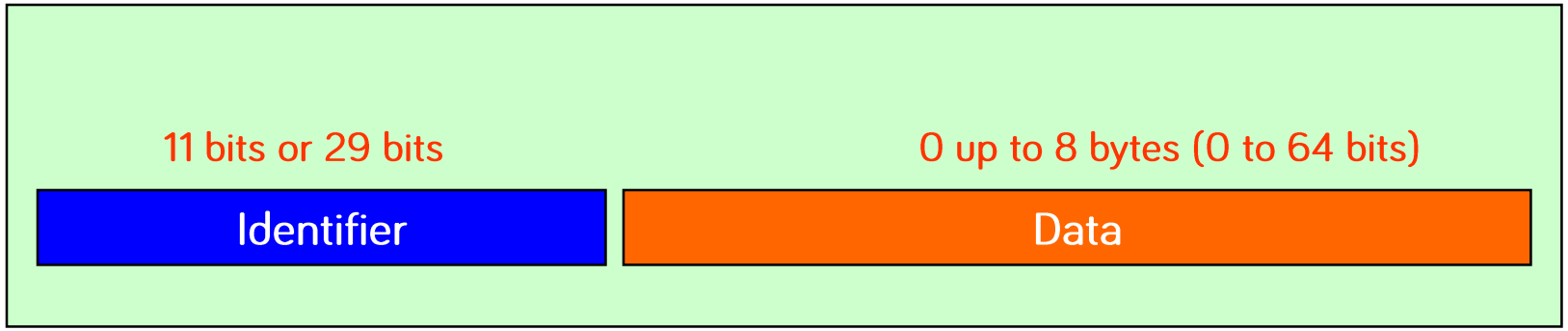
# PART 3: Data Link Layer


- Allows reliable forwarding of data through the physical layer
- Is based on another standard called CAN 2.0B with subsequent synchronization, error control, and flow control



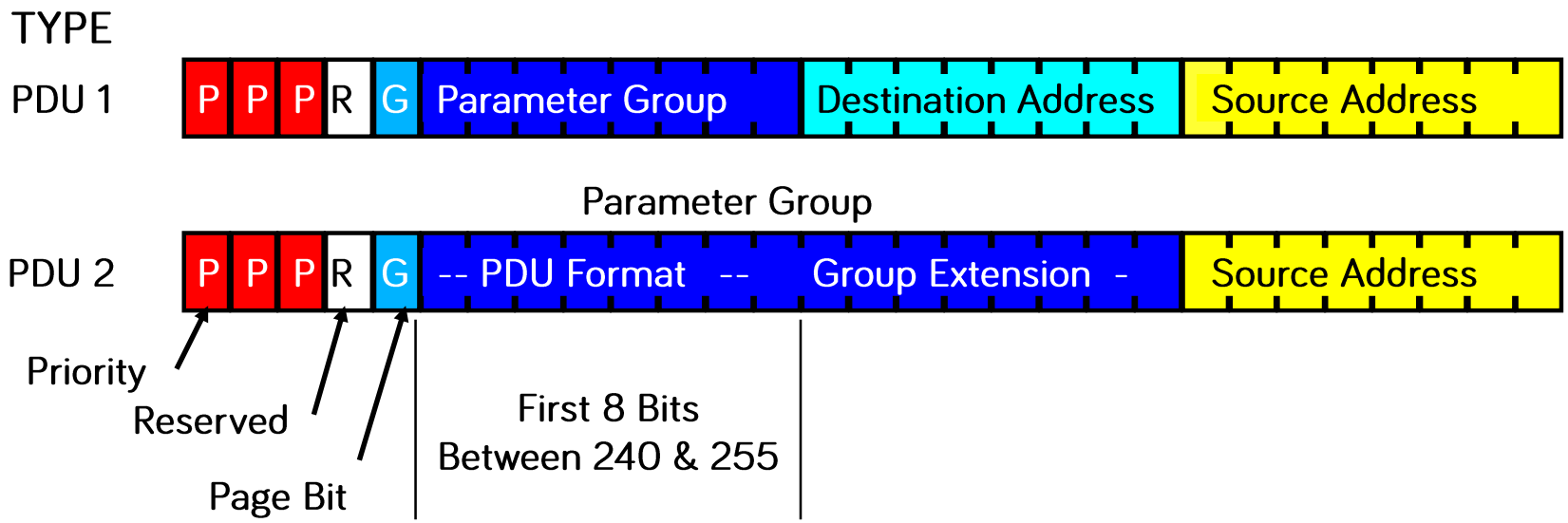
# ISOBUS Messages

Digital messages are similar to CAN 2.0B messages:



# Message Configuration

- Two identifier types (PDUs)
  - PDU 1:  a message sent from one ECU to another ECU
  - PDU 2: a message sent from one ECU to All (broadcast)



# Types of Messages

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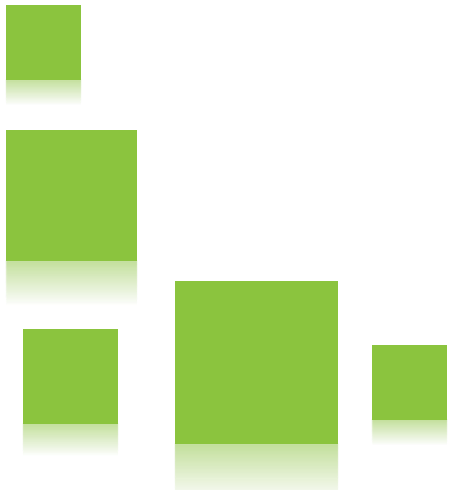
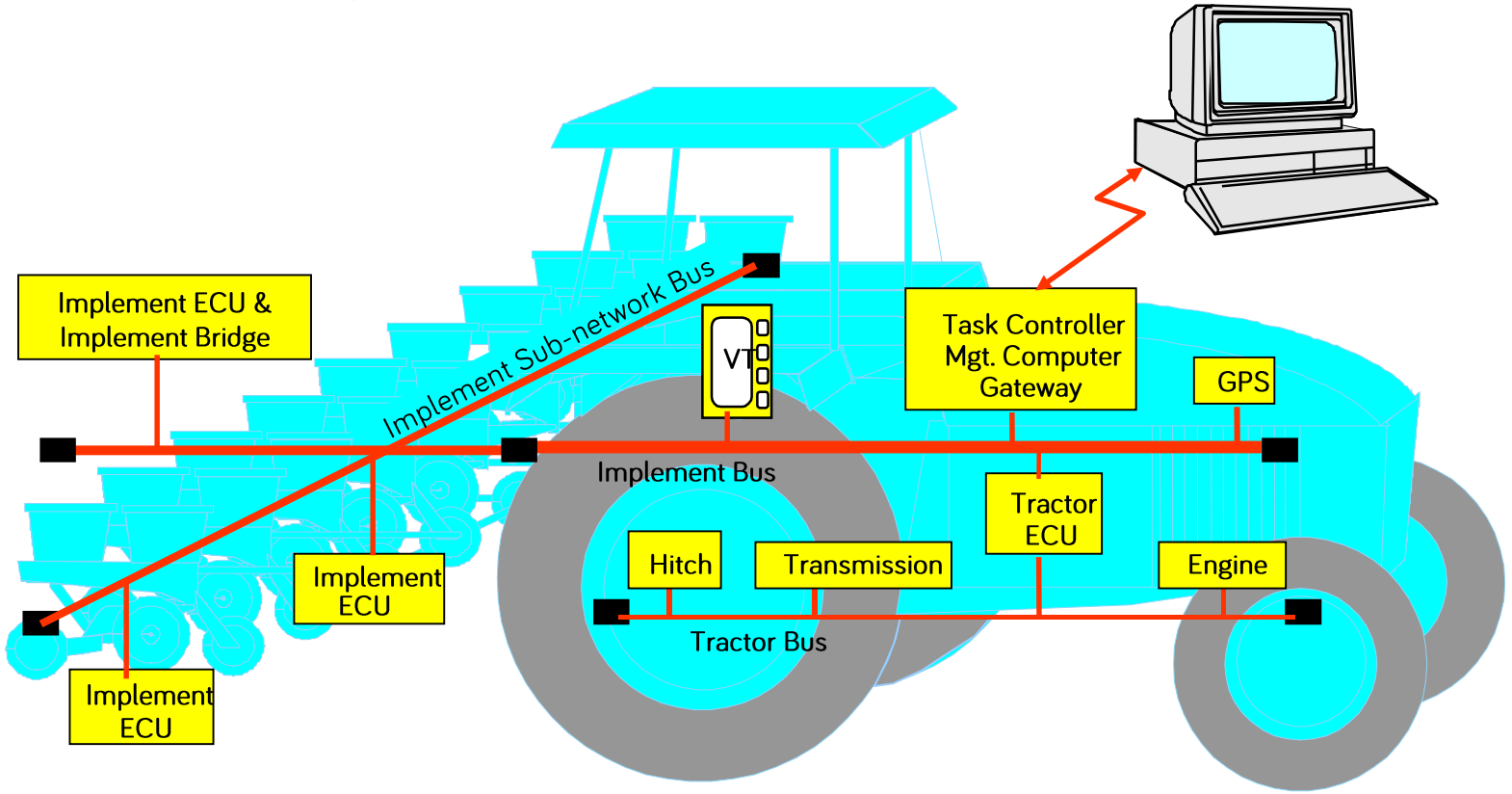
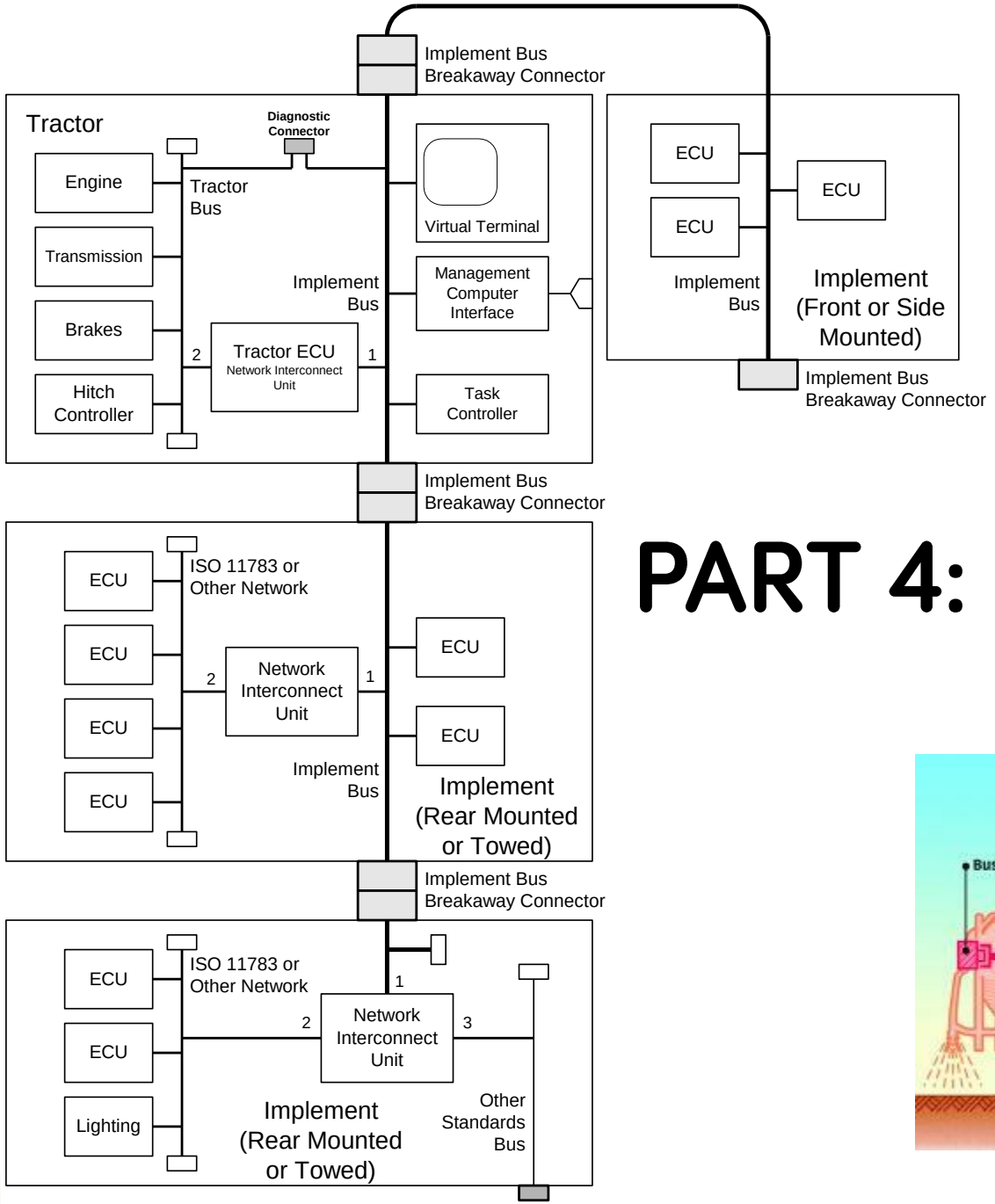
- Types: command, request, broadcast responses, acknowledgement, group functions, proprietary
- Proprietary messages are useful when there is no need to fulfil the standard, or when the information must be hidden
- A reply from a specific destination is always required
- The tractor ECU always gives acknowledgement



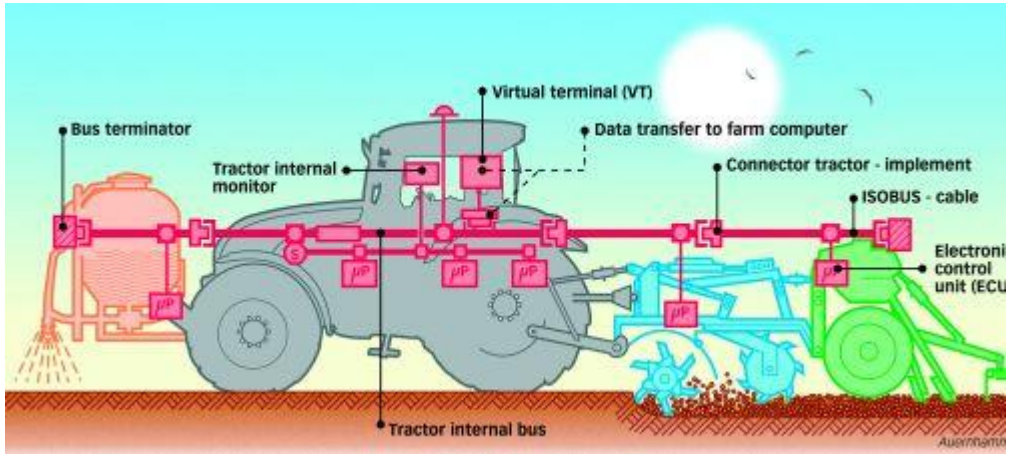
# PART 4: Network Layer

- Defines how different subsystems should be named and connected



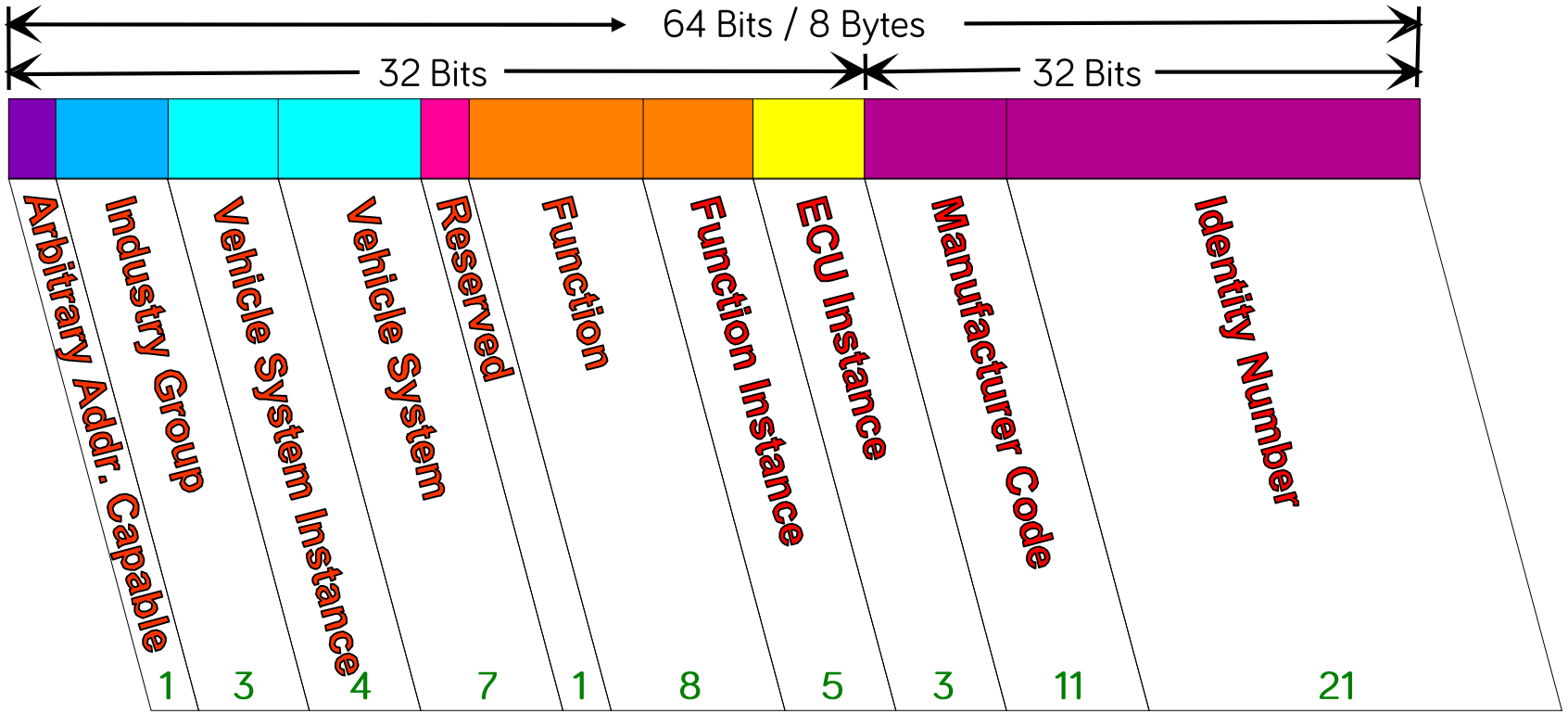



# PART 4: Network Layer



# PART 5: Network Management

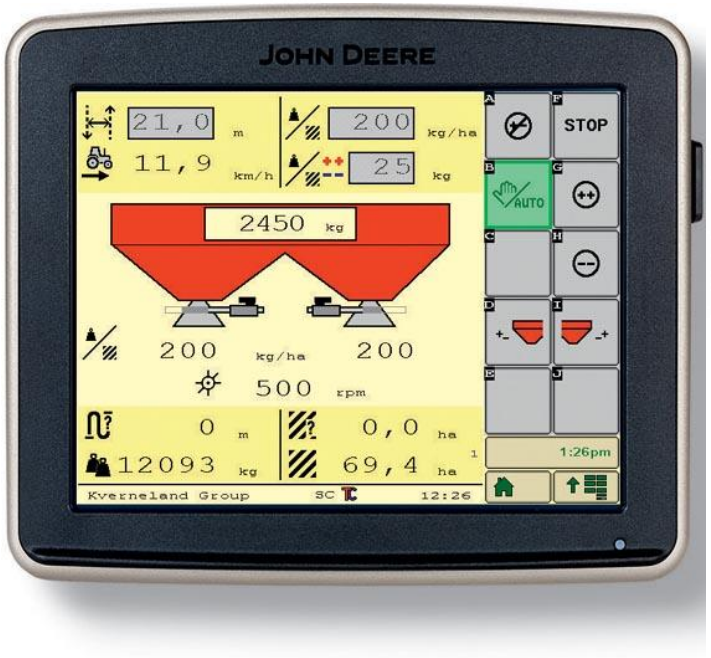
- NAME STRUCTURE



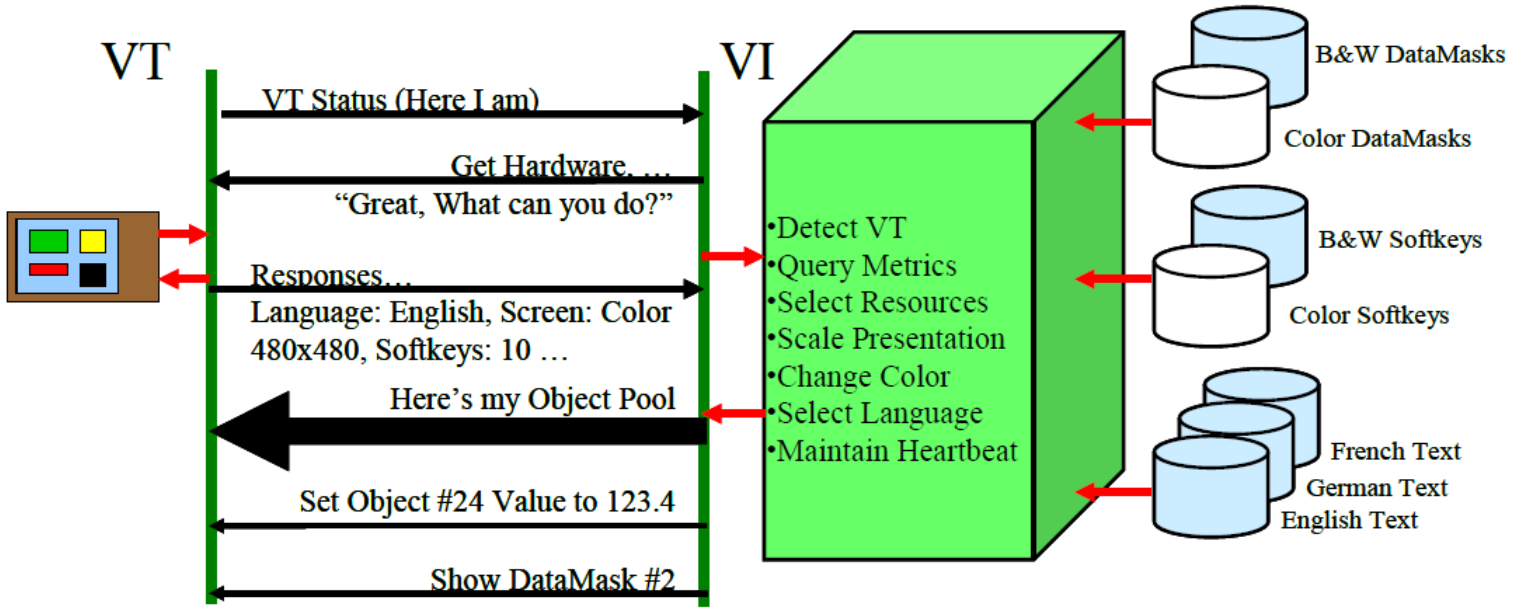
# Address Claim


- When an ECU is turned on, a Power On Self Test (POST) is started
- Then, a message is sent to all other ECUs asking for an ADDRESS
- If two ECUs ask for the same ADDRESS, the one with the shortest NAME wins: “the lowest number wins”

# PART 6: Virtual Terminal




- The Virtual Terminal (also called Universal Terminal) is just a screen to visualize information and an interface with operator
- It does not process the information (may include other devices in the same box)
- Is controlled by one (or multiple) ECU(s)
- There are several types (classes) depending on complexity



# Virtual terminal

- With only on Virtual Terminal, a tractor and several implements can be displayed and controlled at the same time


36,0
400
0,0
25
104
72
0,3
1294
5,8
0,00
72
0
0,0
0,0
0:00
35
0,00
0

# PARTs 7 & 8: Application Layers


Defines the basic messages for vehicle control:

- ISO 11783 Part 7 : Implement Message Application Layer
  - Basic Messages
    - Ground Speed, Time/Date
    - Three Point Hitch, Auxiliary Valves, PTO
    - Navigation/GPS
    - Lighting
    - Process Data Message (Task Controller/Implement)

- ISO 11783 Part 8: Power train messages (SAE J1939/71)
  - Broad vehicle info and control messages
    - Engine/Transmission/Braking/Ipanel
    - Speed/Temperatures/Pressures
    - etc. ( ~200+ pages)

# Basic Messages

| Message Title | Usual Source |
|---|---|
| Time and Date | Tractor ECU |
| Wheel Based Speed and Distance | Tractor ECU |
| Ground Based Speed and Distance | Tractor ECU |
| GPS Position and Status data | GPS/Navigation ECU |
| Attitude (Bearing, Pitch, Roll, Altitude) | GPS/Navigation ECU |
| Hitch Status (Position and Draft) | Tractor ECU |
| Power Takeoff Status | Tractor ECU |
| Auxiliary Valve Status | Tractor ECU |
| Hitch and PTO Commands | Implement ECU |
| Auxiliary Valve Commands | Implement ECU |
| Lighting | Tractor ECU |
| Process Data | Task Controller/Implement ECU |
| ECU Power Status and Extension | Tractor/Implement ECU |

# Parameter definition

In the “Data dictionary” all messages that can be exchanged using the Bus are detailed.
For example:

**Parameter Example**

**5.2.5.43**

| | |
|---|---|
| Barometric Pressure: | Absolute air pressure of the atmosphere |
| Data Length: | 1 Byte |
| Resolution: | 0.5 kPa/bit gain, o kPa offset |
| Data Range: | 0 to +125 kPa (0 psi to 18.1 psi) |
| Type: | Measured |
| **Reference:** | 5.3.36 |

# PART 9: Tractor ECU

Defines the structure and functions of the main ECU, the one controlling the tractor:

- There are 3 types of tractor ECUs:
  - Class 1: capable of managing basic internal info of the tractor
  - Class 2: capable of managing global info of the tractor
  - Class 3: can accept any order from all equipment. In any case, the TECU can deny it.
- There are two other categories normally included in 2 & 3
  - -N accept information from a GPS
  - -F accept information from front-mounted equipment

# Tractor ECU also controls electric supply

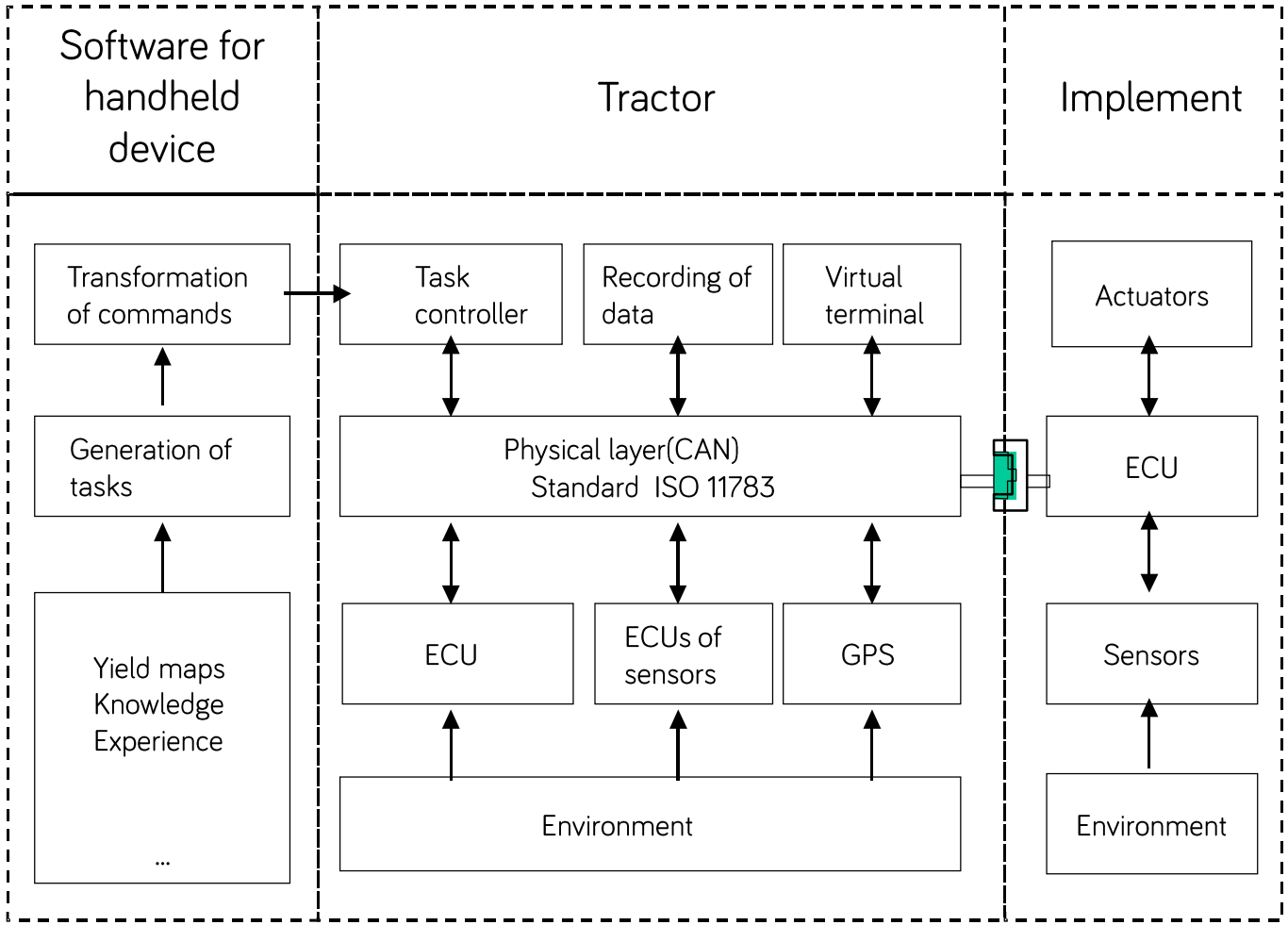
- Minimum available intensity for the equipment is 15A (12V)
- Minimum available intensity for the segment tractor – machine: 30A (12V)

# PART 10: Task Controller

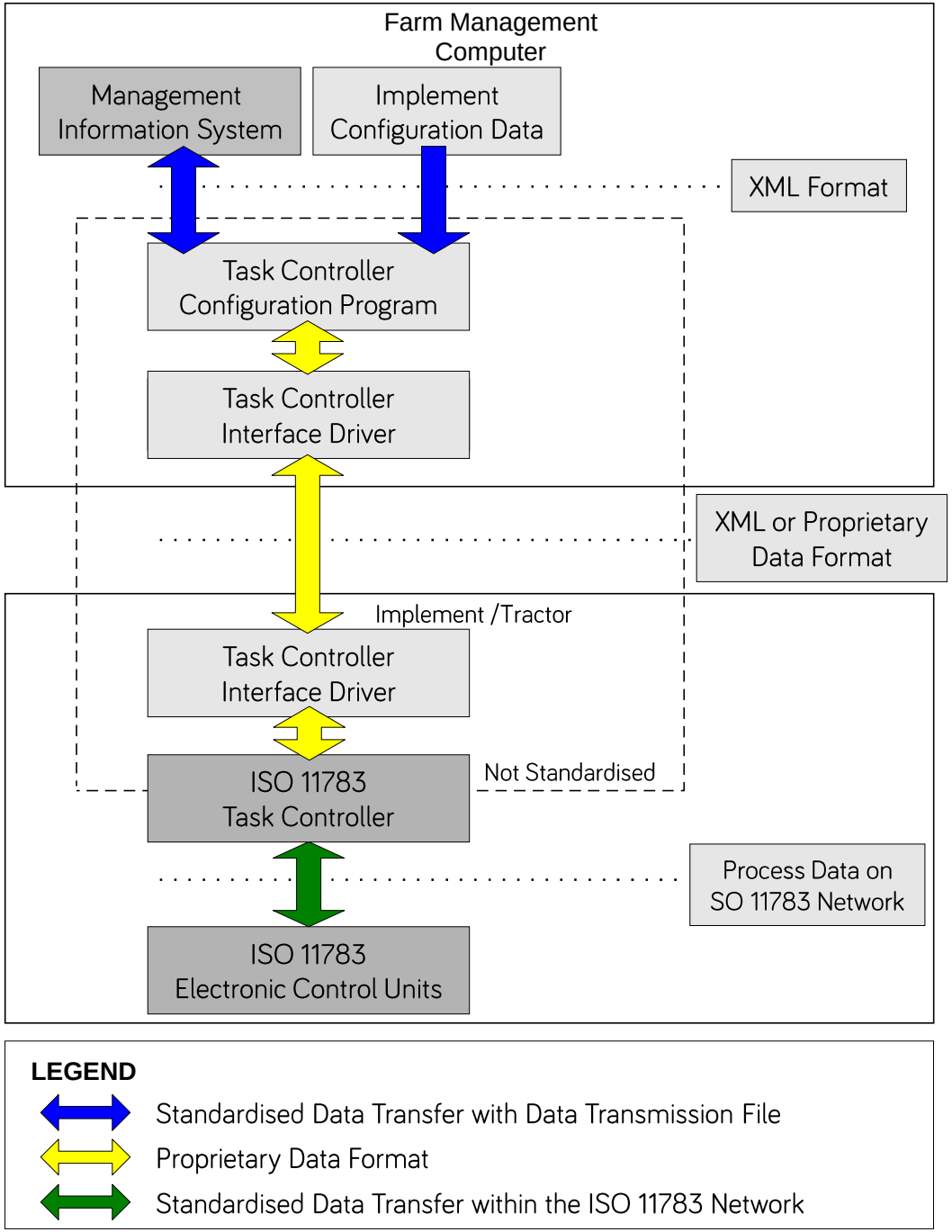
Two main functions:

- Management of **inputs** (pesticides, seed, fertilisers…)
- Management of **activities**
  - Recording of activity status (off/working)
  - Control of variable rate technology application (using section control and/or precision agriculture procedures)

# Task Control using Software




- In many cases the FMIS software (farm management information system) is used to transfer tasks to the tractor-implement

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# Interfaces and devices of a task controller

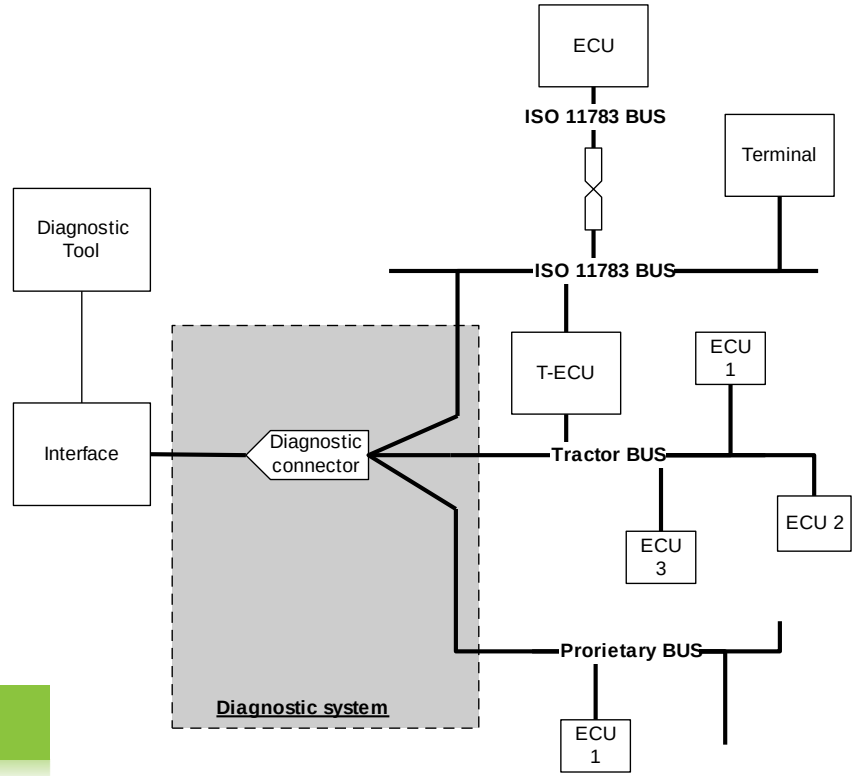
- XML (eXtended Markup Language)
- This language is the basis of data exchange
- It is a hierarchical sequence of text elements
- Each element consists of an open tag and a closing tag

# PART 11: Mobile Data Element Dictionary

- Available ONLINE: maintained by the VDMA *https://www.vdma.org*
- http://dictionary.isobus.net/isobus/
- It has an integrated XML tag interpreter

# PART 12: Diagnostic System

- Defines how the diagnosis of a ISOBUS system should be done, as well as the connectors and protocols for it
- The standard includes three diagnosis protocols: KWP2000, ISO15785, and J1939-73



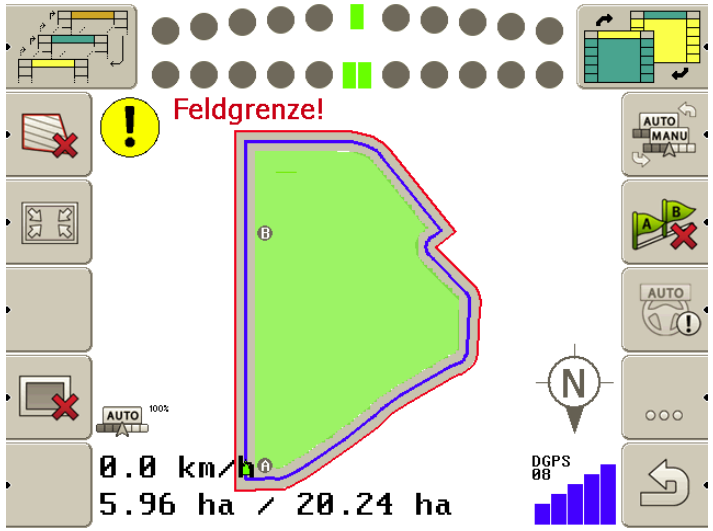

| Pin | J1939 | ISO 11783 |
|---|---|---|
| A | Battery (-) | Battery (-) |
| B | Battery (+), unswitched | Battery (+), unswitched |
| C | CAN_H | CAN_H Tractor Bus |
| D | CAN_L | CAN_L Tractor Bus |
| E | Shield (J1939/11) | K – Line (?) |
| F | J1708 (+) | Proprietary Bus K – Line |
| G | J1708 (-) | Proprietary Bus L – Line |
| H | Proprietary OEM use | CAN_H Implement Bus |
| J | Proprietary OEM use | CAN_L Implement Bus |

# PART 13: File Server

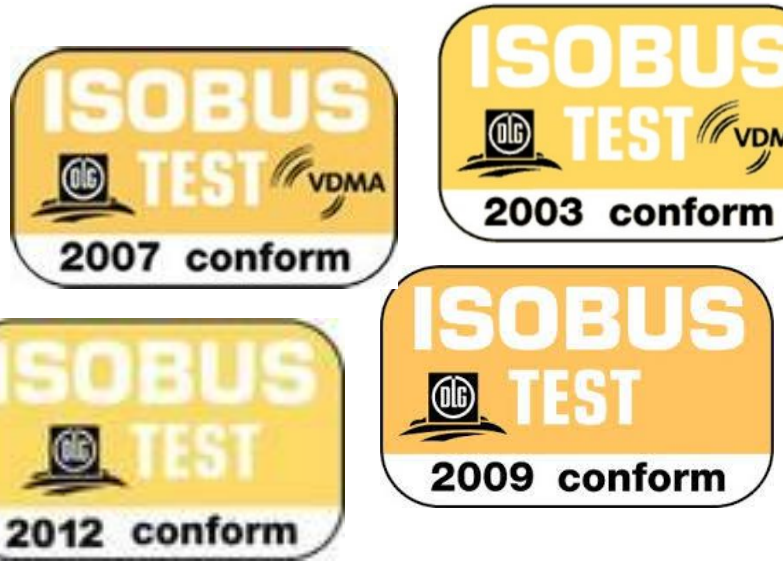
- A file server is a specific ECU inside the tractor
- Normally it is associated or included in the virtual terminal case
- Its main function is the storage of data
- Allows the control of tasks (Gateway) unique to the management information system (FMIS)

# PART 14: Sequence control

- Its main purpose is to enable the automation of a sequence of commands (i.e. switching on/off hydraulic valves, pumps, motors…)
- It allows easy operation for headland management




# What is a Plugfest?





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- Meetings among electronic manufacturers to test compatibility of devices
- Every 6 months: Nebraska, Italy, Germany, France…
- Normalized conformance test are applied, to ensure compatibility with standard (ISO, AEF)

# The AEF: ISOBUS in practice


- Agricultural Industry Electronics Foundation: an association among manufacturers to promote ISOBUS www.aef-online.org
- AEF created a new modular sticker, easy to read and understand by users
  - UT: universal terminal (= virtual terminal)
  - TECU: tractor ECU class
  - AUX-N: intelligent management of hydraulic connections (AUX-Old = non intelligent)
  - TC-BAS: basic task control (totals)
  - TC-GEO: georeferenced task control (→ **precision farming**)
  - TC-SC: task control with section control (**automation**)
- Extended compatibility tests
- Online database to check compatibly for farmers www.aef-isobus-database.org

# Display compatibility Chart

(as of May 1, 2012)

| | | Virtual Terminal<br>Manual Rate Control<br>Population Bar Graph<br>Seed Spacing<br>Skips & Multiples | Task Controller<br>Automatic Swath Control<br>Prescription Rate Control<br>As-applied Mapping |
|---|---|---|---|
| Deere GS3 – 2630 |  | ✓ | ✓<br>Requires Deere unlock code. |
| Deere GS2 – 2600 |  | ✓ | Section control requires Deere unlock code, additional Deere rate controller box, and harness. Prescription rate control is not supported. |
| Case Pro 600/700 |  | ✓ | Case has not yet released a fully functional task controller for the Pro 600/700 display. |
| New Holland IntelliView III |  | ✓ | New Holland has not yet released a fully functional task controller for the Intelliview III display. |
| AGCO C2000 |  | ✓ | ✓ |
| AGCO C3000 |  | ✓ | AGCO has not yet released a fully functional task controller for the C3000 display. |
| Topcon X30 |  | ✓ | Topcon has not yet released a fully functional task controller for the X30 display. |
| Trimble FmX |  | Trimble has not yet released a Virtual Terminal | Trimble has not yet released a fully functional task controller for the FmX display. |
| Ag Leader Integra |  | ✓ | Ag Leader Integra has not yet released a fully functional task controller for the Integra display. |

# The future of ISOBUS?

- ISOBUS has resolved communication between machines… but:
- It is expensive (?): only top tractors include ISOBUS; however the costs of physical and electronic components tend to be smaller. Besides, a new version of "**ISOBUS low cost**" is being developed
- It is not designed to transmit big volumes of data (images, videos, advanced sensors…) → **high speed ISOBUS**, Ethernet-ISOBUS are being explored
- It is not designed to supply high electrical power (prototypes with 700v DC or 300V 3F have been designed by some manufacturers)
- It does not standardize **wireless communication** → **Wi-Fi ISOBUS** → working group 5. There are technical and legal implications:
  - which wireless protocols? are they safe?
  - who stores the data: farmer, manufacturer, other? Who is the owner?