

ISOBus: the Industry Perspective

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1. Introduction

Since ISO organization in early 90s took the lead in the definition of an industry standard for the communication protocol among electronic devices of different manufacturers, it became immediately clear that this technology would have become key for the agricultural electronics.

Two factors were mainly driving the development of the standardization in the area of communication protocol and physical connectivity among different electronic devices installed on Tractors and Implements:

- the multi brand approach of certain markets;
- the fast growth of electronic application to the agricultural machinery industry.

1.1. The Multi brand markets

From an electronic point of view, an agricultural tractor is an open system which changes its mission based on the type of device connected to it. One of the main missions is to transfer power to trailers and implements. All the significant ways of transferring power to the implement were already standardized or being standardized in early 90s [2]:

- mechanical power (PTO);
- hydraulic power (remotes sockets);
- low voltage electrical power (7-pole trailer socket);
- analog electronics (ISO11786 – Tractor Mounted Sensor Interface).

Digital “power” was then the new frontier to be developed. **Figure 1** provides the best example of what happened to several customers intensively using tractors with several electronic implements. In these applications the customers had to make permanent installation of multiple screens, each connected to a specific implement “talking” to the implement electronics with a proprietary language and protocol. The resolution of the cabling issues caused by these type of installations was the main focus for the standardization.

The European market was and is today the main market where the multi brand interconnectivity represents the biggest challenge and it is currently the market where the ISOBus has the widest application.

1.2. The fast growth of electronics

Similarly to other Industries, the agricultural industry saw a significant growth of electronics application starting from mid-late 80s [3]. Manufacturers with multiple development locations were also affected by the lack of a standardized protocol. In a fast growing environment the consolidation of Product Development organizations was not always a priority and therefore the presence of a robust industry standard was significantly supported by most of the industry players to drive a more efficient product development. Each team could easier concentrate on the development of the functionalities which could provide a competitive advantage. Even companies joint ventures, partnerships and acquisitions were affected by the availability of a standard and the maturity of development in the ISOBus technology.

2. Today: the application of ISOBus technology

After almost 20 years of application and development the ISOBus (as defined in the standard ISO11783) has become a key element in the design of modern agricultural machinery.

Even if the “plug and play” approach was the main concept inspiring the creation of the ISO11783 standard, there have been many factors which prevented a smooth and fast introduction of the ISOBus products in the market:

- the complexity of the standard (more than 1,000 pages divided in 14 sections) *Source : [1]*;
- the rapid evolution of digital technology;
- the lifecycle of components of agricultural tractors and related return of investments;

The first two items mainly drove the creation of an industry consortium called AEF (Agricultural Electronics Foundation) born to address the main industry issues coming up from the application of the ISOBus standard. This allowed manufacturers to create a common interpretation of the standard when applied to real products.

After a first period in which all the ISOBus sections release levels were defined in a certain ISO11783 implementation level it became evident that a more practical approach was needed to address the increasingly complexity. Eight main functionalities, each of them with its set of ISO11783 sections release, were then released by AEF, covering the main functional aspects addressed by the standard (**Fig. 2**). The maintenance of the defined functionalities and the creation of the new ones needed for the industry is one of the critical activities which prevents incompatibility issues when connecting ISOBus devices developed by different manufacturers. Other activities essential for the compatibility of components are the creation of an Industry Conformance Test and the organization of test sessions called plugfests. All the above cannot be achieved without a strong cooperation between manufacturers. The following paragraphs will provide some examples of the latest implementation of ISOBus applications.

2.1. UT - Universal Terminal

A first example on how the standard evolved in the years can be seen in the Universal Terminal (or Virtual Terminal as called in the ISO11783 standard). Starting from low resolution (200x200) B/W screens on the first applications now the standard allows the creation of more complex colour screens (see **Fig. 3 to 6**). Even if the creation of the UT screens still requires some testing with devices of different manufacturers at the AEF plugfests, with the release of UT functionality in the AEF conformance test, most of the screens debugging can be done on the bench thus accelerating the development of enhanced UI/UX (User Interface/User Experience).

All the electronically controlled functions of the ISOBus device connected to the network can be managed using the screens created on the UT.

Today hundreds of different products in the agricultural machinery industry successfully use the UT functionality.

2.2. TECU - Class 3 Proprietary Automation

A more recent application of the standard “opens the way” to the development of new functionalities, allowing the automation of tractor and implement combination and closing the control loop while operating the machinery in the field.

The TECU class 3 messaging system allows the implement electronics to control in real time several critical systems of the tractor. The control algorithms running on the implement electronic controllers, using both the sensors of the vehicle and the sensors on the implement, through the algorithms

proprietary of the implement manufacturer, can:

- adjust in real time the electromechanical or electrohydraulic subsystems of the vehicle to optimize the Tractor-Implement combination. The results that can be obtained are:
 - increase of the accuracy and the quality of the agricultural operation;
 - achievement of a more efficient operation in the field;
- decrease operator's fatigue in comparison with a manual control of the implement.

Figure 7 shows the tractor systems that can be controlled by the ISOBus electronic devices connected to the vehicle by the standard connectors.

An ISOBus tractor can have up to 2 internal and 2 external standard connectors to connect several electronic systems, controls and devices placed on the implement and/or inside the vehicle cab (see **Fig. 8**). Vehicles can be remotely driven by using external joysticks, steering, and control systems connected to the above sockets

One important drawback to be considered in this application is related to the fact that, without a protected communication, the system could be subject to misuse and generate unexpected hazards on the tractors. For this reason currently in the market there are no real open Class 3 applications. All of them are protected by proprietary encrypted communication which requires the definition of digital pairing keys to be used by an authentication algorithm. Therefore only "trusted" applications can be authorized for the class 3 communication.

This way of proceeding, in the long term, generates an overload for the manufacturers who need to create a network of trusted partners to manage the pairing keys and the verification and validation of each application and each subsequent design modification after initial launch.

Production volumes are still quite low but this can only represent the tip of the iceberg once the industry will finalize the development of a robust system to manage component certifications and have digital certificates released by independent organizations. This is the reason why the industry is concentrating now the attention towards the TIM (Tractor Implement Management) system, as we will see in chapter 3.

2.2.1. TECU - Class 3 Large Square Baler Feedrate Control

A first example of Class 3 application using the control of the tractor speed can be made with the CNHi Intellicruise™ system developed for New Holland large square balers. Here, the control algorithm on the baler adjusts the tractor speed based on the swath size measured by a combination of sensors placed on the baler (**Fig. 9** and **10**).

The advantages of the system can be summarized as follows:

- targeted productivity (t/hour);
- operators comfort;
- productivity improvement: 6-9% more throughput (ton/hour) compared with inexperienced driver;
- fuel consumption: 4 % improvement total efficiency (liter·hour/ton);
- efficient speed variation & optimum feeding;
- no need to monitor tractor speed;
- less experienced drivers can be used;
- more uniform bale density and final quality (**Fig. 11**).

Finally, it has to be highlighted the fact that the whole swath bailing operation could be further automated by using dedicated swath detection sensors and using the class 3 steering messaging system to have the Tractor-Implement system following the swath path while adjusting the bailing speed.

2.2.2. TECU - Class 3 Round Baler Stop-Bale-Eject-Start

A second example can be done mentioning the Intellibale™ (Stop-Bale-Eject-Start) developed for New Holland variable chamber round balers (2017 AE50 award for innovation). These, in addition to the tractor transmission control, use also the automation of the hydraulic oil flow taken from electrohydraulic remote valves. This last is needed to open and close the baler tail gate to allow the ejection of the baler. **Figure 12** shows the automatic cycle and **Figure 13** the New Holland round baler and T6 series tractor during automation.

Automating tractor and baler functions will reduce the repetitive steps that an operator has to make throughout the day:

- tractor stop and start – fewer leg and feet movements – no clutch or brake required;
- tailgate raise & lower - fewer arm and hand movements – no remote activation required;
- operator will feel less tired at the end of a full day baling;
- optimized cycle time of tractor and baler functions will be the same at start of day and end of day:
 - Reduction in reaction times due to operator fatigue is no longer a factor.

2.2.3. TECU - Class 3 Camera Supported Seedbed Preparation

A third example of the class 3 application is the “Camera Supported Seedbed Preparation” system developed by Poettinger in collaboration with CNHi Italia (**Fig. 14**). The system, awarded for innovation at the 2017 Agritechnica show, is a clear confirmation on how the Automation capability offered by the ISOBUS technology can bring innovative solutions for the agriculture.

Here the simple usage of the standard Class 3 messaging set on a current production New Holland tractor has allowed the development of an innovative seeding system closing a loop between a camera placed on the implement and the tractor transmission control.

3. The near future: TIM

As we have seen in chapter 2, while some Tractor-Implement automation applications are already in the market, the usage of proprietary authentication algorithms does not represent the solution for the industry.

The “plug and play” approach today used by ISOBUS components needs to be kept for the automation functionality. The main difference from existing products is related to the fact that automated functions are multi-brand distributed control systems controlling safety related functions. In here stricter rules need to be applied in order to guarantee products safety and to avoid as much as possible grey areas in the domain of manufacturers’ liability.

To achieve this, the manufacturers are introducing on their products the authentication algorithms to manage the communication with other authorized products. This implies the integration of these algorithms in the current electronic modules and/or the development of new components with an electronic architecture designed for the security.

Also here the manufacturers are cooperating to create a common way of managing the TIM system. Common project teams are working on the specifications while developers are participating to joint test sessions to evaluate the implemented solution.

As the authentication algorithms require the integration of digital certificates used for the encryption of data, the industry, by means of AEF, has selected a PKI (Public Key Infrastructure) provider to manage the future release of the certificates. These last will be obtained by the manufacturers after a successful conformance certification.

All the above, for the level of complexity and the magnitude of the investment represents the current challenge. Nevertheless, similarly to other industry sectors, where the availability of automated functions has represented a competitive advantage for the manufacturers, also in the agricultural machinery the diffusion of the automation between tractors and implements is destined to a significant growth.

4. Future challenges: COPL and HSI

As technology evolves, manufacturers can take advantage of new opportunities providing farmers with a higher productive and more efficient farming cycle. COPL (Cost Optimized Physical Layer), wireless in field communication and higher speed communication protocols are the areas on which the industry is concentrating the effort, as far as the on board communication networks are concerned.

4.1. COPL (*Cost Optimized Physical Layer*)

One of the challenges that manufacturers have today is related to the cost of the ISOBus components and network cables when these are applied to Specialized and low power vehicles. Electronics on these vehicles and on the implements they use is following a similar growth than higher power machinery had in the past years. This means that the applications seen up to now can also be applied to this segment of agricultural machinery bringing similar benefits to the farmers.

While there are some markets (Japan is an example) that are trying to move towards a different communication standard, possibly oversimplifying the ISOBus concept and creating components and machinery incompatible with the ISOBus network, the intent of the majority of agricultural industry is to optimize the cost of the current ISOBus network to keep backward compatibility. The use of a different communication network standard for a different segment of agricultural machinery would inevitably create confusion in the market and significant inefficiencies for the agricultural machinery manufacturers. To avoid the diffusion of new incompatible standards a team of expert has been set.

The areas where the team is concentrating the effort are:

- move from active to passive termination;
- harness optimization (move from twisted quad to twisted pair, allow longer stubs);
- use of 3.3 V transceivers.

4.2. WIC (*Wireless In field Communication*)

The wide diffusion of various wireless technologies in every area of our life is creating more and more pressure from the market to the manufacturers. Some proprietary solutions already exist but, similarly to what happens for the wired connection of components, also here the manufacturers need to face the multi brand attitude of a high number of farmers.

A standard solution that will allow a seamless integration of machines working in the same area while communicating wireless will have to be provided by the agricultural machinery industry.

Use cases under development for this type of application are:

- cooperative machines;
- process data exchange;

- display the GPS-Positions and machine status of the fleet on a display;
- common coverage map;
- A-B line exchange;
- streaming service (cameras, sensors).

4.3. HSI (*High Speed ISOBus*)

HSI is the new protocol at which the agricultural manufacturers are looking to cover new use cases in the farming industry. The attempt here is to expand the existing ISOBus system with an added higher speed network.

The use cases currently considered for the development of the standardization proposal are the following:

- sophisticated visualization on more than 2 newer UTs (3D, higher resolution, more information, better user experience – reduced latency, more rate application layers, manuals...);
- real time application process control for multiple sections (Task Controller, Section Control, Sensor Peer control, headland sequence control)
- distributed high resolution position/correction signals;
- video systems connection;
- improved service and diagnosis (flash ECUs, Logfiles, raw data streams for debugging);
- high voltage data connection.

The selection of the physical layer and the integration of the high speed network in the IBBC (Implement Bus Breakaway Connector) are the first challenges to be faced. See **Figure 15** for the current definition of the system architecture.

5. Conclusions

ISOBus, after 2 decades of life, is a well-established standard in the agricultural industry for most of the Tractor-Implement electronic combinations. While this is still true for the majority of applications, there are several factors that make the standard to continue evolving: cost optimized solution for specialized and low power vehicles on one side and higher bandwidth and higher performance to keep the same “plug and play” approach for newer use cases mainly driven by the evolution of the digital technology. A positive cooperation between manufacturers on non-competitive areas of development needs to be reinforced to make the technology evolve as the application of the electronics to the farm industry is far from having reached a market saturation.

References

- [1] **ISO11783**, International Standard Organization.
- [2] **Facilitating agriculture automation using standards**, Robert K. Benneweis (2006)
- [3] **Evolution of electronics for mobile agricultural equipment**, M. L. Stone, R. K. Benneweis, J. Van Bergeijk (2008)

FIGURES

Figure 1 - Multi Brand Implement Electronics in Cab installation (mid 80s)



Figure 2 - Released ISOBus functionalities

-  **Universal Terminal**
-  **AUXiliary-Old, AUXiliary-New** (safety/critical)
-  **Tractor ECU**
-    **Task Controller**
Basic, Geo, Section Control
-  **Isobus Shortcut Button**
-  **Data Logger**

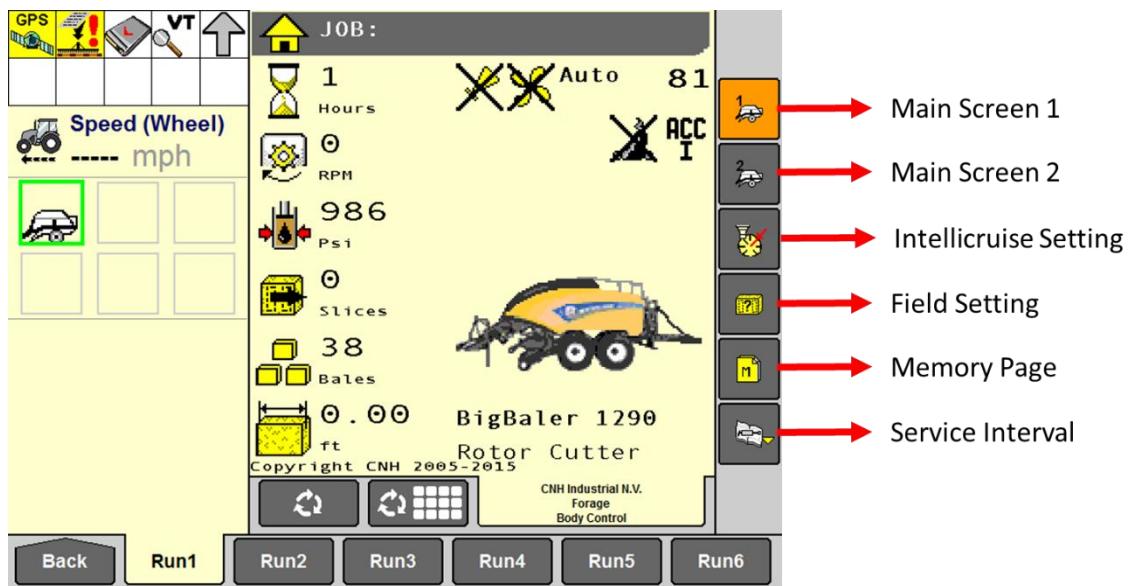
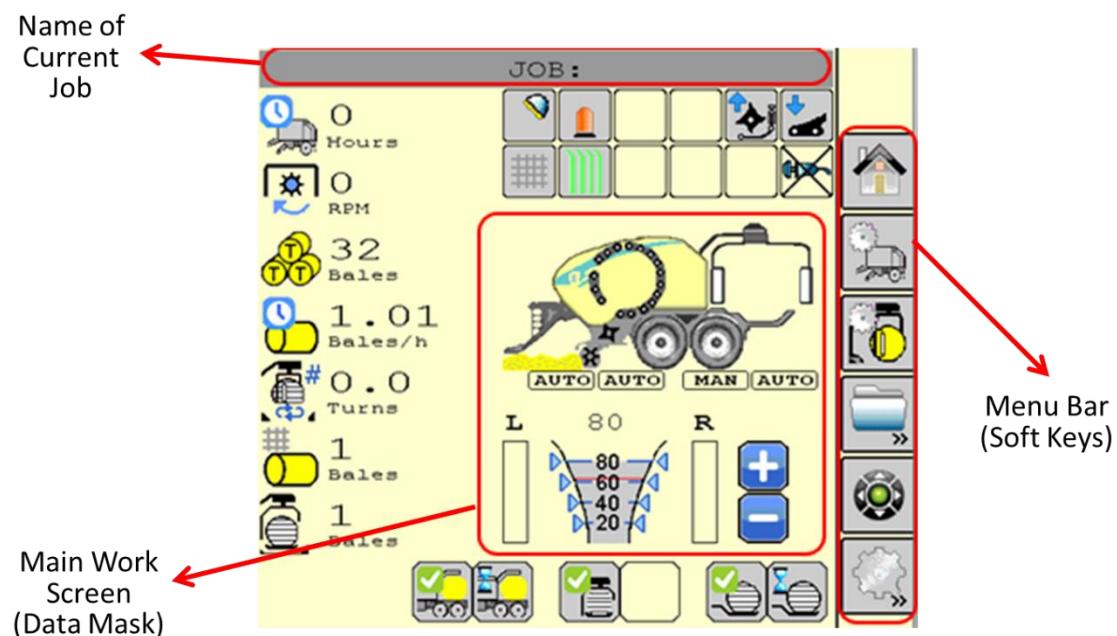
Figure 3 - VT Screen for a Large Square Baler**Figure 4 - VT Screen for a Combi Baler (Main VT elements)**

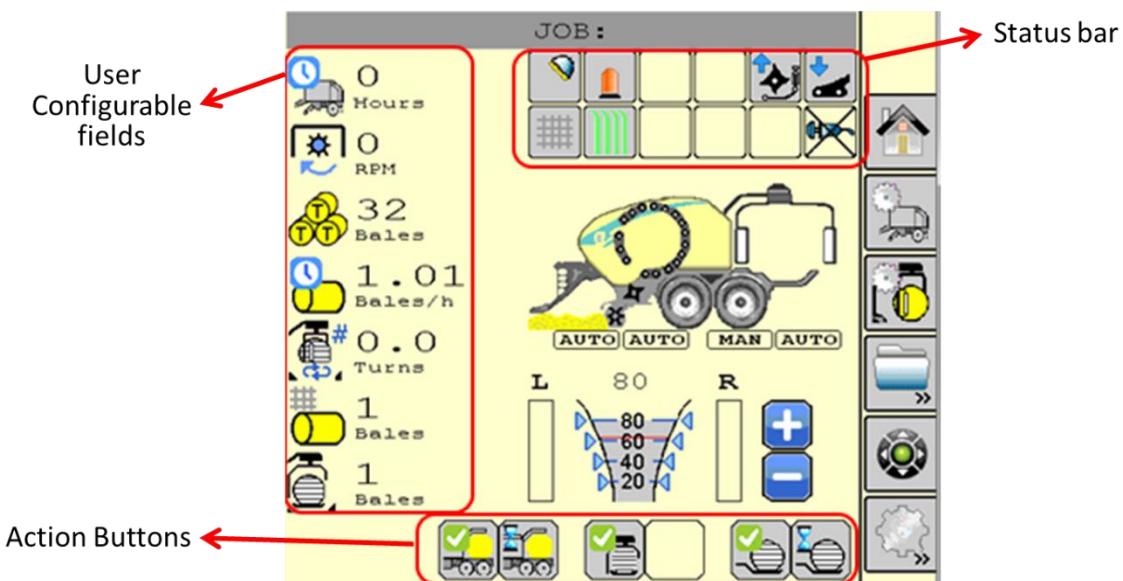
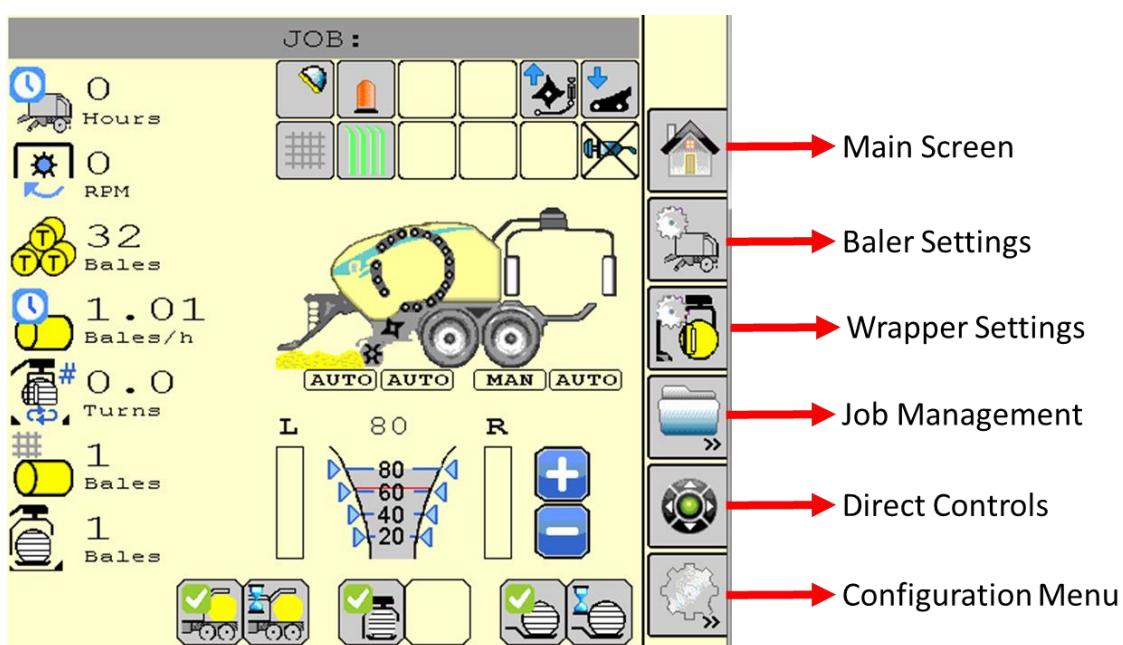
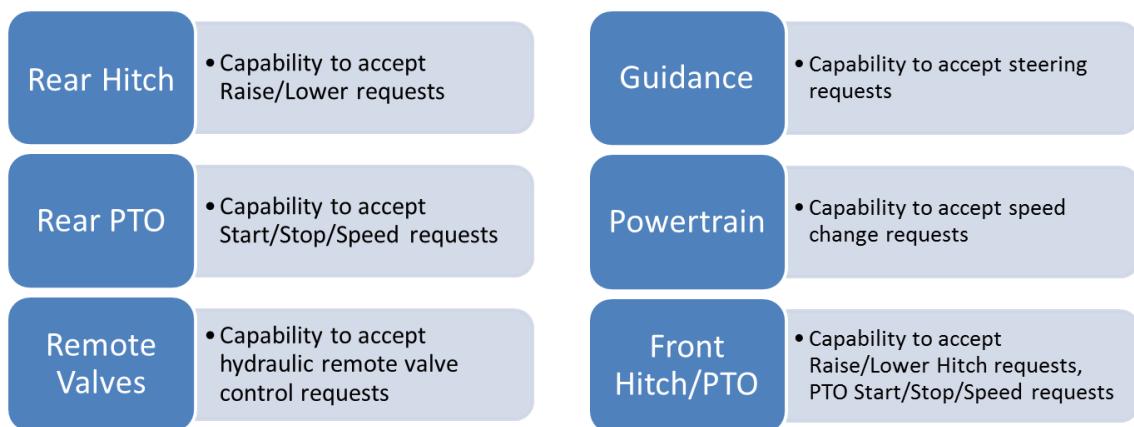
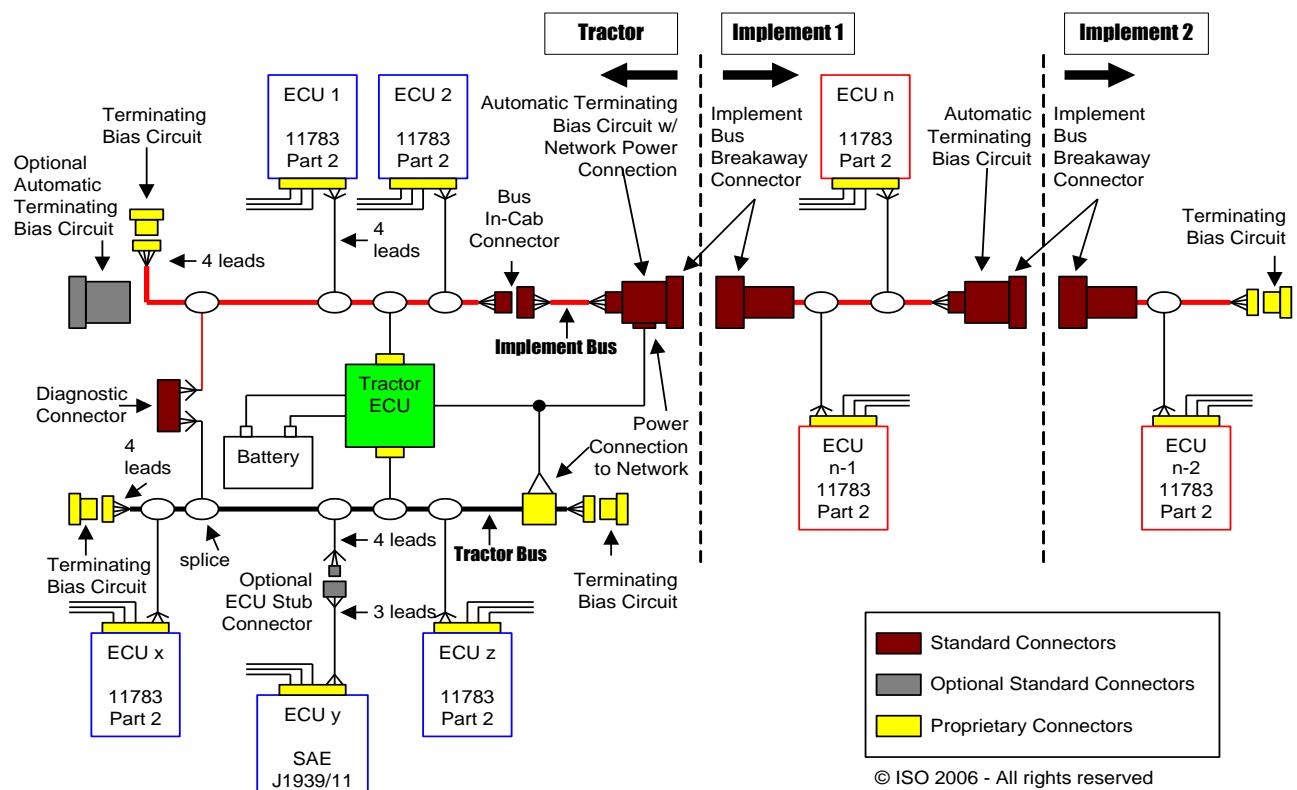
Figure 5 - VT Screen for a Combi Baler**Figure 6 -** VT Screen for a Combi Baler

Figure 7 - Tractor systems that can be controlled by Class 3 messages**Figure 8 -** ISOBus physical layer

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Figure 9 - Speed higher with smaller swath dimension**Figure 10 -** Speed lower with bigger swath dimension

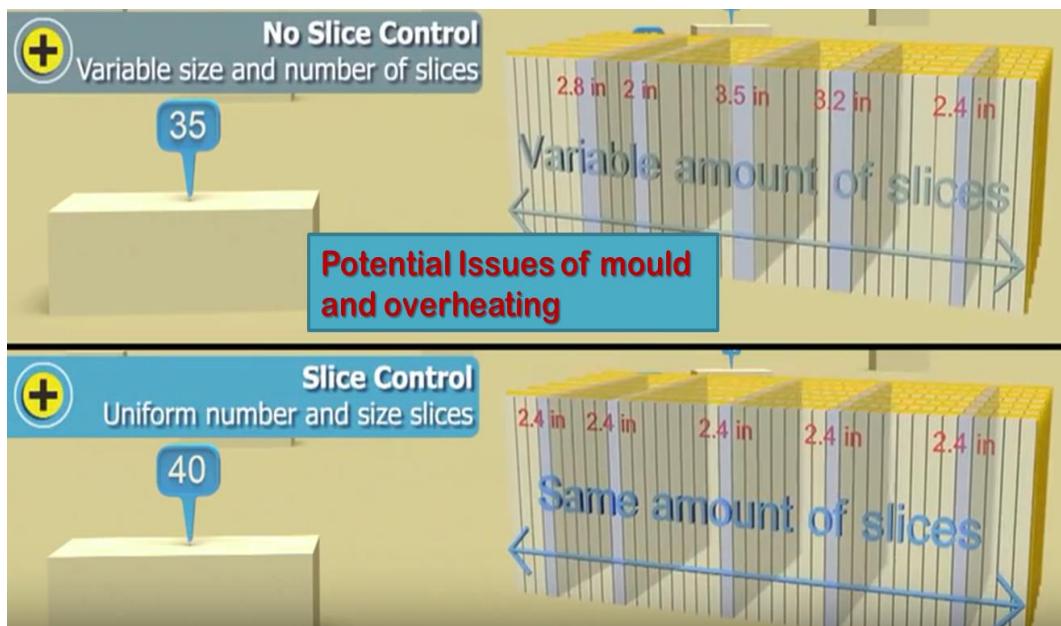
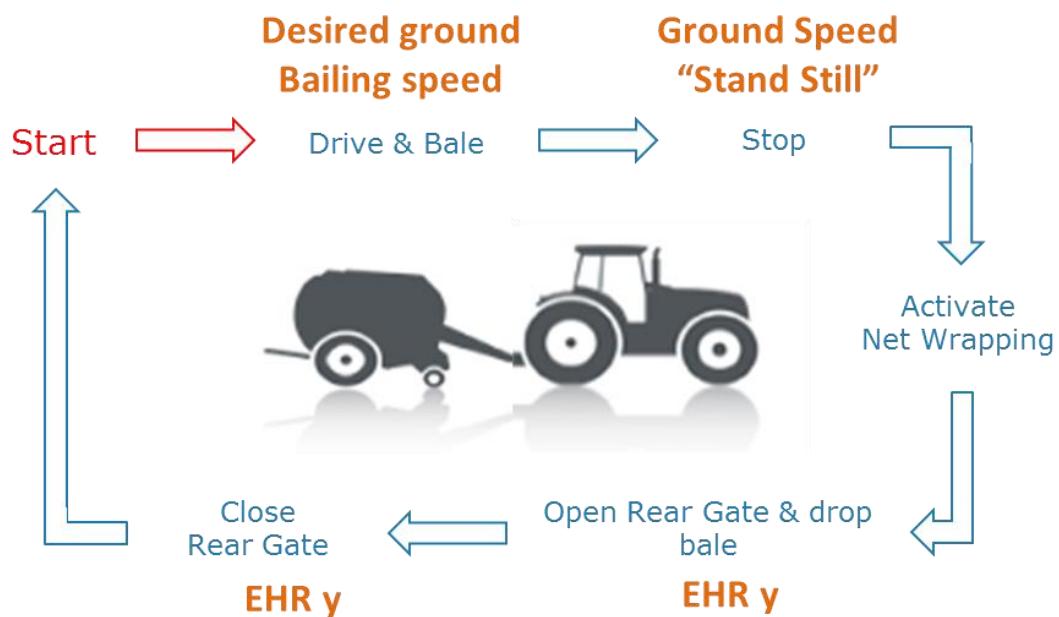
Figure 11 - Comparison of manual vs. automatic federate control**Figure 12** - Round Baler cycle (automated functions in orange bold)

Figure 13 - New Holland round baler and T6 series tractor during automation



Figure 14 - New Holland T7 series tractor with Poettinger planter during automation



Figure 15 - Current definition of HSI network architecture