Tractor-Implement-Automation and its application to a tractor-loader wagon combination

Dr.-Ing. Martin von Hoyningen-Huene, Dipl.-Ing. Dr.-techn. Markus Baldinger MSc

1 John Deere Werke Mannheim
2 Alois Pöttinger Maschinenfabrik GmbH Grieskirchen

Abstract
John Deere has developed a Tractor-Implement Automation (TIA). At the same time Pöttinger and John Deere have invented a tractor-loader wagon automation. The tractor and certified implements exchange information bi-directionally based on current ISOBUS implementation level and a protected communication layer. The implement can be controlled via the ISOBUS terminal and can dynamically request changes of tractor parameters. The Tractor-Implement Automation is the first-to-market functionality allowing bi-directional communication and will be on sale for 2010.
The first implements which are using these benefits are John Deere round balers for automation of the repetitive actions of the baling process and Pöttinger loader wagons for continuous speed control and prevention of blockage during loading process.
This article presents Tractor-Implement Automation in general and expands on the system solutions with a John Deere Baler and a Pöttinger Loader Wagon.

Keywords
Tractor-Implement Automation, agricultural industry, forage, hay, loader wagon

1 INTRODUCTION
In the last years a lot of automation and optimization has been taken place for both the tractor and the implement. John Deere and Pöttinger have invented an automation system, see figure 1, which optimize the entire system.

Figure 1: Intelligent Tractor-Loading Wagon Automation
1.1 Definition and relevance of tractor-implement automation

While optimization of efficiency has advanced impressively over the last decades within the tractor and on the implement, respectively, a large opportunity has remained unexploited to a high extent: the dynamic optimization of the tractor-implement system, see table 1.

Table 1: Levers for productivity increase in agriculture

<table>
<thead>
<tr>
<th>Levers for Productivity Increase in Agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automation within machine</td>
</tr>
<tr>
<td>• Automation and control in self-propelled machines or in tractor implements w/o link to the tractor (e.g., Harvest Smart; SprayerPro)</td>
</tr>
<tr>
<td>Tractor Implement Automation</td>
</tr>
<tr>
<td>• Improvement* of agricultural operating processes by information exchange between implement and tractor in order to automatically control actuator parameters and/or operation sequences.</td>
</tr>
<tr>
<td>Multi-machine management</td>
</tr>
<tr>
<td>• Application planning and control of different machines from a central instance (connected to farm management)</td>
</tr>
<tr>
<td>• Interaction and co-operation between machines (e.g., leader – follower)</td>
</tr>
<tr>
<td>Farm Management</td>
</tr>
<tr>
<td>• Economic decision-making based on all relevant information such as achievable prices, cost, weather, soil, yield</td>
</tr>
<tr>
<td>• Related task planning, resource planning and process execution planning</td>
</tr>
<tr>
<td>• Reporting (for decision-making, traceability and to authorities)</td>
</tr>
</tbody>
</table>

Talking ISOBUS (2007), this refers to two different ISOBUS elements: to ISOBUS sequence control (e.g.,) and to ISOBUS TECU Class 3. While the first refers to automated operating sequences such as headland management for tractor and implement, in this article only the second element is discussed and referred to as Tractor-Implement Automation (TIA).

It is the next step into agricultural system automation and addresses the need for tactical efficiency solutions as defined in Hahn (2008).

Closed control loops can be used for process optimization focusing on productivity increases through acceleration and/or cost reduction, improved operator comfort and better work quality. The benefits have been investigated, demonstrated and quantified by Thielicke (2005), including the examples of a tractor-baler and a tractor-loader wagon combination. This dissertation was an important part of the John Deere R&D activities in this field that started in 2001.

1.2 Overall concept

In the John Deere Tractor-Implement Automation, tractor and implement use the current ISOBUS implementation level to its full extend, e.g. the Virtual Terminal part to control the implement via the ISOBUS display in the tractor cab (such as John Deere 2600). Additionally both exchange information bi-directionally. This is realized based on the current status of the ISOBUS part TECU Class 3, supplemented by additional proprietary message handling for information not yet provided with the standard.

ISOBUS does not provide the possibility of a protected environment for safety-critical applications such as tractor speed control or PTO control, yet.

Therefore, a security system to control tractor function access has been developed by Deere. It allows certified implements to control certain tractor parameters.
With the current version of John Deere Tractor-Implement Automation, the following tractor parameters can be controlled by the tractor-implement system:

- Tractor speed control
- Variation of the tractor acceleration rate level
- Automated Stop Function
- Tractor E-SCVs (valve state and flow rate)
- PTO gear and on/off.

The tractor allows the implement to choose between different levels of acceleration / deceleration of the IVT transmission including the possibility for selected implements to command a faster acceleration / deceleration than normally available.

For rear PTO-driven implements, the tractor additionally provides an approximated PTO torque signal. Automation will be offered for John Deere 6030 Premium series tractors. The first implements to use these features are John Deere 864 Balers and Pöttinger Jumbo Loader Wagons. The roll-out to further balers, loader wagons and other implements is planned. John Deere, Pöttinger and other implement manufacturers involved in Tractor-Implement Automation intend to translate the experience out of the joint projects into the standardization process in order to finally be able to realize Tractor-Implement Automation 100% based on ISOBUS standard. The huge productivity benefits that, in a first step, are limited to selected implements and Deere tractors would then be also available for other tractor-implement combinations.

2 SOLUTION DESCRIPTION

2.1 Features of the Deere 6000 Premium TIA Tractor

Many agricultural processes are discontinuous processes where regular interactions of the operator are needed, e.g., to stop the tractor or to actuate the SCVs. In addition the permanent manual speed control to the needs of the application challenges the operator. It also offers potential for improvements and automation. Therefore, the first version of TIA addresses these issues. Further extensions to other tractor features such as steering can be expected. The intention hasn’t been to build prototypes, but to launch series production. Therefore, the step-by-step introduction of different features together with a sound security concept has been selected.

The features of the TIA-Tractor are now described in more detail:

2.1.1 Automated Speed Control

The TIA tractor offers the possibility to command a target speed and an acceleration (/ deceleration) rate. This continuous speed control allows the tractor-implement system to adapt to varying working conditions, such as the volume variations of a windrow in case of the loader wagon, as demonstrated by Thielicke (2005).

The TIA tractor also provides a relative PTO torque signal measured on the tractor. This can also be used to control the speed (see Thielicke (2005)) or to calibrate a speed control using a swath sensor. While an ultrasonic swath sensor detects swath volume, a calibration with the PTO torque offers implements with a pick-up the possibility to approximately control the speed based on the swath mass. The PTO Load Control regulates the tractor wheel speed dependent on the measured PTO torque. If the PTO torque is high (e.g. very big swath) the forward speed reduces automatically. If the torque is low (e.g. small swath) the speed increases until the torque is optimal or a maximum forward speed is reached.

This feature is only offered with tractors that have a infinite variable transmission (IVT) drive.

2.1.2 Variation of the acceleration rate level

The level of the acceleration rate can be changed by the implement. For implements such as the baler and the loader wagon, the acceleration rates associated with the drive lever, clutch and brake are more aggressive than in manual mode. This means that "dropping the clutch" accelerates the tractor more rapidly when in automation than an operator can get on the same tractor without automation active.
This unique feature is only possible in automation mode and allows the tractor to understand when a heavy implement is mounted and a higher acceleration rate is acceptable (inputs based on e.g. weight, comfort and safety issues). The operator has the possibility in automation mode to choose the acceleration rate level of the tractor between a more comfortable and a more efficient option. This feature is only offered with tractors that have an infinite variable transmission (IVT) drive.

2.1.3 Automated stop function
The automated stop function is based on a signal from the implement to stop the tractor, which can occur when a process is completed. This is very helpful for applications where the operator has to stop the tractor many times per day (e.g. round baling). This feature is only offered with tractors that have an infinite variable transmission (IVT) drive.

2.1.4 Automated SCV-Control
All hydraulic systems can be automated by using SCV flow requests or control the valve state, for example when the implement requests hydraulic oil, the tractor in turn will provide the requested quantity of oil to execute the operation. This can be used to enhance the automation level of the implement.
In many cases, implements are equipped with individual valve stacks in order to allow for automation on the implement alone, e.g. planters for special crops. In these cases, the cost for this additional valve stack on the implement can be saved without losing on automation.

2.1.5 Automated PTO Gear and PTO on/off function
The PTO gear can be changed (in stand-still) and the PTO can be switched on or off automatically.

2.2 Tractor-implement Communication
The basis for the information exchange is ISOBUS. Table 2 shows some examples of messages used according to the ISOBUS Protocol (ISO 11783 (2007)):

<table>
<thead>
<tr>
<th>Function Group / Function</th>
<th>Tractor Status Message:</th>
<th>PGN Cmd Byte</th>
<th>ISO 11783 Part 7 Section</th>
<th>Implement Request Message:</th>
<th>PGN Cmd Byte</th>
<th>ISO 11783 Part 7 Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCV (Flow Rate, Valve State)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auxiliary Valve 1 (First Rear Valve)</td>
<td>Auxiliary valve 1 estimated flow</td>
<td>65041</td>
<td>B.14</td>
<td>Auxiliary Valve 1 command</td>
<td>65073</td>
<td>B.14</td>
</tr>
<tr>
<td>Additionally Valves</td>
<td>According for additionally valves</td>
<td></td>
<td>According for additionally valves</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rear PTO (Engagement, Mode, Speed)</td>
<td>Primary or rear PTO output shaft</td>
<td>65091</td>
<td>B.9</td>
<td>Hitch and PTO commands</td>
<td>65090</td>
<td>B.10</td>
</tr>
<tr>
<td>Vehicle Speed</td>
<td>Machine selected speed</td>
<td>61474</td>
<td>B.28.1</td>
<td>Machine selected speed command</td>
<td>64835</td>
<td>B.28.2</td>
</tr>
</tbody>
</table>
Additionally to this ISOBUS Class 3 implementation in the Tractor Control Unit (TECU), proprietary messages are used for the following functions:

- Interface for bi-directional communication between tractor and implement
- Control of access to tractor functions
- Interface for certified implements
- Further parameters needed not specified within ISOBUS Class 3 yet

2.3 Round Baler

The round baling process is a discontinuous process where regular interactions of the operator are needed for bale ejection (stop tractor, open & close the gate). In addition, the driver permanently has to adapt speed depending on the windrow volume and conditions.

With the first step of automation offered for the 864 baler from 2010 on, the implement automatically runs the bale ejection sequence. A next step could be to run at maximum speed w/o blocking the baler by controlling speed depending on a set maximum PTO load as described by Thielicke (2005).

2.3.1 Manual round baling

The process sequence for a round baler consists of a number of steps that are repeated for each bale. As first step of the baling process shown in figure 2, the baling chamber has to be filled evenly after starting operation. As soon as the chamber is filled, the operator has to stop the tractor and the tying process of the press has to be started. Afterwards, the operator opens the baler gate with a hydraulic control valve (SCV). After having verified that the bale has been completely left the chamber, the operator has to completely close the gate by again actuating the SCV. Finally, the operator can start forward motion again to bale the next bale. This process is repeated more than 400 times a day (40 bales/hour). This monotonous repetition fatigues the operator, resulting in mistakes, reduced quality such as uneven bales or bales of different size and can reduce efficiency. Additionally, the driver has less energy to control the steering and the speed of the combination. If this leads to a blocking of the baler, precious time gets lost.

Figure 2: Automation of the Round-Baling process (green arrows: automated functions as of today)
2.3.2 TIA Tractor-Baler Automation

After connecting the baler, the certification is checked. After approval by the TECU, TIA is activated. This approval process is shown in the tractor display (ISOBUS VT) as represented in figure 3.

![Figure 3: TIA approval process](image)

- not available ➔ deactivated ➔ ready for activation ➔ activated ➔ active ➔ (flashing) Pause

This general approval process means for the example of the round baler:

- **not available** – TIA not connected or no TIA approval by the tractor
- **deactivated** - TIA is installed and approved, but activation has not been prepared.
- **ready for activation** – All required requests have been successfully processed, activation can be
- **started**: operator can activate the system (pressed the activation button adjacent to the pie diagram)
- **active** – TIA is active, baler commands tractor and the system acts in automation mode.
- **pause** – TIA is active but in „pause“: baler waits for approval by the driver in order to re-start the automatic process

The John Deere 864 round baler uses the elements of John Deere TIA explained in chapters 2.1.2, 2.1.3 and 2.1.4.

With the first step of tractor implement automation available now, all green arrows in figure 3 are automated, i.e. Stopping, opening and closing of the gate are automated so that the operator can concentrate on the demanding task of filling the baler, including steering and adapting speed.

**Automated stop**

In stopping the baler, it is key to find the right point in time. State of the art is that the operator has to use clutch and/or brake and not release it before tying has been finished, the bale has ejected and the gate has been closed. With TIA, the tractor stops automatically when the baling chamber has the optimum filling. Neither clutch nor brake has to be used. By varying the deceleration level, the operator can adjust how quick the tractor stops. The system solution also prevents another typical pitfall of manual operation: tying can not start before picking up material has stopped. This allows to produce bales with the constant, desired diameter and a high tying quality. Downtime can also be reduced by eliminating the possibility that the tractor is not stopped in time.

**Automatic request of hydraulic power to open and close the baler gate**

After the automatic tying cycle has been completed, the baler requests hydraulic flow to open the rear gate. Normally the SCV switch has to be used for opening the gate and the progress has to be watched via the mirror until the bale is ejected as shown in figure 4. Following ejection the bale gate can be closed.

![Figure 4: Opening and closing the gate with manual operation](image)
On vehicles with automation the gate opens directly after the tying process is finished, by monitoring the gate position as well as the bale ramp motion, the gate is only opened as much as needed, saving time, and then closed automatically immediately after the bale has left the chamber. After completion of this cycle, the display informs the operator and asks him to initiate tractor motion again. In this state the baler limits the tractor acceleration actively to ensure proper material flow into the baler.

**Automated Start of the tractor after acceptance by the driver**
For security reasons, the driver gets an optical and acoustical signal that the system is ready for restart. He has to restart by using the left-hand reverser. Alternatively, if the driver has chosen to brake additionally to the automated stop function, he can release the brake to restart.

To summarize, the automatic process can be represented as shown in figure 5.

**Figure 5: Representation of TIA for baling (blue: speed, green: bale size, red: hydraulic state)**

1. Start of baling, round baler determines acceleration to optimize quality
2. The tractor accelerates depending on speed request commands from the baler
3. The baler commands to stop
4. The tractor decelerates (with the level preset by the operator), stops, the tying process is initiated
5. Tying is finished, the baler commands hydraulic flow to open the gate (red line)
6. The gate opens automatically
7. The baler commands gate closure (after the baler’s ramp has signaled that the bale has left the baling chamber)
8. The gate closes automatically
9. After the gate has closed, the baler signals the operator that he can re-initiate tractor motion
2.4 Loader Wagon

The automation of the system consisting of a Pöttinger “Jumbo” or “Torro” loader wagon, a John Deere T1A Tractor and a Pöttinger swath scanner. This system allows a continuous optimization of forward speed during operation, depending on the swath volume and the optimum operating point. Additionally the overall system is able, to prevent blockage during loading process.

2.4.1 Sensor input

The speed control is calculated depending on a number of different input parameters. The main key sensing elements for input parameters are the geometry of the swath, the torque of the rotor, the charging level and also the actually forward speed.

Geometry of the swath - ISOBUS Ultrasonic Sensor Bar

Together with LCM GmbH (Linz Center of Competence in Mechatronics), Pöttinger has developed a new ISOBUS ultrasonic sensor bar with 9 ultrasonic sensors to scan the surface, see figure 6. It communicates with the tractor-implement system via ISOBUS.

![Figure 6: Pöttinger ultrasonic swath scanner](image)

The swath sensor samples the surface with 9 ultrasonic sensors across the full working width. With this metrics the geometry for the swath is derived. In figure 7 one can see the principal operation of the system with five sensors. In practice there are 9 sensors used.

![Figure 7: Function principle of Pöttinger swath scanner (schematic representation)](image)
Further information such as the swath height and width, the center, the eccentricity and the cross section are derived from the scanning information. Therefore the control system is able, to classify the existing swath and can derive a control strategy adapted to this parameters. Additionally with the linkage of the cross section information and the tractor speed, a volume flow rate can be predicted. In figure 8 one can see the calculated cross section.

![Swath Measurement](image)

**Figure 8: Swath measurement**

**The torque of the rotor**
The torque of the loader wagon rotor is also used to improve the speed control. In combination with the volume flow rate provided by the swath scanner and the torque of the rotor a mass volume flow rate can be calculated. 

With this information, the tractor speed is also controlled, the details of the control system can be seen in chapter 2.4.2. In figure 9, the torque of the rotor is indicated as a percentage.

![Load Measurement](image)

**Figure 9: Load measurement**

**Charging level**
A third important information for controlling the loading process and the forward speed is the continuous measurement of the charging level of the loader wagon. This means, that the speed is linked to the charging level. The higher the charging level, the lower the speed commands and vice versa.

Additionally to these elements, the following information is used for the control system:

- Tractor: Current speed
- Loader Wagon: Pick-Up position
- Loader Wagon: Scraper floor situation – on or off
2.4.2 Pöttinger Loader Wagon and TIA

The system is shown in figure 10.

In this illustration, the most important sensor information is represented. With this data, the following actions are triggered depending on the respective working point:

**Automatic Speed Control**
With the volumetric flow rate (forward speed * swath area) and the rotor torque, the target speed is calculated and forwarded to the tractor: the smaller swath and torque are, the higher the requested speed and vice versa. This results in a controlled loading process allowing for operation in the optimum point. In total, 10% productivity increase, increased driving comfort and protection of the system can be achieved, see 3.3.

**Variation of acceleration level**
An increased charging level of the loader wagon is translated into decreased deceleration and acceleration levels. Further parameters, such as terrain slope, the weight etc. can also be included in the future.

**Different driving modes**
The operator has the choice between two operating modes:
1. ECO Mode
   The loader wagon is operated with a workload between 70% and 90%, to be chosen by the operator. This increases the lifetime of the machine components and results in overall reduced fuel consumption.

2. MAX Mode:
   The loader wagon is operated with a utilization of 95%. This allows for maximum loading speed and maximum productivity while minimizing the risk of blockage of the loading process.

**Automatically deactivating of the PTO**
Automatically deactivating the PTO increases operator comfort: the PTO is switched off automatically in case of system hold-ups due to overload.
Next steps
As for the baler, further features can be nicely integrated into the existing TIA systems. For the loader wagon, it is planned to differentiate between loading operation and transport operation, distinguished by the position of the pick-up. For lifted pickup, additional settings such as maximum speed can be integrated.

2.4.3 Measurement results
To see the correlation between the swath measurement data and the data getting from the PTO-moment, a lot of measurements were performed. Figures 11 and 12 show two examples.

The picture shows that a change in swath size (a bigger swath area) results in a torque increase on the rotor (increase represented towards the bottom, the yellow line is printed reverse).

In some cases, a certain delay is observed when the forage is pushed forward by the pickup before it is collected.

Figure 11: First example of test measurement

Figure 12: Second example of test protocol
In figure 12 one can see, that a blockage of the loading process has held. This can be seen in an surge of the swath area as well as in the PTO-moment.

To see, if the entire system can prevent this blockage, which is shown in figure 12, a diagram with the reaction time of the individual components (swath scanner, loader wagon and tractor) as well as the reaction time of the entire system is considered. The results of this reflection can be seen in figure 13.

**Time reaction / impacts:**

<table>
<thead>
<tr>
<th>Time/Impact</th>
<th>Reaction Time (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swath and PTO-moment measurement</td>
<td>~135 ms</td>
</tr>
<tr>
<td>ECU</td>
<td>~155 ms</td>
</tr>
<tr>
<td>LW valves</td>
<td></td>
</tr>
<tr>
<td>scraper floor</td>
<td>~500 ms</td>
</tr>
<tr>
<td>movement of the scraper floor</td>
<td></td>
</tr>
<tr>
<td>~675 ms total time: Pöttinger</td>
<td></td>
</tr>
<tr>
<td>Without scraper floor</td>
<td></td>
</tr>
<tr>
<td>~7 m total time: John Deere</td>
<td></td>
</tr>
<tr>
<td>time / distance until reaction of</td>
<td></td>
</tr>
<tr>
<td>Loader wagon:</td>
<td></td>
</tr>
<tr>
<td>0,675 s / 3,375 m</td>
<td></td>
</tr>
<tr>
<td>tractor:</td>
<td></td>
</tr>
<tr>
<td>0,305 s / 1,525 m</td>
<td></td>
</tr>
</tbody>
</table>

**Forward speed**

- 5 m/s = 18 km/h

**Distance swath scanner to pick-up**

- ~7 m

**Figure 13: Reaction times in the system**

With a given deceleration rate of approx. 1 m/s² on flat ground, the tractor-loader wagon combination can reduce speed by approx. 20% within the reaction time (assuming a forward driving speed during operation of 4-5 m/s).

The field evaluation has shown that this is usually sufficient to prevent blockage during loading process. A practical field application with the overall system can be seen in figure 14.

**Figure 14: Practical field application**

In this illustration the connection between the cross section of the swath, the torque of the rotor and the forward speed can be seen.
3 CUSTOMER BENEFITS

3.1 General
The tractor automation can increase productivity – especially for less skilled drivers, increase comfort, reduce operator fatigue, reduce the risk of operator-caused downtime and improve work quality. Some of the greatest challenges facing the agricultural industry in the future are; changing environmental conditions, limited number of available working days and reduced availability of skilled labor. Taking these key challenges into account, farmers will have to utilize their resources more efficiently and effectively, being more productive in each working day. One solution to these challenges will be the intelligent tractor to optimize tractor-implement combinations:

Increased Productivity:
- Increased performance through optimized speed control using the PTO load control function and higher vehicle acceleration rates
- Significant reduction of idle time
- Reduction of operator fatigue by eliminating reoccurring and serial tasks
- Reduced operating costs can be achieved by allowing less skilled operators to maximize the productivity
- Performance measurements executed by the Martin-Luther University of Halle on early prototypes show significant potential for system productivity increases depending on the field and crop conditions.

Increased end product quality and operator comfort:
- Reduced number of operations within the cab
- Relief of the driver, concentration on control functions
- Reduced fatigue, reduced task complexity, more enjoyable work
- Less tiring after long working days
- Reduced Operator Skill Requirements: Quality job execution less dependent on operator skill level

3.2 Round Baler
The tractor baler automation system provides customer value in different aspects:
- Accelerate the bale ejection cycle by stopping the tractor immediately after target size is achieved, opening the gate, ejecting the bale and closing the gate
- Start baling after acceptance by the driver
- Achieve Better quality of the bales ("One-size“-bales“)

These benefits have been validated by different customer focus groups during 2009. It was important to understand the important of the significant comfort increase provided by the system even if this is difficult to be quantified in monetary terms.

3.3 Loader Wagon

3.3.1 Overall benefits
- A conservative calculation shows that a productivity increase of at least 10 % can be achieved, resulting in an annual savings potential of 1000,- EUR p. a. (for 300 operating hours).
- The driver’s comfort is significantly improved since the driver no longer has to adapt the speed to the swath conditions.
- Both experienced and inexperienced drivers benefit from automation during daytime, but even more during operation in the dark.
• By reducing peak loads, the components are protected increasing machine life time and reducing total cost of ownership.

• The uncomfortable job of removing blockages has to be performed less frequently.

3.3.2 Efficiency calculation

10% higher productivity, annual savings potential of ~ 1000 EUR (for 300 operating hours)
It is realistic to assume that over 50% of the operating time, the operating speed can be increased by TIA. Since the later cuts over the year produce less yield / ha than the earlier ones, the speed reduction potential is reduced. Based on 300 operating hours, 50% = 150 hours remain as impacted by TIA. Assuming a field-farm distance of 2.5 km, about 25% of this time is loading time, i.e. time when the rotor is operated. This leads to a relevant annual rotor operation time of approx. 38 hours. Average cost during loading operation is 200 € per hour. Assuming the 10% speed increase which is conservative compared to the performed tests results in an hourly TIA-related benefit of 20 € or 750 € p.a. (with 38 hours).

The second main effect is that TIA allows to prevent system downtime cost due to overload, i.e. blockings.
Assuming again 150 relevant operating hours or 375 annual loads. Assuming a system overload for one load in ten, 37.5 downtimes occur annually.
It is conservative to assume that the operator looses in average 3 min by manual interference (stopping, pulling back, releasing overload, restarting) which results in approx. 2 hours lost time p.a. Assuming 130 € total cost per hour, prevented downtime allows for 250 € annual benefit.

Adding up the two elements quantified, intelligent automation with TIA results in 1000 € annual benefit, or 3000 € for three years.

Longer life time and reduced maintenance cost / TCO
Other customer benefits are more difficult to quantify yet very relevant.
Preventing system overload, hence peak loads protects the drive train elements, resulting in longer lifetime and less maintenance cost.

A further significant benefit is increased operator comfort. Less fatigue and the avoidance of the intricate removal of blockings is a very important benefit. It allows the operator to run the system longer per day which could easily translated in another very tangible benefit due to higher annual utilization, e.g. in the case of contractors.

4 NEXT STEPS
Deere, Pöttinger and other partners will subsequently introduce more TIA features and products to realize further features that have already been investigated deeply in research and advanced development. Other manufacturers are also expected to introduce similar solutions based on ISOBUS Class 3. Deere and Pöttinger intend to finalize within the Agricultural Industry Electronics Foundation AEF (2009) ISOBUS Class 3 together with the other members of AEF. The vision is that Tractor-Implement Automation finally becomes one element of ISOBUS with a specific feature-based certification against a defined test procedure as currently performed for ISOBUS VT functionality to allow for TIA plug and play with all approved implements.

5 CONCLUSIONS
In this paper, the newly launched Deere Tractor-Implement Automation as well as a Tractor-loader wagon automation with a Pöttinger JUMBO has been presented. Therefore the first two implements are available for this system solution. The functionality and customer benefits have been also described.
Therefore two entire systems for a tractor implement automation are available for the customer and provide them new perspectives for the future farming.
ACKNOWLEDGEMENTS
The authors would like to thank the John Deere tractor engineering in Mannheim an Waterloo as well as the John Deere Hay&Forage engineering in Ottumwa and Arc le Gray and the involved colleagues in marketing and product management. Same applies to Pöttinger where the authors equally want to thank the engineering team in Grieskirchen and the marketing and product management. The teams have done a great work, especially also by working in a great cross-unit and cross-company team, respectively to provide integrated system solutions for our customers.

REFERENCES


Contact:

Dr.-Ing. Martin von Hoyningen-Huene
Manager Business Development Tractor-Implement Automation
John Deere Werke Mannheim
John Deere Straße 90, D-68163 Mannheim
phone: +49 (0621) 829-5009
fax: +49 (0621) 829-455009
Email: vonHoyningen-HueneMartin@JohnDeere.com

Dipl.-Ing. Dr.-techn. Markus Baldinger MSc
Head of Test department / Mechatronic Engineering
Alois Pöttinger Maschinenfabrik GmbH
Industriegelände 1, A-4710 Grieskirchen
phone: +43 (0)7248 / 600 2401
mobile: +43 (0)664 / 80 380 2401
Email: markus.baldinger@poettinger.at