

# Global trends in the development of monitoring systems for mobile agricultural equipment

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**Abstract.** In this paper, systems for remote monitoring of equipment from various manufacturers are analyzed. Such systems are currently offered by a number of manufacturers of tractors and other mobile agricultural equipment. They are designed to management the operation of a diesel engine; hydraulic transmission management; management of working bodies (maybe several); active security; comfort and climate control; navigation, communications and other multimedia systems. However, in the literature there is no system analysis of them. Therefore, the aim of the study is to analyze and generalize advanced solutions in the development of remote monitoring systems of the largest domestic and foreign manufacturers of agricultural machinery and equipment. The development of remote monitoring systems of domestic and foreign manufacturers, including those awarded at the International agro-industrial exhibitions, were analyzed and summarized. The authors summarized the characteristics of monitoring systems and showed their application areas. The article discusses innovative telemetry and monitoring systems for agricultural machinery, which allow optimizing the process, making adjustments to the settings, planning maintenance, saving fuel, and increasing productivity.

## 1 Introduction

The transition to advanced digital and intelligent production technologies is one of the main directions of development of world agriculture, an important factor ensuring the growth of labor productivity, lower costs for the production of food and agricultural raw materials, improving product quality and reducing its losses. The current level of agricultural production is determined by intelligent machine technologies and technical equipment of a new generation with modern information support and instrumentation. The implementation of digital intelligent agricultural technologies requires a radical change in the paradigm of technical support, based on the development and use of new automatic and unmanned vehicles, equipment and software for managing machine work processes, navigating technical means, monitoring technological operations, monitoring crop yields, and analyzing development diseases and pests on plants and other technological functions [1-3].

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Incorrect technical and technological adjustment of modern agricultural machinery, which is a combination of complex mechanical and electronic systems, can lead to significant underutilization of its potential capabilities. Its effectiveness also depends on the human factor: the performance of different machine operators under the same conditions can differ by 40%. The systems for automatic collection and analysis of information and transmission based on this control commands allow improving the efficiency of use of equipment, reducing material and time costs for organizing control over its work, collecting, processing and analyzing data on the progress of technological processes. Such systems are currently offered by a number of manufacturers of tractors and other mobile agricultural equipment. Modern machines use a large number of electronic systems that intensively exchange data during operation, and computer diagnostic technologies are being developed. An analysis of the sources showed that up to eighty independent but adaptive electronic systems with various sensors that also carry out diagnostic functions are involved in cars, tractors and combines. The following systems can be noted as the main ones: diesel engine management; hydraulic transmission management; management of working bodies (maybe several); active security; comfort and climate control; navigation, communications and other multimedia systems [4-8]. An analysis of research by Russian and foreign scientists showed that the current global trend is the use of remote monitoring systems of machines, including monitoring of technical condition and diagnosis. The aim of the study is to analyze and generalize advanced solutions in the development of remote monitoring systems of the largest domestic and foreign manufacturers of agricultural machinery and equipment.

## 2 Materials and methods

The development of remote monitoring systems of domestic and foreign manufacturers, that were awarded at the International Agricultural Exhibitions, such as AGROSALON (Moscow, Russia), Agritechnika (Hanover, Germany), SIMA (Paris, France), Zolotaya Osen' (Moscow, Russia) and others were analyzed and summarized.

## 3 Results

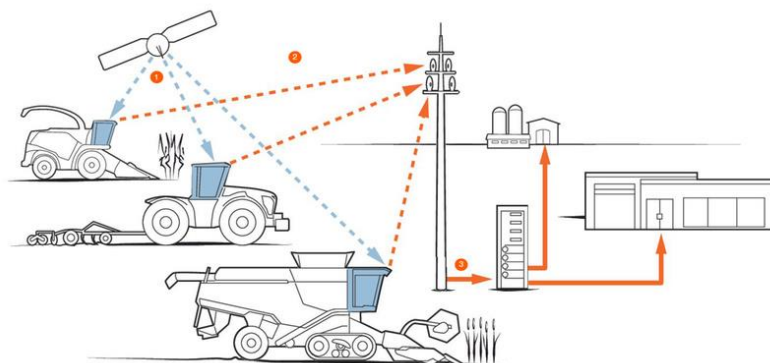
The analysis showed that the main task of telemetry systems and monitoring of agricultural machinery is to increase the productivity of the fleet of agricultural machinery. It is achieved by optimizing the process based on an analysis of working time, making adjustments to the settings, collecting, recording and documenting data, increasing the operational reliability of machines, and improving service planning. Using GPS satellites, the location of the machines is determined, and mobile communications at regular time intervals transmit to the single server data of GPS coordinates, time and nature of work, technical indicators. You can enter the system from a desktop computer, laptop, tablet or mobile phone. The information operated by the system is available for viewing and analysis both in real time and in the form of reports [9, 10]. Some of these telemetry and agricultural equipment monitoring systems are shown in Table 1.

**Table 1.** Telemetry and agricultural machinery monitoring systems

Manufacturer (company)	Designation of systems
Claas	TELEMATICS
John Deere	JDLink
AGCO	AGCOMMAND
New Holland	PLM Connect

Case IH	AFS Connect
Rostselmash	AGROTRONIC
Farvater	System of monitoring and control of agricultural machinery
GLONASS Telematics	Wialon Hosting
Scout Group of Companies «Sckaut»	Sckaut

The main objective of the Telematics system by Claas company is to increase the productivity of the entire fleet. This is achieved by optimizing the performance of the process based on an analysis of working time, making adjustments to the settings of the equipment used, collecting, recording and documenting data, increasing the operational reliability of machines, and improving the planning of maintenance work. Using GPS satellites, the location of the machines is determined, and over 200 different parameters about GPS coordinates, time and nature of the work performed, and technical indicators of the machines are transmitted to the unified server via mobile communications at regular intervals. The operation diagram of the Telematics telemetry system is shown in Figure 1.



**Fig. 1.** Operation diagram of the Telematics telemetry system: 1 – receiving location data via satellite; 2 – transfer of data and machine settings over a mobile network to a server; 3 – data call by the farmer or remote diagnostics by the dealer.

Testing the TELEMATICS system on combine harvesters in Germany and the UK showed that it can reduce the harvesting period by three days, increase machine productivity by 10 percent, the utilization rate of working time by seven percent, and reduce costs by at least 0.5 percent.

The JDLink telematics system by John Deere company allows you to monitor the operation of machines directly from the office, as well as from anywhere with Internet access or from a mobile phone. Depending on the set of functions, it is divided into JDLink Select, JDLink Ultimate and JDLink Harvest Modules. Machine location information is provided on a Google color map. The capabilities of the JDLink telemetry system modules are shown in Table 2.

**Table 2.** Capabilities of JDLink telemetry system modules

	JDLink Select	JDLink Ultimate	JDLink Harvest Modules
Location of machines	+	+	+
Geo-borders	+	+	+
Operating hours	+	+	+

Maintenance Planning	+	+	+
Fuel consumption	–	+	+
Use of machines	–	+	+
Diagnostics of machines	–	+	+
Machine Settings	–	–	+
Productivity of machines	–	–	+
Service ADVISOR Remote	+	+	+

The Service ADVISOR Remote function is optional, designed for use by John Deere dealers in diagnosing and updating machine settings.

The New Holland PLM Connect telematics system by New Holland company allows you to constantly monitor machines from the office, send and receive information in real time. Depending on your individual needs, you can choose the entry-level PLM Connect Essential package or the advanced professional PLM Connect Professional package. Key features of the first package: tracking the movement of machines on an interactive map; viewing the path traveled by each mobile device; creating geofences for farms and fields and setting up curfew notifications; receiving notifications by e-mail or SMS when the technical tool leaves the geofence or when the ignition is switched on after working hours; creation of individual reports on the location of machines and engine hours. The PLM Connect Professional package contains all the functions of entry-level packages, as well as the function of displaying various images to track operating parameters and machine error codes.

Rostselmash company developed for its machines the remote monitoring and telemetry system AGROTRONIC, designed for remote control of technological processes in order to optimize operating modes of equipment and use working hours, prevent violations, and provide logistics. Moreover, the information operated by the system is available for viewing and analysis both in real time and in the form of reports for a certain period. The AGROTRONIC system allows you to control fuel drains, unauthorized unloading of harvesting machines, all types of downtime, increasing the efficiency of machinery in the farm by analyzing working hours, optimizing settings through remote control of machine operating parameters, maximizing the use of machine power by comparing performance indicators and optimizing settings, reduce time for maintenance, analyze processes, improve planning and logistics, reduce costs of machinery fleet owning and improving agricultural performance indicators. System components: communication module built into the on-board computer (GPRS modem); external Glonass/GPRS-antenna; SD memory card; SIM card. You can enter the system from a tablet or mobile phone, or from a laptop or desktop computer. Menu sections (tracking, notifications, analysis, management) are displayed on all pages of the remote monitoring website at the top of the page. The main page displays general and comparative information on all equipment available to the user for display for the current day.

The AvtoGRAF monitoring system is designed to: control the expenditure of production means (fuel, fertilizers, plant protection products, time), help organize rational logistics, monitor compliance with technical requirements for the performance of work, control the amount of harvested yield (when using special sensors). An Avtograf controller (a device transmitting and processing information) is installed on a tractor, combine, or other mobile equipment. The necessary sensors are connected to it. A SIM card of a local GSM mobile operator is inserted into the device and external GPS and GSM antennas are connected. Through the GPRS channel, information about the position of the equipment, the fuel level

in the tank and other parameters is sent to the server of the Avtograf or farm. In case of loss of communication, the controller starts recording information in its internal memory (up to 60 days). In order to process the received information, it is enough to connect any computer to the Internet, install a special free program and enter a password to enter the system. The program provides a wide range of options for displaying data on an electronic map and in the form of graphs, their analysis and reporting. The results of using the system: reduced fuel costs, fertilizers, plant protection products, seeds; increase productivity and product quality, increase the efficiency of crop management; visibility of labor results; prompt reporting on all stages of the production process; increasing employee discipline.

The Farvater company develops and manufactures monitoring and control systems for agricultural, special equipment and vehicles under the brand names Can-Way and Line-Way. Their application allows you to implement high-quality and multi-level control of the operation of equipment in all operating modes; to analyze the operation of equipment based on the cost ratio (fuel, motor resources, etc.); conduct remote diagnostics of engines, components and assemblies; predict routine maintenance to prevent unscheduled equipment repairs. Using the systems of monitoring and control of equipment of the Farvater company allows you to: reduce the cost of maintenance and operation of equipment by 30%; carry out round-the-clock monitoring of operating modes and condition of the equipment with the possibility of obtaining information as about general parameters (consumption, fuel level, engine temperature etc.), as well as on special parameters of the operation of mechanisms and assemblies, for example, monitoring the operation of hydraulics, a threshing drum, filling the hopper with grain or the amount of grain in the tank, grain moisture, etc.

ITEMS company installs AvtoGRAF monitoring systems on cars, which allow you to monitor all movements of the technical equipment, deviations from routes using GLONASS and GPS. One of its key functions is fuel consumption control system (FCCS). FCCS in most cases is implemented through the installation of a fuel level sensor (FLS). The company "ISS (Integrated Security Systems) STELS" is developing GPS/Glonass systems that allow you to monitor the location of the vehicle in real time, accounting for worked hours; fuel consumption; frequency of maintenance; remotely block the engine. The monitoring system for maintenance intervals is configured in the monitoring program for moto-hours or mileage. The owner of the machine receives notifications of the need for maintenance by e-mail or mobile phone. The satellite tracking system of the Navigation Systems (NS) company allows you to determine the quality and operation modes of equipment, notify of malfunctions, etc. The module reads data from the can-bus and allows you to monitor fuel consumption, engine speed, coolant temperature, total mileage and other indicators. The ANTOR MonitorMaster satellite monitoring system (ANTOR Group of Companies) records the actual hours worked, equipment downtimes, monitors tire pressure and temperature, which makes it possible to prevent uneven wear of treads for wheeled vehicles, maintaining optimal tire pressure and extending their life by 10-15%. In recent years, remote monitoring systems have been actively developed not only for the condition of vehicles, but also for their operators (drivers) and assistance [11-15]. The characteristics of some systems for remote monitoring of equipment are given in Table 3.

**Table 3.** Characteristics of some systems for remote monitoring of equipment

No	System name	Developer	Purpose
1	Telematics	Claas company	Improving the operational reliability of machines, improving the planning of maintenance work. Using GPS satellites, the location of vehicles is determined, and over 200 different parameters are transmitted to a single

			server via mobile communications at regular intervals about GPS coordinates, time and nature of work performed, and technical indicators of machines.
2	AGCOMMAND	AGCO Corporation	Fleet management. A comprehensive wireless information solution for farmers and dealerships, which allows you to evaluate in real time up to 25 basic parameters of the machine, as well as to compare the efficiency of use.
3	AFS Connect	Case IH company	Allows you to remotely diagnose and communicate with drivers using GPS signals and wireless data networks. AFS Connect system uses a combination of GPS satellites and cellular technology to wirelessly connect equipment from Case IH AFS Pro 300 or Pro 700 displays to office computers.
4	JLink	John Deere company	Provides the information needed to make a decision on the efficient use of fuel, optimizes the use of the machine, and allows it to be diagnosed. Service ADVISOR Remote is an optional feature used by John Deere dealers to diagnose and update machine settings. Service ADVISOR Remote saves repair time, as the dealer does not need to travel specifically for diagnostics. Instead, he can remotely diagnose, troubleshoot, and deliver the necessary parts. Allows you to monitor the operation of machines directly from the office, as well as from anywhere with Internet access or mobile phone.
5	Remote Diagnostics	Scania company	Allows service and emergency support centers to carry out diagnostics from a distance, reducing downtime.
6	AvtoGRAF	ITEMS company	Allows you to control the fuel consumption of cars
7	AGROTRONIC	Rostselmash Company	Allows you to control fuel drains, unauthorized unloading of harvesting machines, all types of downtime, increasing the efficiency of machinery in the farm by analyzing working hours, optimizing settings through remote monitoring of machine parameters, maximizing the use of machine power by comparing

			performance indicators and optimizing settings, reduce time for maintenance, conduct analysis of technological processes, improve planning and logistics, reduce the cost of the equipment fleet ownership and improve the performance indicators of agricultural work.
8	Can-Way, Line-Way	Farvater company	Allows you to implement high-quality and multi-level control of the operation of equipment in all operating modes; conduct remote diagnostics of engines, components and assemblies; predict routine maintenance to prevent unscheduled equipment repairs.

## 4 Discussions

Currently, foreign and Russian manufacturers of tractors, combine harvesters and other mobile agricultural machinery, including Claas company, John Deere company, Rostselmash company, use various telemetry and monitoring systems. They make it possible to increase the efficiency of its use, reduce the costs of organizing work control and the cost of a equipment fleet owning. For example, the use equipment monitoring and control systems by Farvater company allows you to: reduce the cost of maintenance and operation of equipment by up to 30%; carry out round-the-clock monitoring of operating modes and condition of the equipment with the possibility of obtaining information as about general parameters (consumption, fuel level, engine temperature, etc.), as well as on special parameters of the operation of mechanisms and assemblies, for example, monitoring the operation of hydraulics, threshing drum, filling the tank with grain or the amount of grain in tank, grain moisture, etc. The use of technology companies monitoring systems can reduce the cost of expenses for maintenance and operation of equipment, carry out round-the-clock monitoring of the operating modes and state of the equipment, plan its maintenance.

## 5 Conclusions

- 1) The largest domestic and foreign manufacturers of agricultural machinery and equipment including Claas company, John Deere company, Rostselmash company use various telemetry and monitoring systems.
- 2) The most widely used systems are Telematics, AGCOMMAND, JDLink, AFS Connect, etc.
- 3) Testing the TELEMATICS system on combine harvesters in Germany and the UK showed that it can reduce the harvesting period by three days, increase machine productivity by 10 percent, the utilization of working time by seven percent, and reduce costs by at least 0,5 percent.
- 4) Of the Russian developers, the most common are the systems of Rostselmash company and Farvater company.



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