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Perspectives of the unmanned cargo transport with electric traction development under the conditions of the Russian Federation

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Abstract. The development of road transport in the world is highly connected with increased requirements for safety and cost-effectiveness of carrying out passenger and cargo transportation, reducing the negative impact of road transport on people and the environment, as well as the desire of countries that do not have direct access to energy sources, "get off the oil needle". To ensure the fulfillment of these requirements, the key development areas in the automotive industry of developed countries are unmanned vehicles and electric vehicles. Taking into account foreign experience, the article looks at the prospects and features of developing unmanned cargo vehicles with electric traction, at operation conditions of the Russian Federation, which differ markedly from the conditions of vehicle operation in Central Europe, North America and the countries of the Asian region.

1. Introduction

All leading automakers currently have projects aimed at the creation of autonomous unmanned vehicles (UV) and in 2020-2025 are planning the introduction of vehicles with autonomous control. However, in most cases, we are talking about 3rd-4th levels of traffic control systems automation in accordance with the standard SAE J3016 [1]. At the 3rd level of automation, the traffic control system (TCS) takes full control over the dynamics of the vehicle when the driver reacts appropriately to its signal to intervene. At the 4th level of automation, the TCS takes over the control of the vehicle's movement even if the driver ignores the requirement to intervene in the motion control process. At this level, the management solution is taken by the vehicle TCS.

In 2016, the European Union directive UE (347/2012 & 351/2012) on road safety came into force. The directive prescribes to equip all trucks registered or used within the borders of the EEC with special systems to improve road safety. Driver assistance systems (ADAS) are commonly used, they provide detection of pedestrians, drivers alert about an emergency, traffic assistants in traffic jams, braking, vehicle interaction systems with other traffic participants and road infrastructure.

In comparison with other areas of vehicle development, the creation of UV, ADAS systems and UV components is carried out at a faster pace. As an illustration of this fact, Figure 1 shows the patenting dynamics of developments abroad concerning land UV, ADAS systems and UV components.

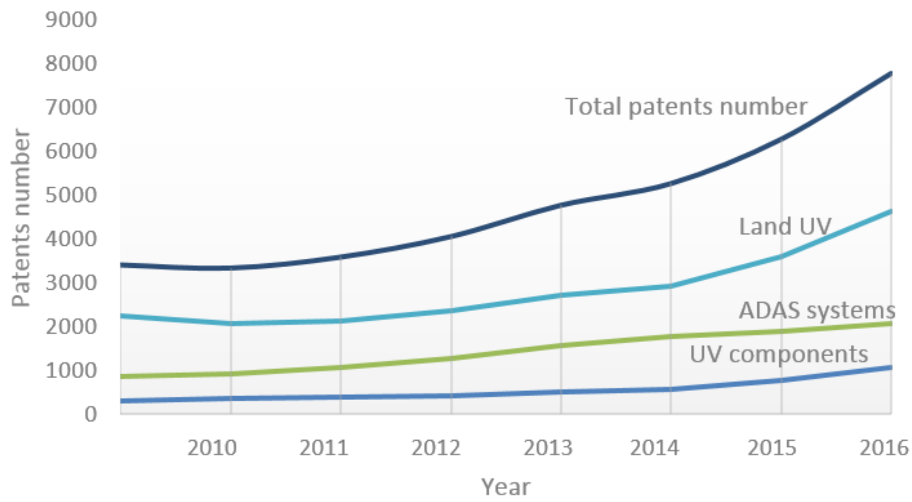


Figure 1. Patenting dynamics of land UV abroad, ADAS systems and UV components in general and separately for the period from 2010 to 2016.

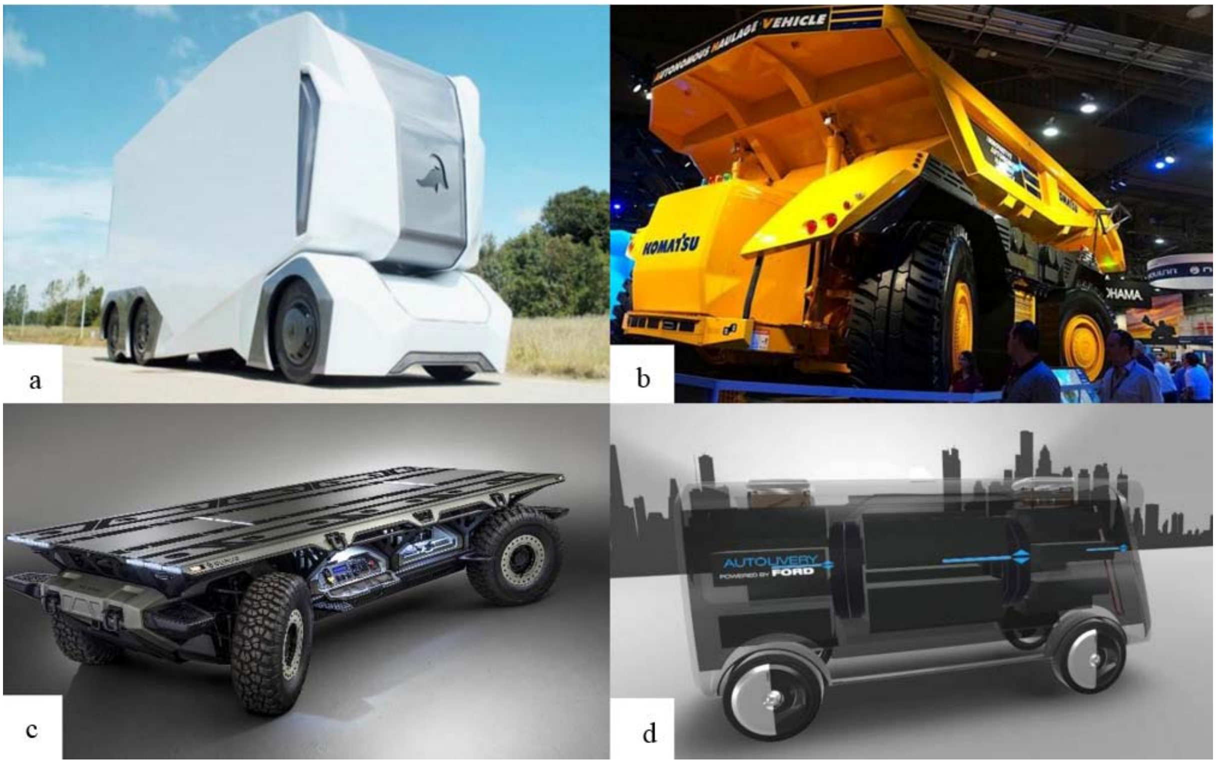
It is considered that the implementation of the UVs will increase productivity and reduce the cost of cargo and passenger transportation, ensure road safety, use the road capacity more efficiently, expand the use of cars for people with disabilities, provide the ability to transport goods in hazardous areas, during natural and anthropogenic disasters or military actions, increase passenger comfort, reduce fuel consumption and travel time, lower harmful emissions and greenhouse gases into the atmosphere [2-7].

Another, the most important direction in promising vehicles creation, is the introduction of cargo electric vehicles [9-11], which do not emit harmful substances, including greenhouse gases, with the exhaust gases of internal combustion engines. The decision to decommission the vehicle with petrol and diesel engines is part of the reducing carbon dioxide emissions (CO_2) program adopted in the climate agreement in Paris in December 2015. According to the experts of this program, the vehicles are responsible for about one-fifth emissions of carbon dioxide into the atmosphere. Norway (2025), Germany (2040), Great Britain (2040), France (2040) and other countries announced plans for a complete ban on cars with internal combustion engines.

Constraints that prevent the wide use of electric vehicles are the need to create an infrastructure for recharging batteries, long battery charging time in comparison with refueling, relatively small mileage of electric vehicles on one battery charge and special requirements for energy accumulation and storage elements. The batteries should be explosion-proof and fire-safe, have small weight and size parameters, high efficiency of charge-discharge characteristics, have a wide range of operating temperatures, minimum self-discharge, long service life, be mechanically robust, easy to maintain and release minimum toxic gases.

2. Main part

The main trend in the development of promising cargo vehicles is the creation of UVs with electric drive. Most foreign developments on unmanned trucks, including ones with electric drive, are being carried out both through the serial cargo vehicles conversion and equipping them with motion control systems using a variety of vision systems as well as by developing fundamentally new designs, recently in a cabinless performance. The main companies engaged in the development of cargo UVs are Einride, Komatsu, Caterpillar, Volvo, Ford, Waymo, a subsidiary of Alphabet, a subsidiary of Google, Otto, a subsidiary of Uber, Daimler concern, etc. In recent years, at cargo UVs development, the emphasis is made on the UVs with an electric drive and without a cabin. Among domestic developers of UVs KAMAZ, UAZ, Cognitive Technologies, KB Aurora, Traft, etc. should be noted. Examples of foreign cargo vehicles developed by foreign automakers are shown in Figure 2.



a) T-pod Cargo UV b) Autonomous Haulage Vehicle (AHV) unmanned dump truck c) SURUS unmanned cargo platform d) Ford cargo platform.

Figure 2. Cargo UVs, developed by foreign automakers.

There is no driver's cabin in the Swedish promising UV T-pod with the Einride control system (Fig. 2a)) [2]. The UV is equipped with a remote control system and rectangular chassis with an electric drive. The remote control is performed by the operator and, according to the developer, is especially important when driving around the city. T-pod technical parameters: weight with full load is 20 tons, length is 7 m (23 feet), battery capacity is 200 kWh, mileage at one charge is 200 km (124 miles) [3]. According to the developer forecasts, the use of T-pod UVs will not only reduce environmental pollution, but also improve traffic safety, create new jobs and reduce transportation costs. According to the plans of 200 trucks, T-pod will be operated between the cities of Gothenburg and Helsingborg beginning in 2020 [4].

Unmanned mining dump truck Autonomous Haulage Vehicle (AHV) of the Japanese company Komatsu (Fig. 2b) is also designed without a driver's cabin [5]. Komatsu has been developing unmanned mining technologies since 2008 in cooperation with Rio Tinto. During this time, its autonomous unmanned dump trucks performed in classical design with the driver's cabin transported hundreds of millions tons of rock in the mines of Chile and Australia. At present, Komatsu company has a serious scientific and technical background and experience of operating UVs for the development of cabinless dump trucks. The AHV technical vision system provides scanning of the surrounding space from all sides of the machine, which allows the dump truck to move in any direction without the assistance of a driver or operator. Due to the lack of a driver's cabin, the bed volume is increased. All 4 wheels of the dump truck are steerable, it has increased maneuverability, which allows to abandon reversal sections on the movement routes in quarries and mines.

The absence of the cabin allowed achieving more uniform load distribution on the wheels: 250 tons of cargo are distributed along the axes almost equally. Komatsu AHV technical parameters: length is 15 m, width is 8 m, load capacity is 230 t, weight is 416 t, engine power is 2700 horsepower (2014 kW), maximum speed is 65 km/h regardless movement direction, tire size is 59/80R6, independent suspension of each wheel, individual transmission of each wheel, independent rotation of each wheel.

General Motors Company has developed a Silent Utility Rover Universal Superstructure (SURUS) unmanned cargo platform also without a driver's cabin [7]. SURUS uses second generation Hydrotec hydrogen fuel cells produced by General Motors, an independent electric drive of each wheel, all-wheel drive steering, a system of lithium-ion batteries (Fig. 1 c) [6]. The length of the platform is 5 m, width is 2.3 m. One hydrogen filling provides the car with a power for more than 400 miles (644 km). Several platforms can theoretically move in unmanned mode behind a leader car. The fuel cell can operate as a mobile generator with alternating current of 120 V, except for charging its own batteries. SURUS can be made in the form of a conventional truck or in the form of a cabinless platform. The dimensions of the chassis correspond to the dimensions of the sea container for the transport of goods: length is from 6 to 13 m, width is 2.4-2.5 m, height is 2.5-2.9 m.

According to GM forecast, SURUS UV can be used as a truck, mobile or emergency power source, in flexible cargo delivery systems, for commercial cargo transportation, as light and medium-tonnage military trucks, only for military use in the future.

The SURUS chassis is designed for military and civil use - in the army, police, rescue services and cargo transportation. The platform can be used as a mobile power plant charged by solar panels and as an ambulance for driving on rough terrain or as an unmanned cargo platform. In addition to absolute noiselessness, the chassis does not emit harmful substances into the atmosphere, fast battery charge is ensured. GM expects that SURUS UV will become the basis for the serial use of fuel cells and will be used in complex transport situations caused by natural disasters and military conflicts. SURUS can move both on the highway and off-road [7].

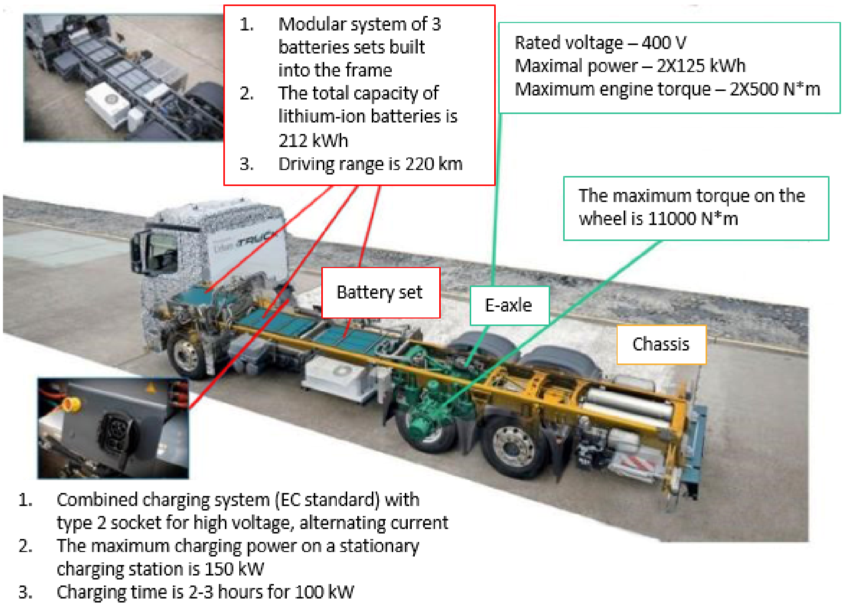
As part of the researching promising technologies program for a metropolis called "City of tomorrow", the Ford campaign introduced the concept of an autonomous delivery service for parcels auto delivery [8]. Appearance of the chassis is shown in figure 2d.

Autodelivery service includes cargo vans and drones. As part of the service, unmanned self-propelled chassis transports any cargo from groceries to medical supplies on the ground and drones deliver them by air at the final stage of transportation in order to ensure cargo delivery to destinations unavailable for UVs. The range of the drones does not exceed 15 m, which is sufficient to transport cargo from the UVs to, for example, private door. The concept "The City of Tomorrow" provides the solution to mobility problems in urban conditions, including traffic jams and air pollution. Ford plans to launch the Autodelivery service in 2021.

From the brief analysis it follows that foreign developments of promising UVs are being carried out almost for the entire range of cargo vehicles with an emphasis on UVs with electric drive and without driver’s cabin.

Compared with UVs, the development of cargo electric vehicles began much earlier. Now they have found wide practical application. Constraints that prevent the large-scale use of electric vehicles claim the creation of an expensive infrastructure for recharging batteries, electric vehicles are characterized by a longer battery charging time compared to fueling, a relatively small mileage of electric vehicles on one battery charge and special requirements for energy storage and accumulation elements. The batteries should be explosion-proof and fire-safe, have small weight and size parameters, high efficiency of charge-discharge characteristics, have a wide range of operating temperatures, minimum self-discharge, long service life, be mechanically robust, easy to maintain and release minimum toxic gases. However, priority is given to electric vehicles due to the parameters of the electric drive, the battery and its components constant improvement and the transition to more mass production.

Among the latest developments of cargo electric vehicles [9-12] the heavy truck Urban eTruck from Mercedes, launched in production; automobile tractor class 8 Nikola One from American company Nikola Motor; port tractor YT202-EV from the leading European manufacturer of port (terminal) tractors - the company Terberg Benschop BV should be noted.



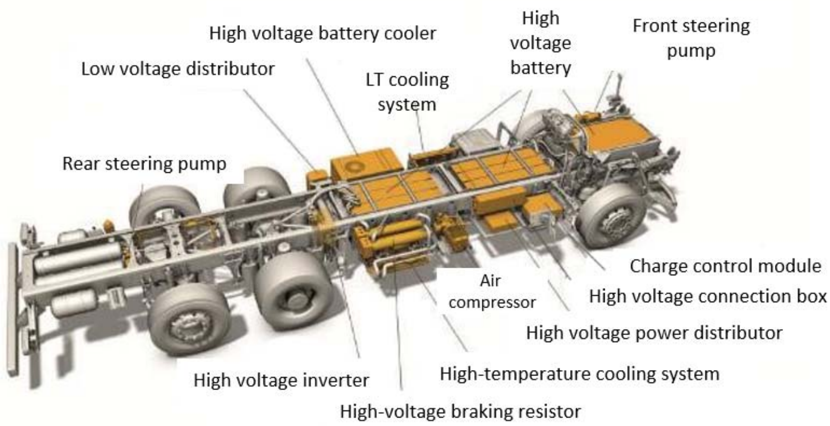


Figure 3. Composition, parameters and layout of the Urban eTruck electric drive main elements on the chassis.

The Urban eTruck truck maximum permissible mass is 26 tons. The Urban eTruck electric drive includes two electric motors with a total capacity of 250 kW located on each side of the car. Their power supply is provided by two modular rechargeable lithium-ion batteries with capacity of 212 kW/h and the regenerative braking system feeds the batteries during braking. The mileage without recharging is 200 km. The FleetBoard telematics system allows the driver to communicate with the traffic controller, allowing the planning of the delivery route. All information about the current state of the machine is displayed on a 12.3-inch display located on the front of the driver's cabin. The cargo vehicle Urban eTruck is a modular type. Serial production of the machine is planned to begin after 2020.

Truck Nikola One can work on electricity, natural gas and other types of fuel. It can carry cargo weighing about 36 287 kg and at the same time pass 1609 km without a single stop. The battery capacity is 32 kWh and it is charged through the turbine, as well as from regenerative braking. The car is equipped with six electric motors with a total output capacity of 2000 horsepower and a torque of 5017 N·m. According to the developer, the operating costs of Nikola One are 2 times less than in case of conventional diesel trucks.

The Terberg YT202-EV, designed for public roads, is equipped with a lithium-iron-phosphate battery with a voltage of 614 V. The mileage of road train, including a single tractor and a standard tilt semitrailer, is 100 km. The charging time of the batteries is from 2 to 4 hours. The road train operates as a part of the Scherm fleet, which specializes at the delivery of spare parts from the warehouse to the BMW plant. In comparison with the diesel analogue, when fuel consumption exceeds 50 thousand liters, the Terberg electric traction machine saves 35 thousand dollars.

At present, FSUE "NAMI", with the financial support of the Education and Science Ministry of the Russian Federation, together with PJSC "KAMAZ" as an industrial partner, is developing and piloting a prototype of the unmanned cargo vehicle with electric drive (UCVED) on the basis of KAMAZ chassis with a layout without a driver's cabin for logistics transportation.

Key principles in the development of promising UCVED are unmanned execution, electric drive application, platform volume increased due to the exclusion of the cabin from the chassis structure, driver exclusion from the management process, organization of traffic remote control by an operator, the creation of an electronic traffic control system, working with the use of new technologies for their construction [13, 14], usage of traffic control systems and technical vision.

The UCVED platform includes a cargo platform, an electric drive, a motion control, information processing and communication systems, and control actuators.

The layout solution of the UCVED special chassis is shown in Figure 4.

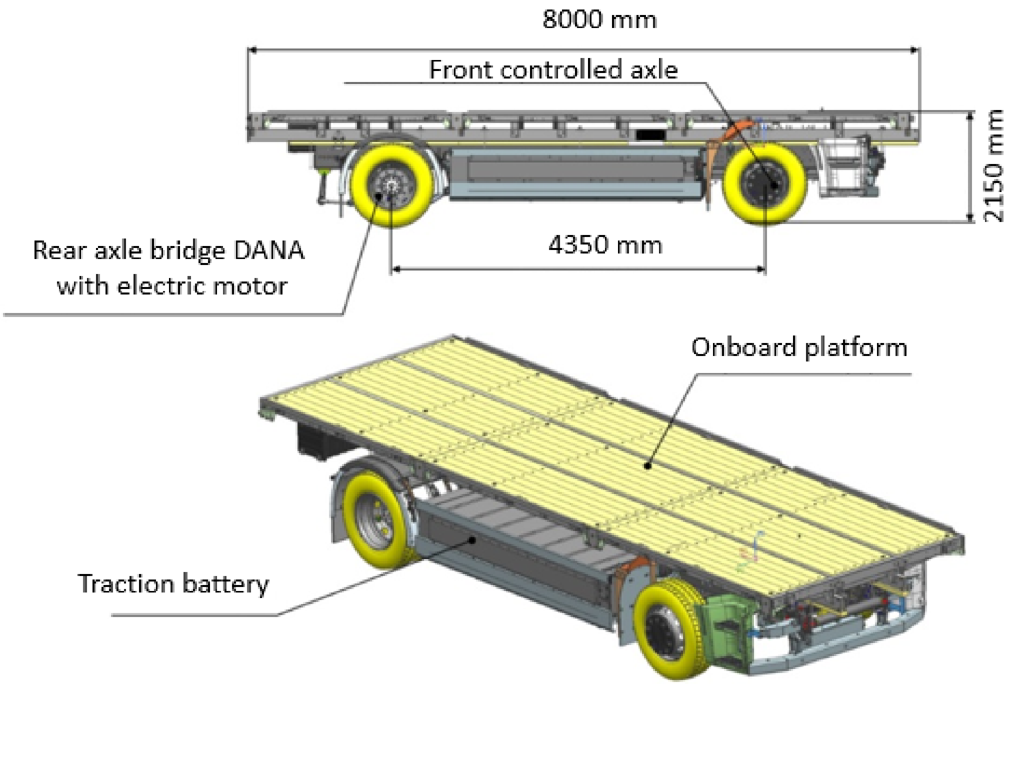


Figure 4. The layout solution of the UCVED special chassis.

The UCVED prototype control system includes a control unit with a microcontroller, a video processing unit, a secondary power source, an executive brake control system, a steering actuator, a navigation car terminal with receiving antennas, a free inertial navigation system, radars, a LIDAR, wheel speed sensors, video cameras. The architecture of the UCVED motion control module is shown in Figure 5.

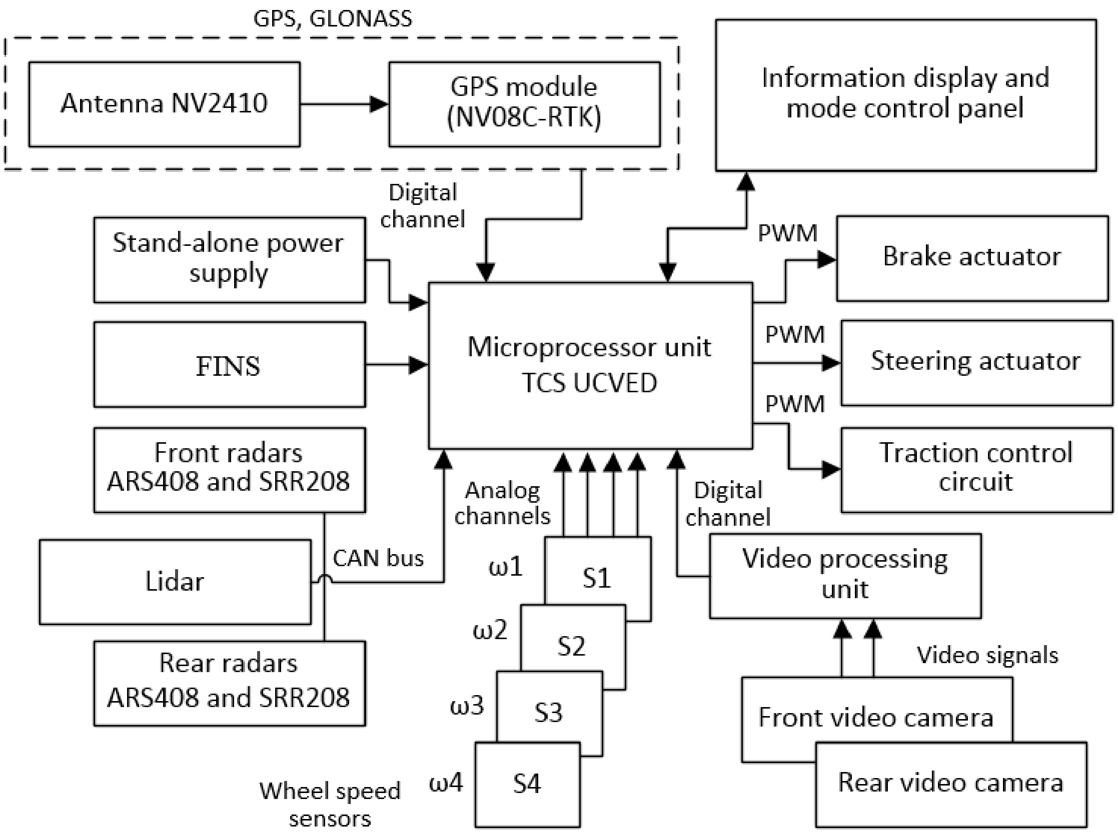


Figure 5. The architecture of the UCVED motion control module.

The main advantages of the project at its implementation are the time and costs reduction of goods and passenger transportation, improving transport and environmental safety, minimizing traffic accidents and the number of human victims in them, reduction of fuel consumption, emission of harmful substances into the atmosphere, more efficient use of road capacity.

At UV creation with an electric drive geographical and climatic features, long distances, low average temperatures for most territory of Russia, lack of proper infrastructure for the electric vehicles operation are taken into account. Application of foreign technical solutions developed for the movement control of unmanned trucks with electric drive in the conditions of their operation is problematic for the road and climatic conditions of the northern regions and the Arctic zone of the Russian Federation, which constitute more than 70% of the country's territory. The following features characterize road and climatic conditions of the northern regions and the Arctic zone of the Russian Federation:

- abnormally low temperatures (down to -60 °C), which significantly reduce the efficiency of battery cells and the functioning of electronic vision systems operating at minimum permissible temperatures not lower than -20 °C;
- long periods of low temperatures, snowfalls, fog, ice cover, etc., snow drifts that do not allow to recognize road markings and make it difficult for the UV systems to operate;
- difficult conditions of off-road driving, allowing the vehicle operation only in the summer and winter seasons;
- at off-road conditions in large areas of these regions, the UV cannot orient that makes it difficult to visualize the UV location on the route;

- limited visibility in the conditions of the polar night;
- unpredictable influence of the geomagnetic situation and the state of the troposphere and the ionosphere of the Earth in the polar latitudes on the uninterrupted satellite navigation signals receiving.

The negative impact on UV operation is also provided by unfavorable operating conditions as windshield contamination, poor illumination (insufficient illumination of traffic lanes), bad weather conditions (snowfall, icing, heavy fog and rain), absence or worn-out lanes marking, etc.

Summarizing the foregoing, it can be argued that the development of unmanned cargo transport with electric traction in the Russian Federation conditions should be carried out by developing additional control technologies, scientific and technical solutions that are comparable to the known ones. It should be noted that the motion control system and electric drive cannot have a universal performance for vehicles operated in various regions of the Russian Federation, for example, southern, northern, Arctic.

The developed cabinless construction of a cargo UV with an electric drive is promising for use in the vehicles platoon, the use of which allows to reduce fuel consumption and harmful substances emissions to the atmosphere by 10-20% at passenger and cargo transportation.

At the development of advanced cargo UVs with electric drive in terms of health safety ensuring of passengers and workers, it is also necessary to solve the problem of their protection against excess air pollution in the cabins and inhabited compartments of the UVs, which is currently not being given due attention.

3. Conclusion

Analysis of the accumulated experience, modern scientific, technical, regulatory, methodological literature on the development of UVs with an electric drive makes it possible to assert that solving this problem, taking into account operating conditions in the Russian Federation, requires the development of designs for advanced cargo UVs with electric drive and the implementation in their traffic control systems of additional, compared with similar European counterparts, functions as:

- identification of the road surface condition, reliable recognition of road markings and road signs;
- ensuring the operability, reliability and efficiency of the electric drive, motion control systems and their components in the conditions of low and ultralow temperatures of the ambient air;
- ensuring the reliable operation of orientation systems on the terrain, especially in the northern and Arctic regions of the country;
- prediction of the condition and destruction of tires;
- determination of suspension and steering dangerous malfunctions;
- recognition in the initial stages of detaching the wheels from the hubs and others.

The use of foreign stabilization systems is limited by unfavorable road conditions. The recognition of road markings by modern technical vision systems is difficult due to road surface contamination during the autumn-winter and spring periods of the year.

The motion control systems construction with physical sensors of information used in foreign analogues makes it necessary to use new materials, technologies and structures that are not available in the Russian Federation. Given the projected long-term isolation of the Russian Federation from the developed countries of the world, this path seems unrealizable.

In the current situation, the use of a new principle for the physical information sensors replacement by virtual technologies based on control technology implemented at FSUE "NAMI" on indirect measurements and integration of management functions is a new scientific and technical solution for creating an efficient and reliable traffic control system for unmanned cargo vehicles intended for operation in the conditions of the Russian Federation, and allows to reduce the dependence of ongoing developments on foreign technologies and components.

The creation of integrated intelligent traffic control systems based on new principles opens the possibility to implement the projects, starting with the operation of unmanned cargo vehicles with electric drive in limited areas and their subsequent introduction to public roads, including the northern regions and the Arctic zone of the Russian Federation. The conceptual core of such systems is mathematics and software, which requires concentration of the developers' efforts in this area.

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