AUTONOMIC LOGISTICS SYSTEM OF INTELLIGENT MILITARY MOTOR VEHICLES

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Abstract

The paper presents a concept of autonomic logistics system of intelligent military motor vehicles. A classification of vehicles and a definition of intelligent motor vehicles has been provided. The intelligent motor vehicle distinguishes the functional components systems and the integrated control system. The integrated system has been defined to control the intelligent motor vehicles, including subsystems of: data identification, information-and-decision-making and executive components. The data identification subsystem distinguishes the following components: logistic about the state of environment, navigation, and communications. The automatic logistic system consists of the following subsystems: diagnostic, operational, security, and power supply. The purpose and tasks of those subsystems have been examined. The information and decision-making subsystem has been defined: classic, expertise, and hybrid. Tasks of the vehicle setting components subsystem have been defined. A place of autonomic logistic system in the structure of the military motor vehicle has been determined. The development of a design and the implementation of the proposed concept of the autonomic logistic system will significantly increase the performance properties of military motor vehicles in aspect of effective execution of their combat missions.

Keywords: *motor vehicles, logistics, operation, diagnostics, steering*

1. Introduction

Military motor vehicles can effectively be used in conventional combat operations (attack, defence, march, manoeuvre), as well as asymmetric operations that primarily involve:

1) the combat participants are various social and political groups, not associated with the state government bodies of their own country,
2) absence of a single command centre,
3) a joint although not necessarily homogeneous political and strategic concept of operations,
4) a coherent and conceptual performance of various groups against the common enemy, apparently uncoordinated,
5) diversified tactics and non-standard operations,
6) chaos, i.e. fighting without acknowledging any standards, arrangements, and procedures in order to destroy the existing social, political, cultural and economic structures.

Modern military vehicle should be prepared for network-centric warfare whose basic features are as follows:

1) conducting the warfare using information technologies, IT in particular,
2) independent operation of subunits connected by a intranet, preferably wireless, and in view of significant risks joining them into larger formations, capable of repelling the attack of the enemy,
3) common automation of the battlefield, including the automated systems to command and deploy troops, including means of destruction,
4) the use of intelligent unmanned vehicles capable of operating in all conditions.

Taking the basic specified and characteristic features of the contemporary battlefield, future weapons and military armaments and equipment should be chosen for military forces, and particularly: wheeled, tracked, and special-purpose motor vehicles, as well as effective logistics, operational, and diagnostic systems.

2. Intelligent motor vehicle

Intelligent motor vehicle is a machine capable of self-performance of tasks arising from its use purpose and an adjustment of its own operation as a result of changes in environmental conditions or state (Fig. 1) [1, 5].

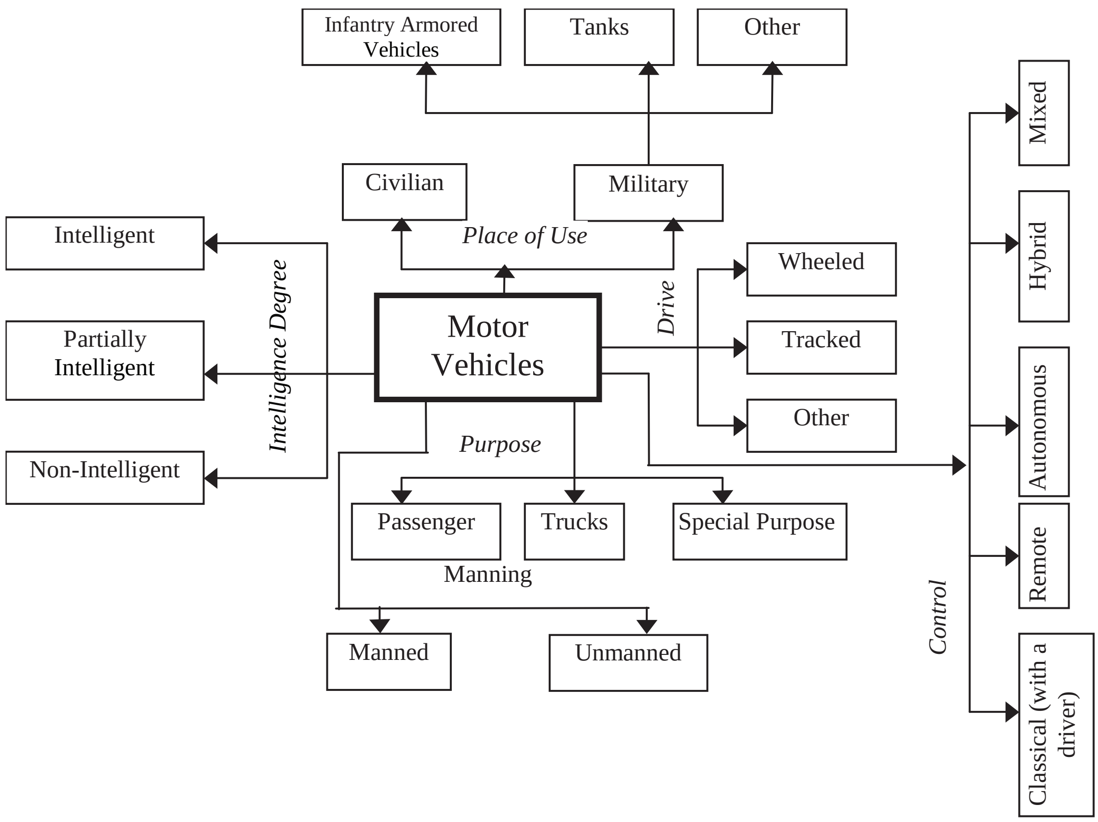

Fig. 1. Division of Motor Vehicles

Unintelligent motor vehicle is not able to automatically carry out its tasks and cannot adjust its operation when either its state or/and external conditions have changed. This means that the vehicle functions are implemented via the driver (operator) and the crew.

Partially intelligent vehicle is a technical system that does not belong to any of the aforementioned groups of objects, which means that some tasks are performed automatically while the other involve the operator. The assumption can be made that currently we use partially intelligent and unintelligent motor vehicles.

The unmanned autonomic vehicle means that it operates independently when performing its tasks and is capable to adapt to the changing environmental conditions.

The remotely-controlled vehicle means that its movement and behaviour in the environment is controlled by an operator. A mixed vehicle means that it operable autonomously, remotely, and by the driver.

The remote & autonomous vehicle (hybrid) combines features of the vehicle groups mentioned above. Considering the definitions provided, one may determine attributes of the intelligent motor vehicle and they are as follows:

- it is capable of detecting hazards resulting from a change in its condition and the environmental dynamics,
- to counteract the identified threats,
- to navigate, i.e. to determine the location and the road of driving in variable traffic conditions,
- to maintain a certain high level of its own safety, that of the driver (operator), the crew and of the passengers,
- reduce the impact of harmful factors (exhaust fumes, noise) on the natural environment,
- to provide a high riding level of comfort for passengers,
- to maintain an relevant motional dynamics and that is to adapt to the current driving resistances,
- high logistical, operational, and diagnostic susceptibility.

The currently used term „vehicles operations" is insufficient, therefore, there is a need to introduce a new term – „Logistics Vehicle System." This is dictated by the following factors:

1) a need to control maintenance and security of vehicles. Such control tools include as follows: rules, methods, and measures of technical diagnostics,
2) operational subsystem is a tool for implementing individual actions of people,
3) the vehicle must be safe on its own, for the operator and its close environment,
4) for their effective operation, the vehicles require materials, including: fuel, oils, lubricants, and spare parts.

Such Logistics Vehicles System is self-sufficient and fully securing their operation.

3. Integrated control subsystem

Intelligent motor vehicle S_{IP} is described by expression (Fig. 2):

$$S_{IP} = < S_{WF}, S_{IZ}, R_{WI} >, \tag{1}$$

where:

S_{WF} – functional components subsystem,
S_{IZ} – integrated IT control subsystem,
R_{WI} – relations.

The integrated control subsystem is described by expression (Fig. 3) [1, 2, 4]:

$$S_{IZ} = < S_{II}, S_{ID}, S_{EN}, R_{IE} >, \tag{2}$$

where:

S_{II} – data identification subsystem,
S_{ID} – decision-making and information subsystem,
S_{EN} – setting (executive) components subsystem,
R_{IE} – relations.

Data identification subsystem S_{II} is described by expression:

$$S_{II} = < S_{IL}, S_{IO}, S_{IK}, R_{IK} >, \tag{3}$$

where:

S_{IL} – logistics data subsystem,
S_{IO} – environmental condition data subsystem,
S_{IK} – navigation and communication subsystem,
R_{IK} – relations.

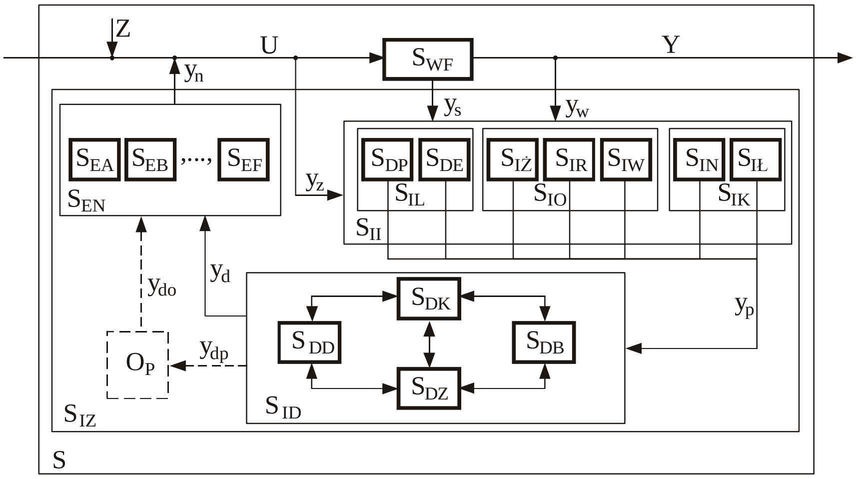

Fig. 2. Simplified diagram of the intelligent autonomic motor vehicle: S – intelligent motor vehicle, S_{WF} – vehicle functional components subsystem, S_{IZ} – integrated computer control subsystem, S_{II} –information subsystem, S_{IL} – logistics data subsystem, S_{DP} – diagnostic subsystem, S_{DE} – operational subsystem, S_{IO} – environmental condition data subsystem, $S_{IŻ}$ – hazards detection subsystem, S_{IR} – driving conditions reconnaissance subsystem, S_{IW} – weather conditions assessment subsystem, S_{IK} – navigation and communication subsystem, S_{IN} – navigation subsystem, $S_{IŁ}$ – communication subsystem, S_{ID} – decision-making and information subsystem, S_{DB} – database subsystem, S_{DK} – communication subsystem, S_{DZ} – tasks identification subsystem, S_{DD} – decision-making subsystem, S_{EN} – setting components subsystem, S_{EA} – setting subsystem of the engine and driving system, S_{EB} – setting subsystem of the steering system, S_{EF} – other setting subsystems, U – inputs, Y – outputs, Z – interferences, O_P – operator, y_{dp} – decisions proposed by S_{DD}, y_p – converted signals, y_z, y_w, y_s – signals on the state of inputs, outputs, and the vehicle, y_d – decisions, y_n – control signals, y_{do} – operator's decisions

4. Autonomic logistics system

Subsystem of logistics data processed

$$S_{IL} = < S_{DP}, S_{DE}, S_B, S_Z, R_{DE} >, \tag{4}$$

where:

S_{DP} – diagnostic subsystem,
S_{DE} – operational subsystem,
S_B – security subsystem,
S_Z – power supply subsystem,
R_{DE} – relations.

Tasks of the diagnostic subsystem are as follows [3, 6]:

- state of the vehicle components at the moment t,
- in case of the vehicle operability, its state at the moment t+Δt – the date of the next diagnosis,
- vehicle resource for the major repair,
- vehicle resource for liquidation,
- state of the vehicle at the moment t-Δt, i.e. localization of component damages.

Diagnostic subsystem is described by expression:

$$S_{DP} = < S_{DK}, S_{DL}, S_{DZ}, R_{DZ} >, \tag{5}$$

where:

S_{DK} – state control subsystem,

S_{DL} – fault location subsystem,
S_{DZ} – state projecting subsystem,
R_{DZ} – relations.

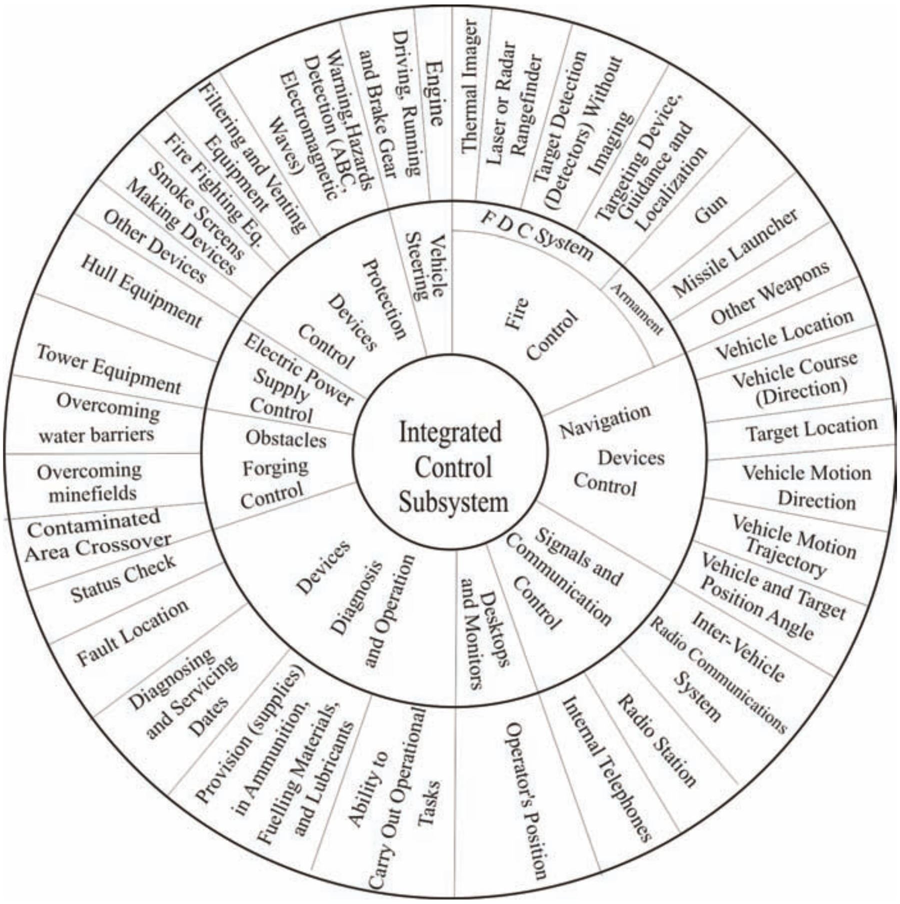

Fig. 3. Graphic chart of the intelligent military motor vehicle using S_{IZ}

Motor vehicles operational subsystem can be presented as follows:

$$S_{DE} = < S_{EU}, S_{EO}, R_{EO} >, \quad (6)$$

where:
S_{EU} – use (usage) subsystem,
S_{EO} – servicing (maintenance) subsystem,
R_{EO} – relations.

The task of the vehicle use (utilisation) subsystem is to inform the crew and the landing troops about how to control and effectively use the on-board equipment. However, the main task of this subsystem is the ability of self-education for: driver, commander, gunner, and the landing troops in the areas of: structural design, maintenance, and the ways of how to use the vehicle in the battlefield.

The subsystem describes the following expression:

$$S_{EU} = < S_{UK}, S_{UB}, S_{UD}, R_{UD} >, \quad (7)$$

where:
S_{UK} – driving compartment use subsystem,

S_{UB} – combat compartment use subsystem,
S_{UD} – landing troops compartment use subsystem,
R_{UD} – relations.

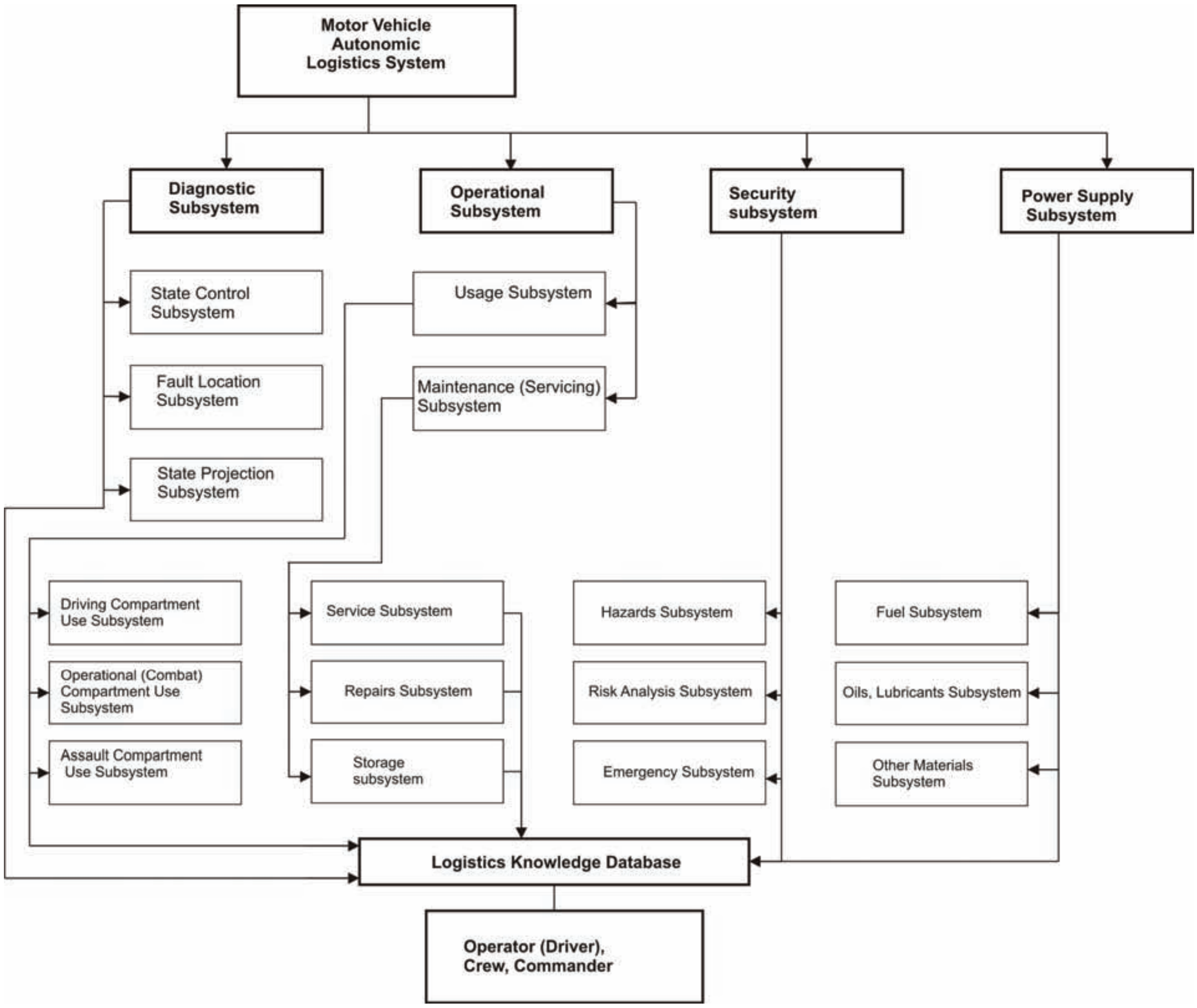

Fig. 4. Functional Diagram of Motor Vehicle Autonomic Logistics System

The main tasks of the servicing (maintenance) subsystem have been formulated as follows:
1) vehicle structure, i.e. the type of diagnoses and maintenance services,
2) dates of diagnoses and maintenance services,
3) implementation of diagnoses and maintenance services: current, periodical, repairs: current and major.

The subsystem includes:

$$S_{EO} = < S_{OO}, S_{OB}, S_{OG}, R_{OG} >, \qquad (8)$$

where:
S_{OO} – current and periodical maintenance services subsystem,
S_{OB} – current repairs subsystem,
S_{OG} – major repairs subsystem,
R_{OG} – relations.

The security subsystem S_B will perform the following tasks:

- to monitor weak links of the vehicle,
- to alarm about a threat to human life,
- to alarm about a threat to natural environment,
- to alarm about a threat to vehicle existence.

Security subsystem is described by expression:

$$S_B = < S_{BZ}, S_{BR}, S_{BA}, R_{BA} >, \quad (9)$$

where:

S_{BZ} – hazards subsystem,
S_{BR} – risk analysis subsystem,
S_{BA} –alarms subsystem,
R_{BA} – relations.

Vehicle power supply subsystem is described by expression:

$$S_Z = < S_{ZP}, S_{ZO}, S_{ZM}, R_{ZM} >, \quad (10)$$

where:

S_{ZP} – fuels subsystem,
S_{ZO} – oils and lubricants subsystem,
S_{ZM} – other materials subsystem,
R_{ZM} – relations.

The main tasks of this subsystem include monitoring of:

1) the state of:
   - fuels, oils, and lubricants,
   - other operating materials,
   - spare parts;
2) places of lubrication and supplementation of operating fluids.

Other components of the data identification system S_{II} and other (Fig. 2) meet the tasks as outlined below.

Environmental condition data subsystem S_{IO} is described by expression:

$$S_{IO} = < S_{IZ}, S_{IR}, S_{IW}, R_{IW} >, \quad (11)$$

where:

S_{IZ} – hazards detection subsystem,
S_{IR} – driving conditions reconnaissance subsystem,
S_{IW} – weather conditions assessment subsystem,
R_{IW} – relations.

The hazards detection subsystem S_{IZ} is designed to:

- determine radioactive contamination of the area,
- determine a contamination of the area with bacteriological and noxious agents,
- identify other hazards, e.g. targets localization.

Driving conditions reconnaissance subsystem (recognition of the environment) has the following tasks:

- to identify terrain roadblocks of the following type: trees, buildings, stones, ditches, concertina-wire entanglement, etc.,
- to identify simple road sections, curves, sudden bents, and so on.

The task of the weather conditions assessment subsystem S_{IW} is to determine: air temperature, pressure, and its humidity.

The navigation and communication system includes the following subsystems:

$$S_{IK} = < S_{IN}, S_{IŁ}, R_{IŁ} >, \tag{12}$$

where:

S_{IN} – navigation subsystem,
$S_{IŁ}$ – communication subsystem,
$R_{IŁ}$ – relations.

The tasks of the navigation subsystem S_{IN} are as follows:

- to localize position of the vehicle,
- to determine traffic route (itinerary) of the vehicle.

The tasks of the communication subsystem include securing:

- the internal communication,
- external communication.

Decision-making and information subsystem is designed to (Fig. 2) [1, 2, 4]:

- store data (database),
- identify tasks to be executed by intelligent vehicle,
- select decisions from a set of allowed decisions,
- store control signals to the setting components subsystem,
- steer the vehicle.

The decision-making and information subsystem S_{ID} may be considered as the following type of subsystem:

- classical,
- expert,
- mixed (hybrid).

The decision-making and information subsystem S_{ID} as the classical subsystem S_{IDK} may be described using this expression:

$$S_{IDK} = < S_{BD}, S_{DK}, S_{DZ}, S_{DD}, R_{BK} >, \tag{13}$$

where:

S_{BD} – database subsystem,
S_{DK} – communication subsystem,
S_{DZ} – tasks identification subsystem,
S_{DD} – decision-making subsystem,
R_{BK} – relations.

The primary task of the subsystem of setting components (executive components of the effectors interface; those of the output system) is to adapt and transfer signals from S_{ID} subsystem to individual components of the motor vehicle in aspect of their automatic control.

The subsystem may be described as follows:

$$S_{EN} = < S_{EA}, S_{EB}, S_{EC}, S_{ED}, S_{EE}, S_{EF}, R_{EF} >, \tag{14}$$

where:

S_{EA} – setting subsystem of the engine and driving system,
S_{EB} – setting subsystem of the steering system,
S_{EC} – setting subsystem of the braking system,

S_{ED} – setting subsystem of the security systems,
S_{EE} – setting subsystem of the cargo loading and off-loading robot,
S_{EF} – other setting subsystems,
R_{EF} – relations.

Place of the autonomic logistics system in the structure of the military motor vehicle has been illustrated in Fig. 5 and 6.

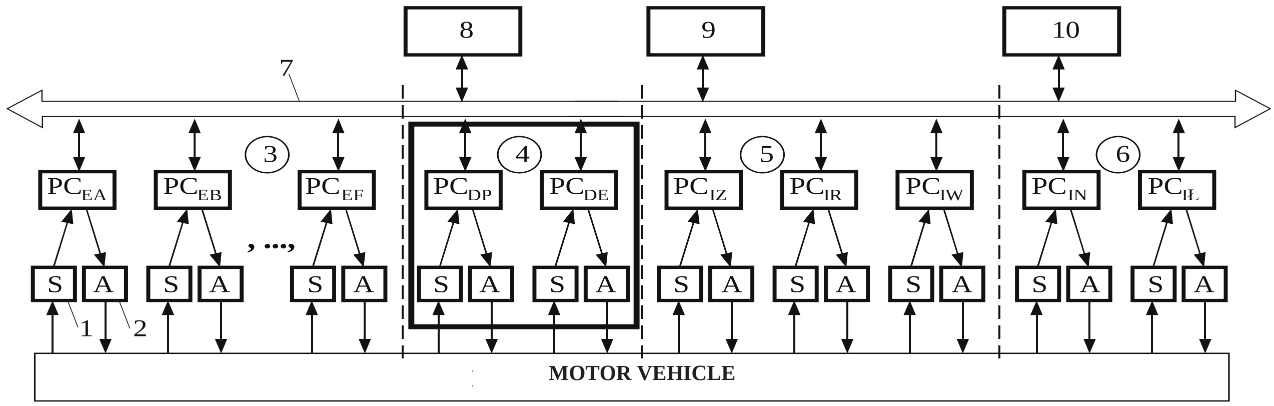

Fig. 5. Simplified Diagram of Motor Vehicle Control System: 1 – sensors of the systems, 2 – setting subsystems, 3 – setting subsystems drivers, PC_{EA} – motor driver, PC_{EB} – driving system controller, PC_{EF} – other setting subsystems driver, 4 – logistics subsystem drivers, PC_{DP} – diagnostic subsystem driver, PC_{DE} – operational subsystem drivers, 5 – environmental condition data subsystem driver, PC_{IZ} – hazards detection subsystem drivers, PCIR – driving conditions reconnaissance subsystem drivers, PC_{IW} – weather conditions assessment driver, 6 – navigation and communication subsystem driver, PC_{IN} – navigation subsystem driver, $PC_{IŁ}$ – communication subsystem driver, 7 – bus bar, 8 – computer of the information and decision-making system SID, 9 – support (backup) computer, 10 – visualization subsystem (monitor, printer)

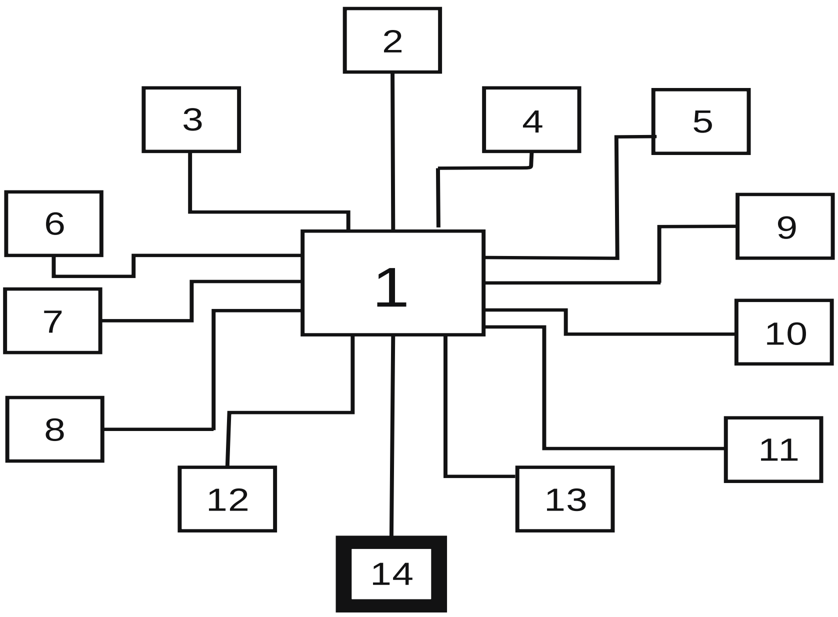

Fig. 6. Diagram of Military Vehicle Telematic System:1 – telematic integrator (e.g. WAN ACCES BOX); 2 – commander's terminal; 3 – commander's control panel; 4 – driver's control panel; 5 – landing troops control panel; 6 – radio stations; 7 – personal radio; 8 - GPS; 9 – Speakerphone; 10 – telephone and emergency console; 11 – video cameras; 12 – electric power supply; 13 – connection of other telecommunication subsystems; 14 – logistics subsystem

5. Summary

The basic feature of the modern battlefield is its dynamics, characterized by operational, tactical, and technical requirements, in particular:

- to combat in n-dimensional space,
- to acquire data in real time,
- to deploy, dislocate, make manoeuvres, and in particular to carry out the fight in any conditions and time.

Therefore, one should believe that the development of the design and implementation of the proposed concept of autonomic logistics system will significantly increase the functional properties of military motor vehicles in aspect of effective execution of combat missions.

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