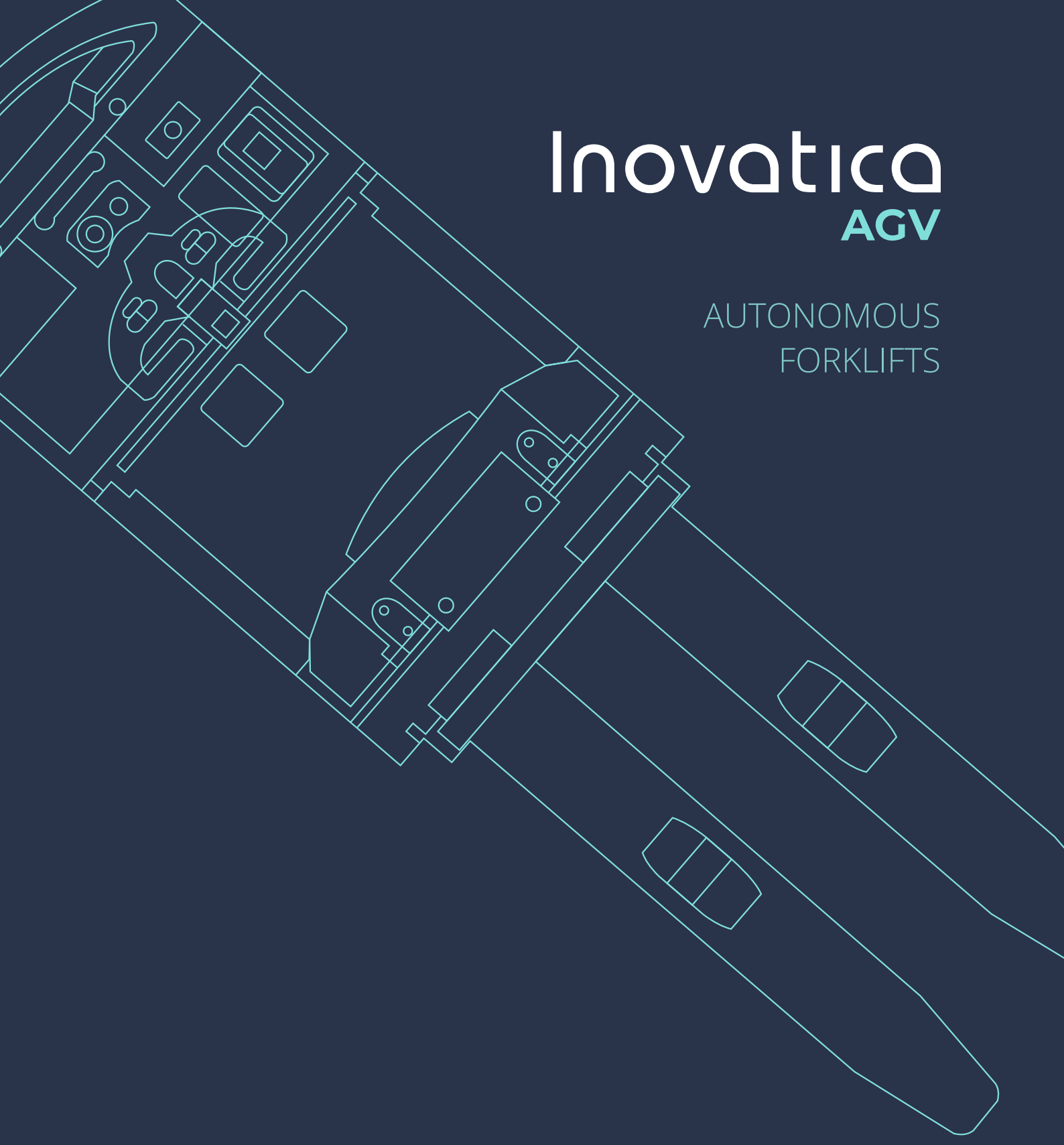
Inovatica
AGV

AUTONOMOUS
FORKLIFTS



Whitepaper ver 1.1

Inovatica AGV Autonomous Forklifts Technology

Contents

01 Introduction

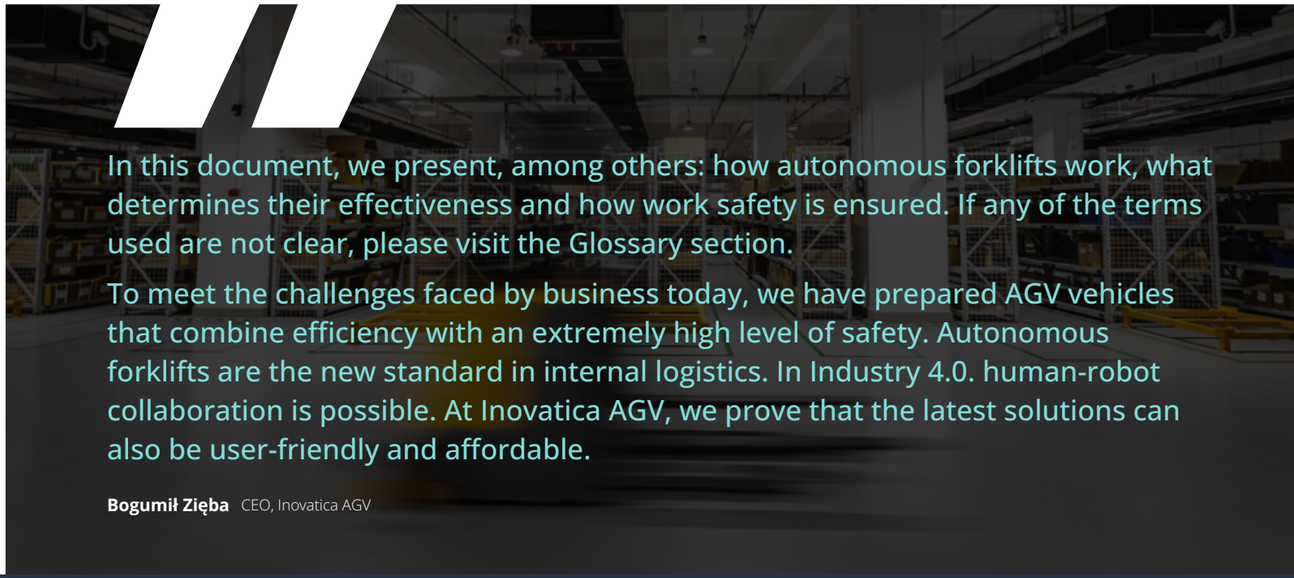
Autonomous forklifts are developed based on business needs. The first automatic (not yet autonomous) forklifts began to be tested in the USA in the 1950s. Since then, these vehicles have undergone a remarkable evolution, but the reasons for their introduction to the market remain unchanged. The priority is to ensure stable, efficient and safe internal transport. Thanks to their efficiency, they are able to provide hall operators with a real competitive advantage.

Autonomous guided vehicles (AGV) are free from the limitations of manual operators. First of all, their efficiency is constant over time, they do not feel tired or bored of repeating identical orders thousands of times. They are also insensitive to poor lighting (or the lack of it), noise, low temperature or unpleasant odors. Additionally, they are able to work invariably in three shifts, only with breaks for battery replacement (approx. 15 minutes). The strength of AGVs is that their operation is predictable and safe throughout their lifetime. The use of autonomous forklifts is a response to the following challenges in internal logistics:

Difficulties in recruiting qualified employees.

Rising salary costs for people with forklift licenses.

High risk of loss of health, life and property in accidents involving a manual operator.



In this document, we present, among others: how autonomous forklifts work, what determines their effectiveness and how work safety is ensured. If any of the terms used are not clear, please visit the Glossary section.

To meet the challenges faced by business today, we have prepared AGV vehicles that combine efficiency with an extremely high level of safety. Autonomous forklifts are the new standard in internal logistics. In Industry 4.0. human-robot collaboration is possible. At Inovatica AGV, we prove that the latest solutions can also be user-friendly and affordable.

Bogumił Zięba CEO, Inovatica AGV

02 Functional scope of the Inovatica AGV

02.1 Autonomous movement of the vehicle according to predetermined routes.

02.2 Horizontal pallet transport: including picking up / putting away pallets from the ground, the so-called „Level 0".

02.3 Vertical transport of pallets, including putting the pallets on the racks.

02.4 Detection of the presence of pallets in the warehouse / production space. The truck, depending on the detection of pallets in a given space, fully autonomously decides about the tasks of pallet transport, depending on the previously established transport strategy, for example: take a pallet from the first occupied pallet socket according to the order of their numbering.

02.5 Slowing down, stopping in front of an obstacle.

02.6 Avoiding obstacles.

02.7 Maintaining the possibility of manual control of the truck.

02.8 Signaling the low battery status and going down to the battery replacement station.

02.9 Integration with buttons, sensors or third systems to accept internal transport orders.

03 Navigation and control

03.1 Vehicle geolocation in confined spaces

Inovatica AGV products are intended to work in confined spaces, i.e. industrial halls and warehouses. In these spaces, due to the shielding of the roof, GPS-based geolocation, which we know from, for example, car navigation, does not work. And even if the signal is available, it does not provide the necessary precision for moving around the hall. This limitation resulted in the need to introduce a new way of locating and navigating inside the halls. A technology that ensures the right quality, and at the same time becomes more and more affordable, is laser navigation, the so-called LGV (short for laser-guided vehicles).

Laser Locating and Navigation (LGV)

The most important advantage of the Inovatica AGV solution is natural navigation, which means that the laser navigation system does not require additional supporting infrastructure such as e.g. mirrors interchangeably called navigation reflectors, magnetic lines, optical lines or special platforms for lifting / putting away pallets from the vehicle, to precisely navigate in the hall.

Natural navigation that does not require additional infrastructure

The system is based on the class of SLAM (Simultaneous Localization And Mapping) algorithms, which allow you to position the vehicle on a simultaneously created and updated map of the surroundings. The initial map of the surroundings is created by manually driving the truck in the hall, during which the truck scans the surroundings with a laser. In this way, a precise, virtual map of the hall is created, on which the truck will then position itself independently.

On the map prepared in this way, the system operator determines the routes of individual missions along with tasks for the Inovatica AGV vehicle. The location of the places for picking up and putting away pallets is defined, as well as determining the paths that the robot can follow, which is described in detail in chapter 7 Implementation of Inovatica AGV vehicles.

The navigation system supports work in many halls or plants and allows you to easily switch between individual, previously prepared maps.

More information about navigation is available in the Frequently asked questions (FAQ) section.

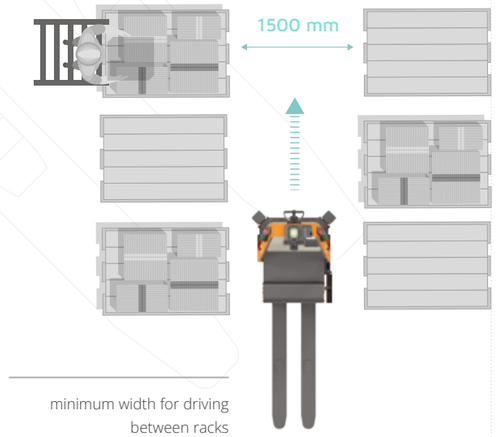
An outline map of the hall after mapping by the laser scanner

03.2 Truck controls

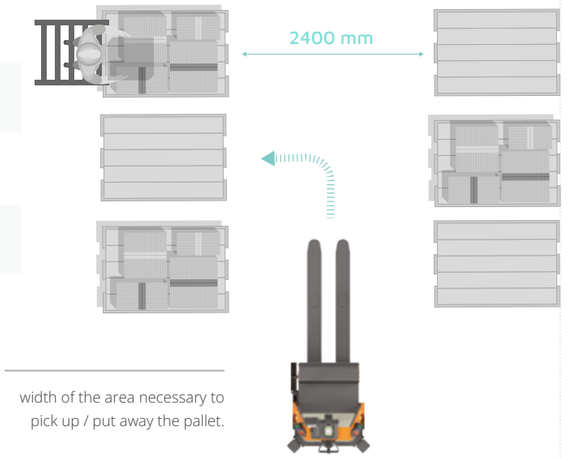
Inovatica AGV autonomous forklifts use advanced control and maneuvering algorithms. They ensure safe driving, execution of tasks and set the truck in the final position with an accuracy of 5 cm and an angle of 5 degrees according to a previously determined route.

Basic information about the space in which the AGV truck can move:

Minimum width of the aisle into which it can drive:	1500 mm
Dimensions of the parking space min.	1200x2650 mm
The minimum width of the corridor allowing to perform a U-turn:	2400 mm
Braking distance (with a load of 1000 kg):	
1 [km/h]	0,4 m
3 [km/h]	1,5 m
5 [km/h]	2,8 m
7 [km/h]	4,5 m
8 [km/h]	5,5 m



minimum width for driving between racks

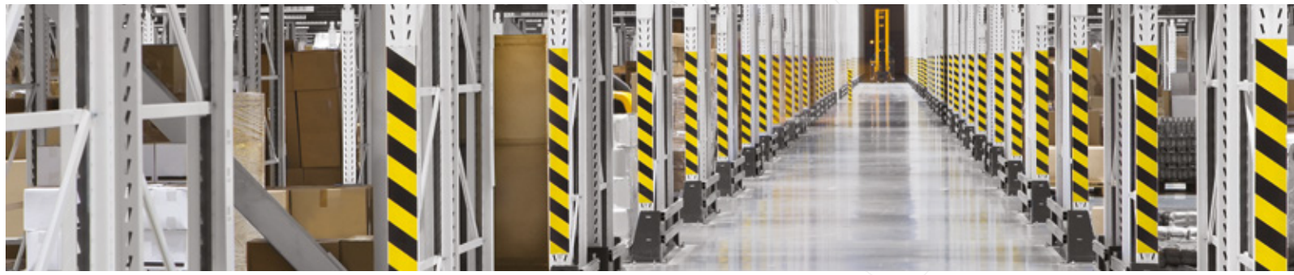


width of the area necessary to pick up / put away the pallet.

03.3 Possibility to work in 2 modes: manual and autonomous

The distinguishing feature of the Inovatica AGV product is the possibility of using the truck in a fully autonomous way, or, according to the needs of the moment, in manual mode.

Switching to manual mode is triggered by touching / using the gripper fitted to the truck. After catching the grapple, the operator can use the truck manually.
The truck is re-switched to the autonomous mode by pressing the appropriate buttons on the vehicle's control panel. Restoring the truck to autonomous operation requires placing it on the route from which it was taken or the starting point.



04 Vehicle management system Inovatica AGV (supervisory system)

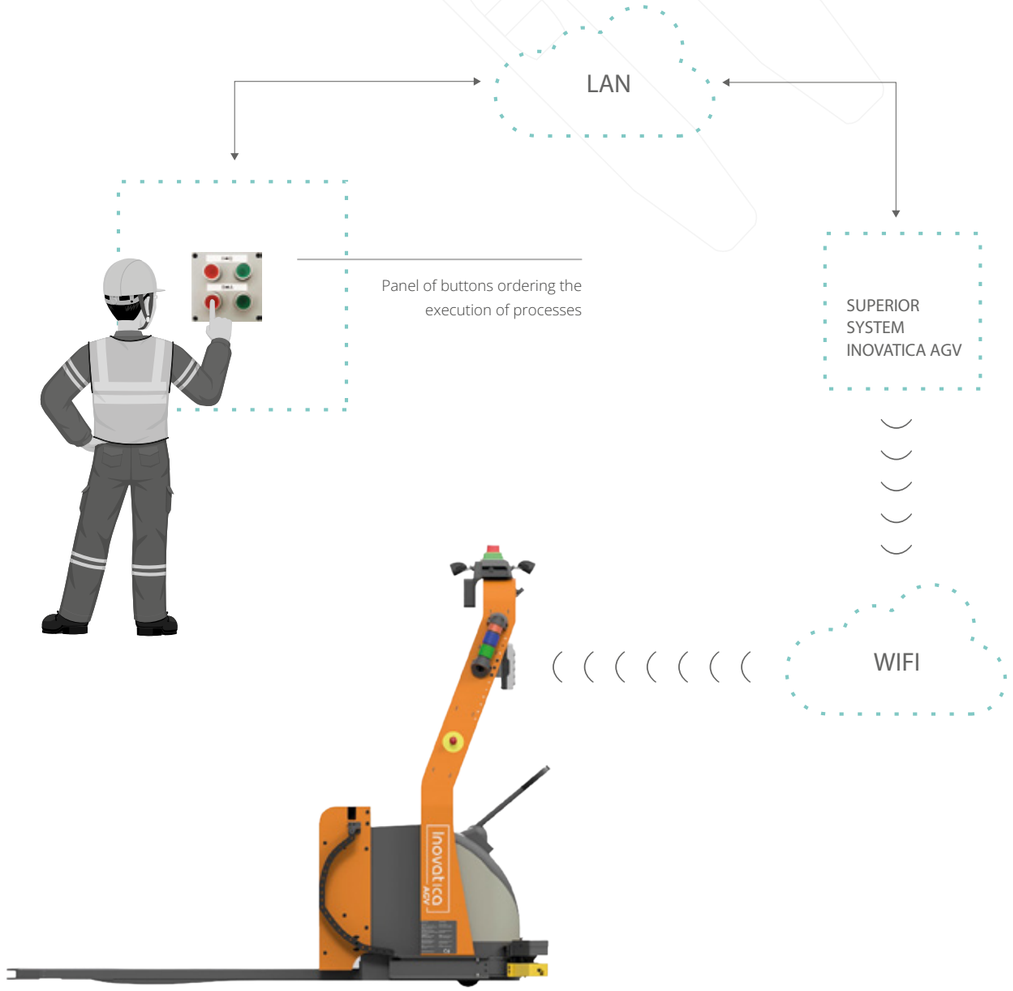
Together with the Inovatica AGV vehicles, the AGV vehicle management system, the so-called supervisory system, is delivered. This system, on the basis of accepted orders / tasks, maps of the surrounding area, designated paths, determines the optimal route to perform its mission for each autonomous forklift truck. The supervisory system can be implemented for individual autonomous forklifts as well as for the entire fleet.

04.1 Ways of issuing orders to the supervisory system

There are many ways of issuing orders to the supervisory system, which are described in the following chapter.

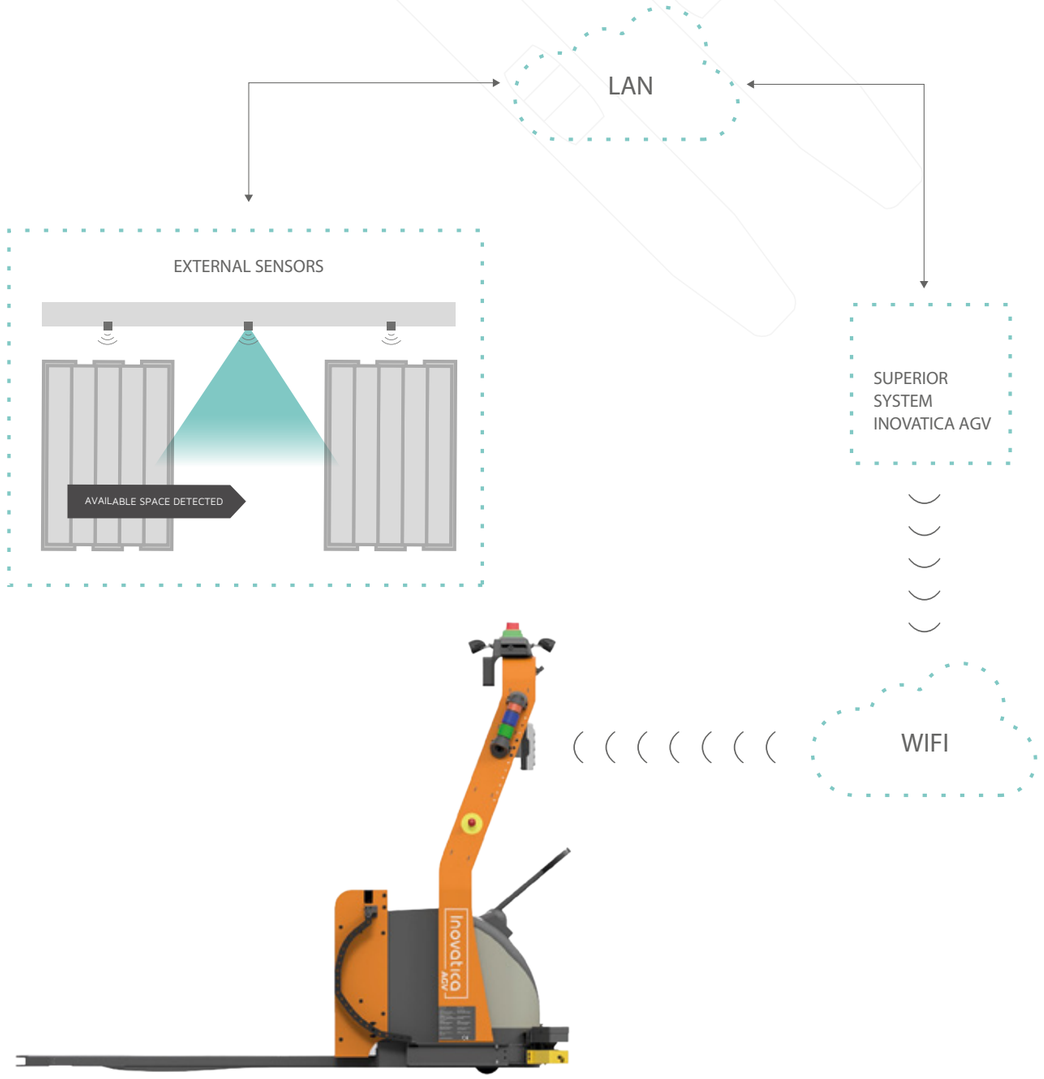
04.1.1 Issuing orders by an employee using the button panel

The orders are issued by the employee using the button panel. The panels are located in places agreed with the customer in the hall. Thanks to this, employees can easily give an order to an autonomous truck by pressing the appropriate button.
As part of the delivery, Inovatica AGV also supplies button panel strips and installs them in places determined during the pre-implementation analysis.
The button panels with which orders are issued to the supervisory system are made in the form of industrial housings. They are equipped with buttons, also in the industrial standard, with the possibility of backlighting.



04.1.2 Issuing orders using sensors

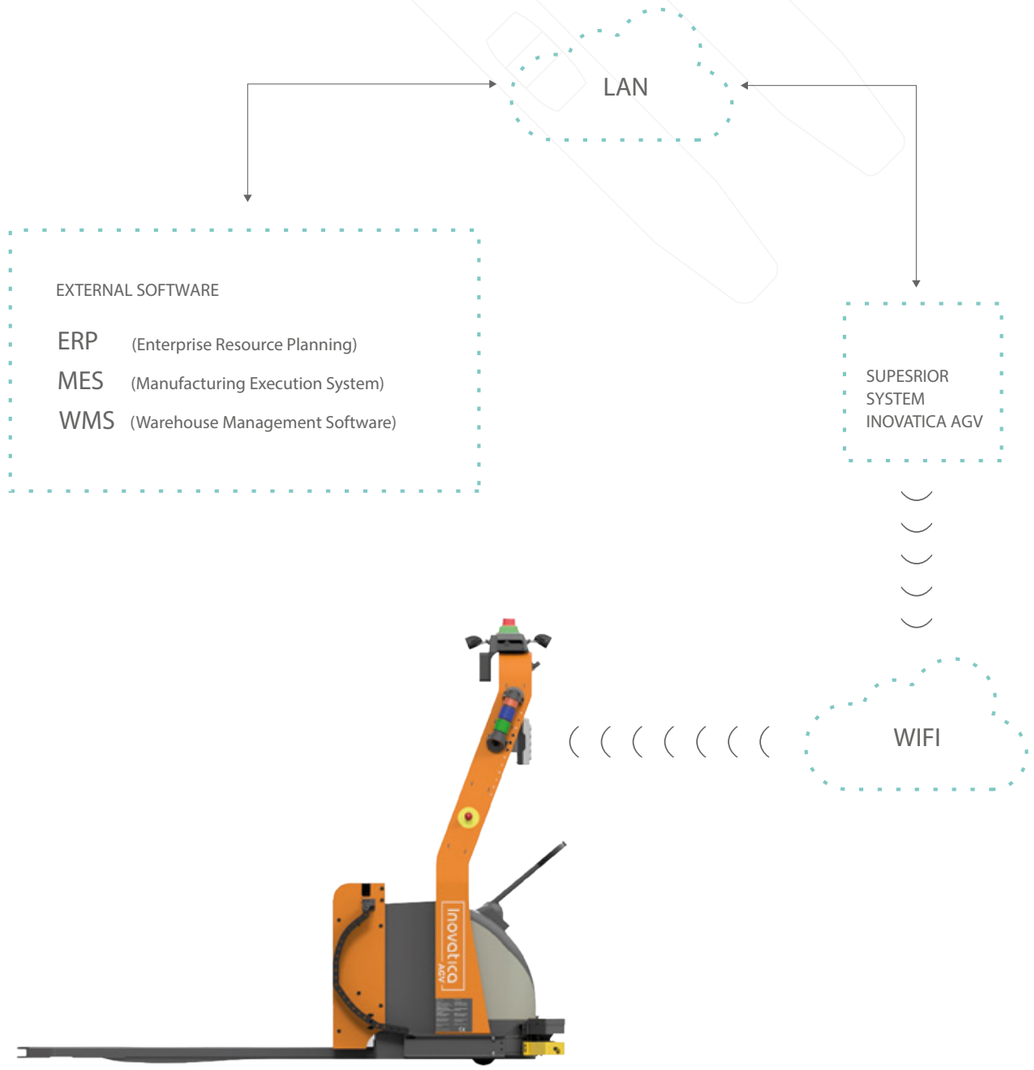
It is possible to automatically ordering tasks to AGV trucks using external sensors. These can be, for example, optical or ultrasonic sensors placed at the end of the roller track or monitoring the occupancy of a pallet space. Integration of the truck fleet with sensors located in the hall is carried out by Inovatica AGV engineers during pre-implementation works.



04.1.3 Issuing orders via external systems to the Inovatica AGV system

The Inovatica AGV software has been implemented in an open architecture that allows easy integration with external systems, e.g. ERP (Enterprise Resource Planning), MES (Manufacturing Execution System), or WMS (Warehouse Management Software).

Each of the above systems can be a source of issuing orders for autonomous forklifts or collecting data on their work (time, number of pallets transported, etc.).



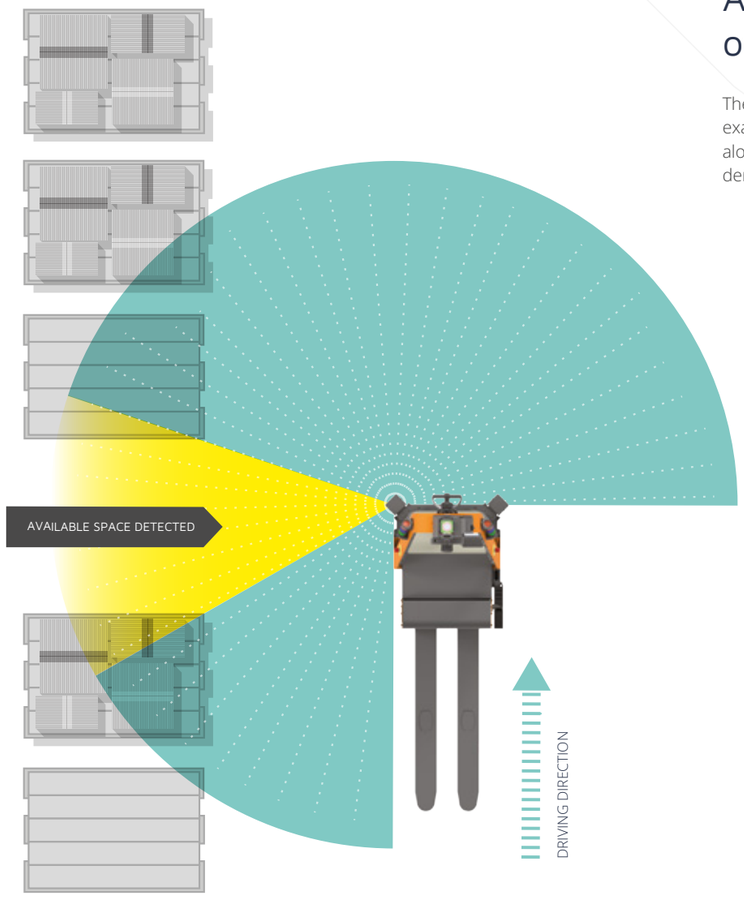
04.1.4 Autonomous issuing of orders

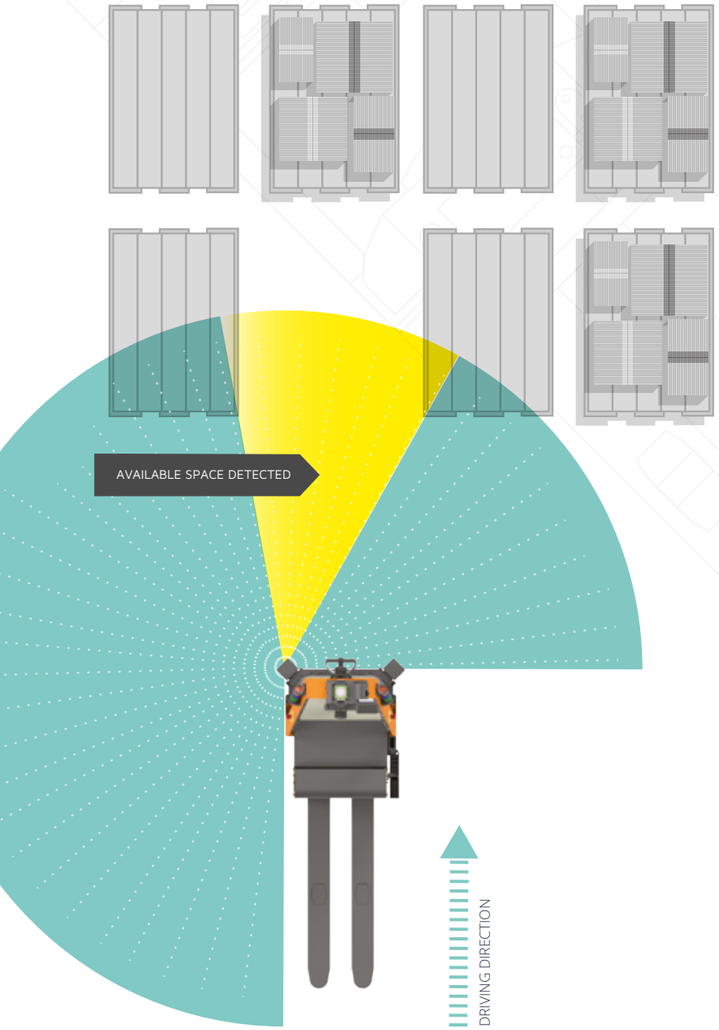
The source of issuing orders may be the autonomous forklift itself, which, in addition to the possibility of transporting the load on the forks, can be used to detect the presence of pallets in the warehouse/production space. The truck, from the moment it detects pallets in a given space, fully autonomously decides on the implementation of individual tasks during transport. This decision depends on the previously agreed transport strategy, for example: "pick up the pallet from the first occupied pallet slot according to the order of their numbering". Likewise, the pallet space occupancy information can also be used to determine the storage space when the truck is transporting the load on the forks.
The method of autonomous issuing of orders was implemented as linear and spatial tasks, which is described in detail below.

04.1.4.1

Autonomous issuing of orders - **linear task**

The job is to pick up/place the pallets in a row, for example along a wall or a railing. The truck travels along a line that marks a row of pallet locations in order to check their occupancy with the help of side lidars.





04.1.4.2

Autonomous issuing of orders - **spatial task**

The task is to pick up/put away pallets from a given rectangular area. The truck fills the area successively with rows of pallets. Carrying out subsequent runs, it uses lidar scanning the space in front of the truck to check the occupancy of pallet spaces.

04.2 Supervisory System - Multiple Vehicle Management

The Inovatica AGV supervisory system allows you to coordinate the cooperation of many AGV trucks working in the same process. The purpose of such coordination is to increase the throughput of a given process or increase its reliability.

This system also allows for the synchronization of many vehicles, it defines, for example, priority at intersections, or preventing another truck from maneuvering in the same zone as another truck to avoid mutual blocking and stopping by their safety systems.

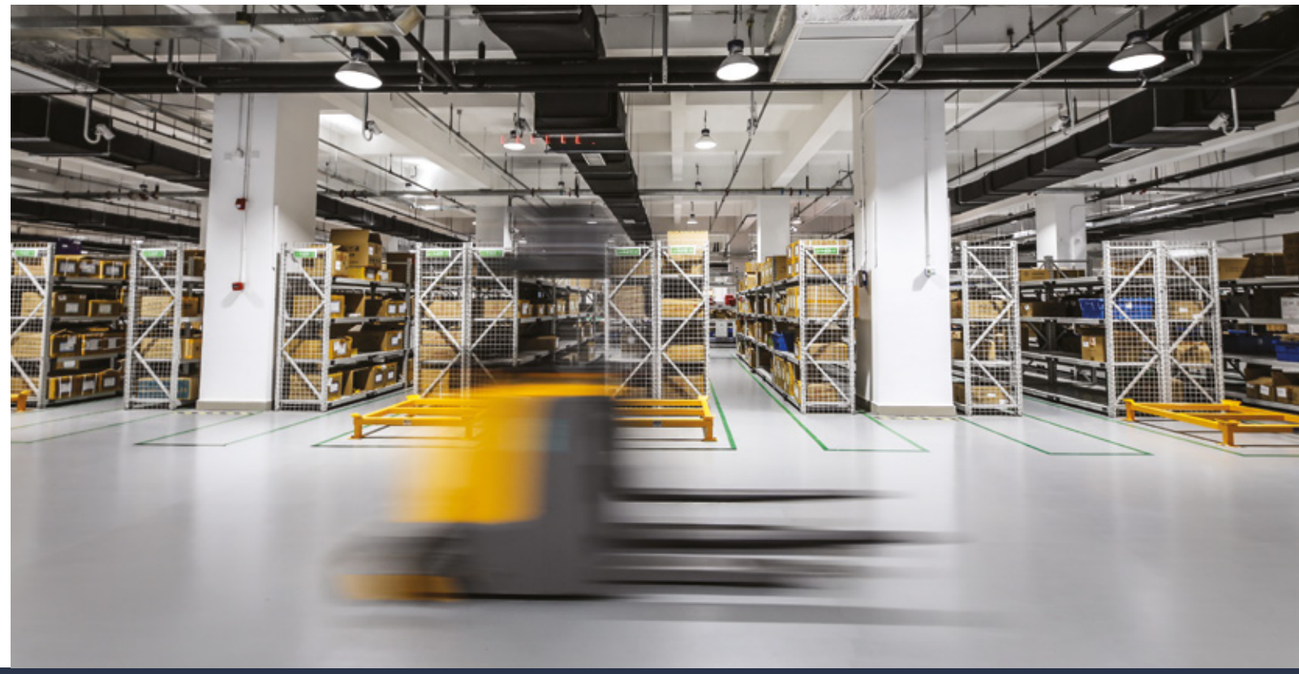
04.2.1 Increasing the throughput of the process

The use of multiple forklifts allows the process to be scaled horizontally. It often happens that a single truck is not enough to meet the need to transport goods within a given internal transport process. Then, the implementation of other autonomous forklifts into the process allows you to increase its capacity.
For example, in a model process for one of the real customers, one truck carries 10 pallets per hour, and two trucks transport 18 pallets per hour. The resulting increase in throughput is 80%.
The role of the Inovatica AGV supervisory system is the optimal assignment of orders to the available autonomous forklifts in order to achieve the maximum throughput of the process.

04.2.2 Increasing process reliability

The cooperation of many trucks in the internal transport process allows to increase the reliability of the entire process through redundancy and make it resistant to the failure of a single autonomous forklift. In the event of failure of one AGV or problems with the task, other robots can take over its functions to avoid blocking the entire process.

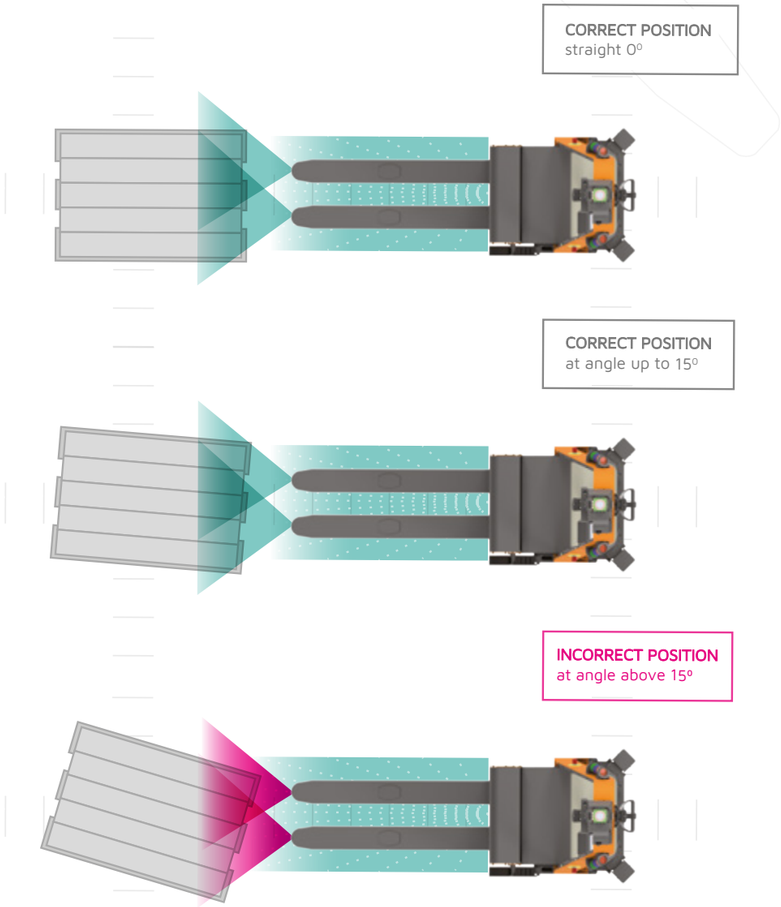
The role of the Inovatica AGV supervisory system is the optimal distribution of tasks so that the function of an inaccessible vehicle is taken over by another vehicle, thus ensuring the continuity of the internal transport process.

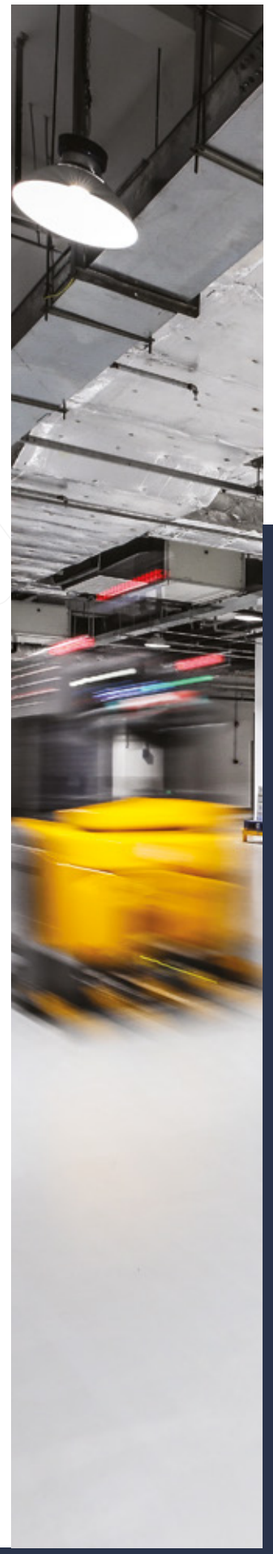


05 The process of picking up and putting away pallets

The process of picking up and putting down the pallet depends on the accuracy of locating the vehicle in space. Thanks to the precise location of the autonomous forklift, with an accuracy of 5 cm and an angle of 5 degrees, it is possible to carry out precise pallet operations such as picking up and putting down pallets.

The distinguishing feature of the Inovatica AGV technology is the ability to detect the position and turn of the pallets in a given pallet slot. For this purpose, the autonomous forklift has been equipped with dedicated laser scanner devices that allow the detection of such a pallet. In a situation where the pallet has been placed inaccurately in the pallet slot (turned even by 15 degrees), thanks to such detection, the autonomous forklift adjusts its driveway path to pick up a "biased" pallet. The detection system is also used to detect damaged pallets of irregular shapes, e.g. it informs about damaged vertical beams.



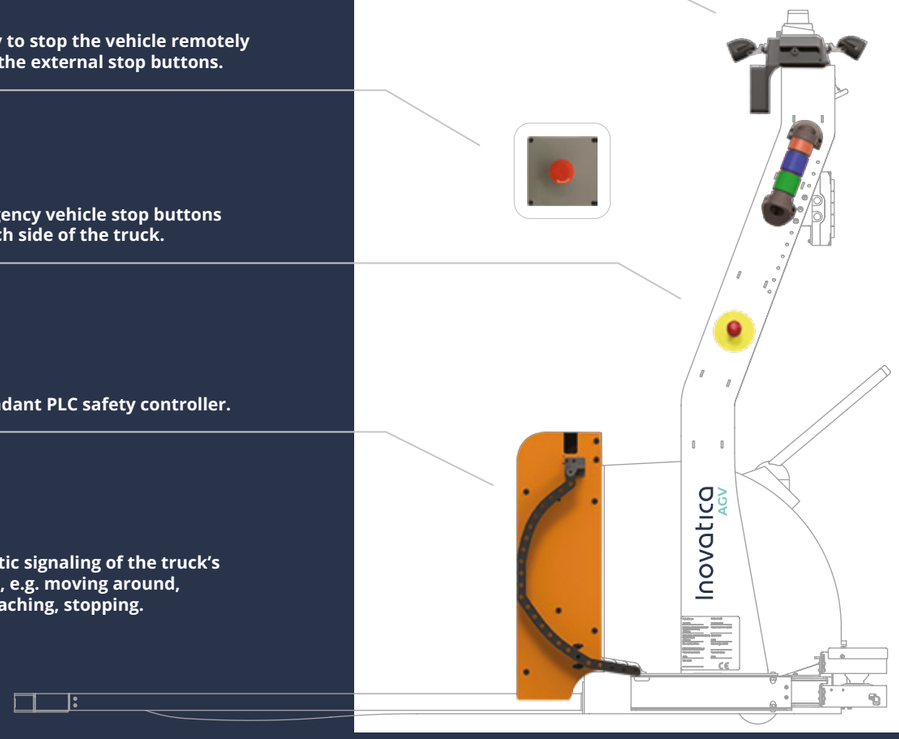


06 Safety systems of Inovatica AGV

Autonomous forklifts significantly reduce the risk of accidents and collisions. This is because work safety is an absolute priority. People working in the vicinity of the truck, the goods transported and the vehicle itself are protected by certified systems. The Inovatica AGV technology ensures high safety of use, among others by:

1 M.Fuskoa, M. Rakytaa, F. Manligb., „*Reducing of Intralogistics Costs of Spare Parts and Material of Implementation Digitization in Maintenance*".

- **360 degree surrondings monitoring by laser scanners, 3D cameras and ultrasonic sensors.**
- **Ability to stop the vehicle remotely using the external stop buttons.**
- **Emergency vehicle stop buttons on each side of the truck.**
- **Redundant PLC safety controller.**
- **Acoustic signaling of the truck's status, e.g. moving around, approaching, stopping.**



The product has a CE declaration and meets the requirements of the following directives:

- **2006/42/WE** Directive 2006/42 / EC of the European Parliament and of the Council of May 17, 2006 on machinery, amending Directive 95/16 / EC;
- **2014/30/UE** Directive 2014/30 / EC of the European Parliament and of the Council of February 26, 2014 on the harmonization of the laws of the Member States relating to electromagnetic compatibility (previously in force 2004/108/EC);

and meets the requirements of the following standards and harmonized standards:

- **PN-EN ISO 3691-4:2020-10** "Industrial trucks - Safety requirements, Part 4: Unattended industrial trucks and their systems";
- **PN-EN 60204-1** „Electrical equipment of machines - Part 1: General requirements";
- **PN-EN 61000-6-4** „Electromagnetic compatibility in the field of automation and industrial robotics";

06.1 Double safety system

The safety of using an autonomous forklift truck is based on 2 key pillars:

- Safety systems that are an integral part of the truck (hardware and software controlled);
- The cooperation of people with autonomous trucks, which has been described in more detail in the chapter on priority

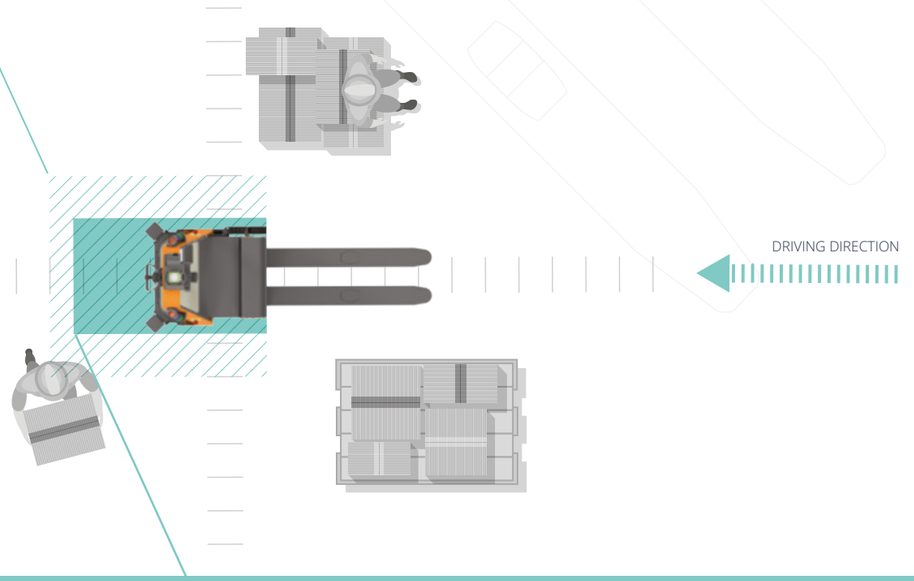
In order to meet high safety standards as well as legal norms, the Inovatica AGV autonomous driving system has been equipped with a double safety system. The redundancy of safety systems results from their characteristics and importance. These are systems of critical importance (mission critical systems) for the safety of users, as in the case of information systems used in aviation or nuclear power plants

Safety systems collect data from scanning the space around the truck. The space is divided into appropriate zones that are scanned by various types of devices/sensors. The devices, on the other hand, are supervised by two independent safety systems.

System supervised by Inovatica AGV software

The first safety system is a system supervised by Inovatica AGV software. This system monitors further zones around the truck, which are dynamically generated depending on the trajectory and speed at which the truck is traveling, as well as the activities performed by the truck.

Dynamic determination of safety zones



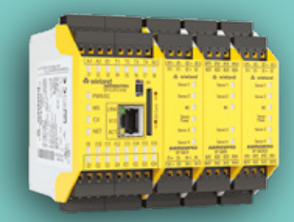
Hardware-controlled system

The second safety system is a hardware-controlled system, independent of the software that controls the autonomous forklift. The latter, redundant system is designed to prevent potential software failures of the truck. The components of the hardware supervised system are highly reliable components certified as SIL2 and PL(d). In addition, the „hardware" safety system monitors the zones closer to the truck, the violation of which causes absolute emergency stops of the vehicle (the system monitored by the software monitors further zones).

Redundant PLC safety controller.

Safety Integrity Level

- SIL2 i PL(d).
- PL(d) - od 10-7 do 10-6.
- SIL2 - 100-1000.



06.1.1 Safety system supervised by software

The safety system monitors further zones around the truck, which are generated dynamically depending on the driving trajectory and speed of the truck. Thanks to the use of a safety system supervised by the software, a smoother ride of the truck is possible, i.e.:

- The gradual slowing down of the truck in front of an obstacle depending on the speed of the truck. If the truck is moving at high speed, the safety system software extends the safety zones, which causes the truck to slow down gradually in front of the obstacle and shortens the zones at low speed.
- Driving of the truck in close proximity to an obstacle when the obstacle is not on the expected path of the vehicle. The software of the autonomous forklift truck generates predictive zones in which the vehicle will be located in the future. On the basis of such designed zones, it only protects the space that will be in front of the vehicle, and allows to smoothly pass objects not being on the path of the truck.

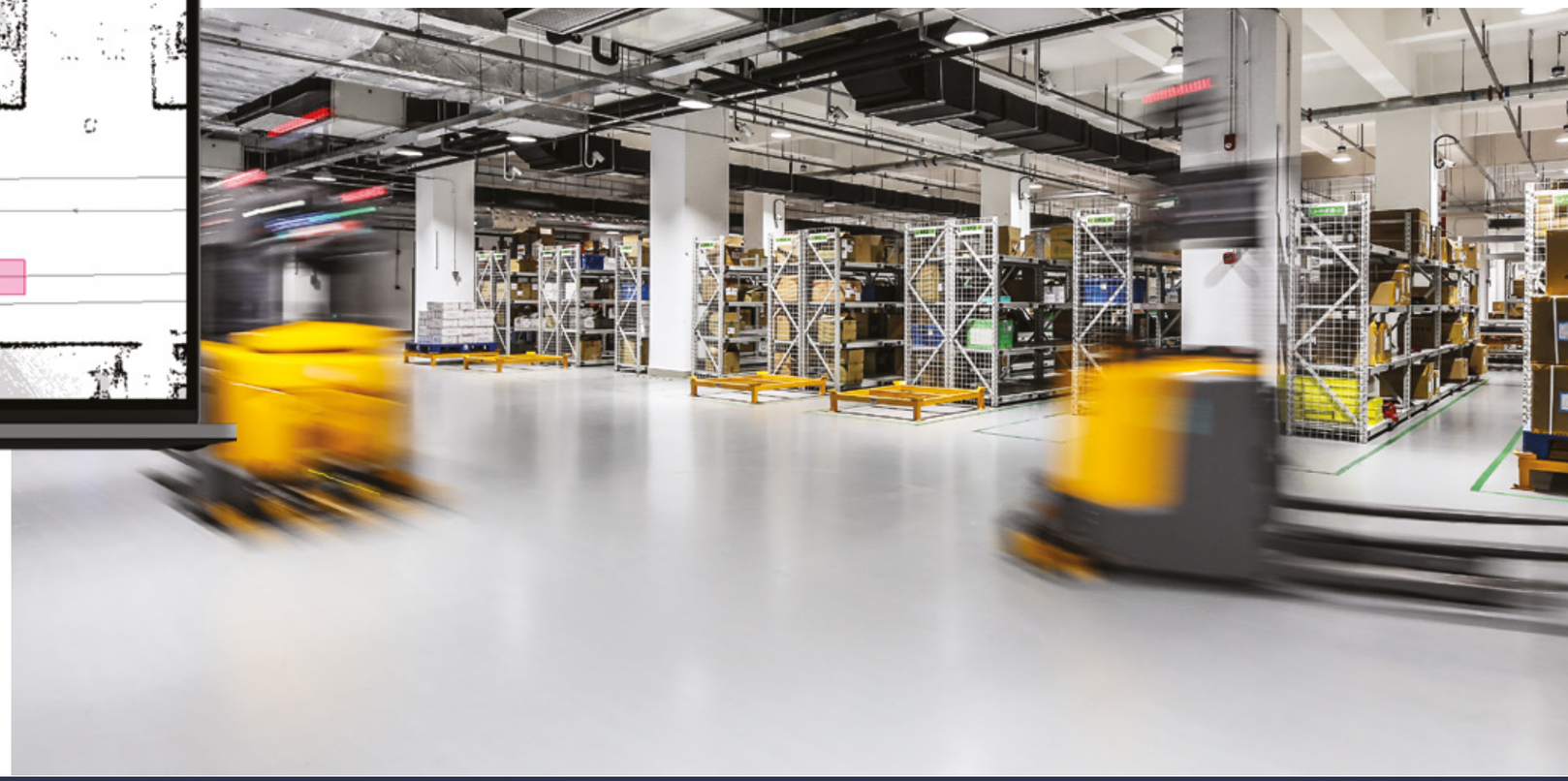
The main difference between a software-supervised system and a hardware-supervised system is that the system is predictive, allowing a smooth ride, while an activated hardware system causes an emergency stop every time.

06.1.2 Hardware supervised safety system

This system is critical to the safety and operation of an autonomous forklift truck. It is independent of the software-controlled system, also in terms of defining and protecting separate safety zones. The monitored area around the truck is smaller than that supervised by the software, but its operation is fully certified. The obstacle detection range is up to approx. 5 m in front of the truck in the default direction of moving and up to 30 cm along the sides of the truck. Pressing one of the safety buttons on the truck also causes immediate braking to a halt.

The hardware system consists exclusively of highly reliable components that meet the SIL2 (Safety Integrity Level) and PL(d) (Performance Level) standards. We explain both abbreviations more fully in the Glossary at the end of the document. In addition, the system is subject to external audits, which mitigates the risk of incorrect operation. The system is based on a PLC which stops the vehicle in the event of violation of the hardware supervised zones.

The fundamental difference between a hardware safety system and a software safety system is that the hardware system is certified. Its activation causes emergency braking every time (these are situations of direct threat to life or health). After an emergency stop with the safety button, the operator must manually confirm that the hazard has been removed and that further work is possible. If, on the other hand, the truck has stopped on its own as a result of detecting a person or objects in the monitored zone, it will also start to move on its own after the obstacle is removed.

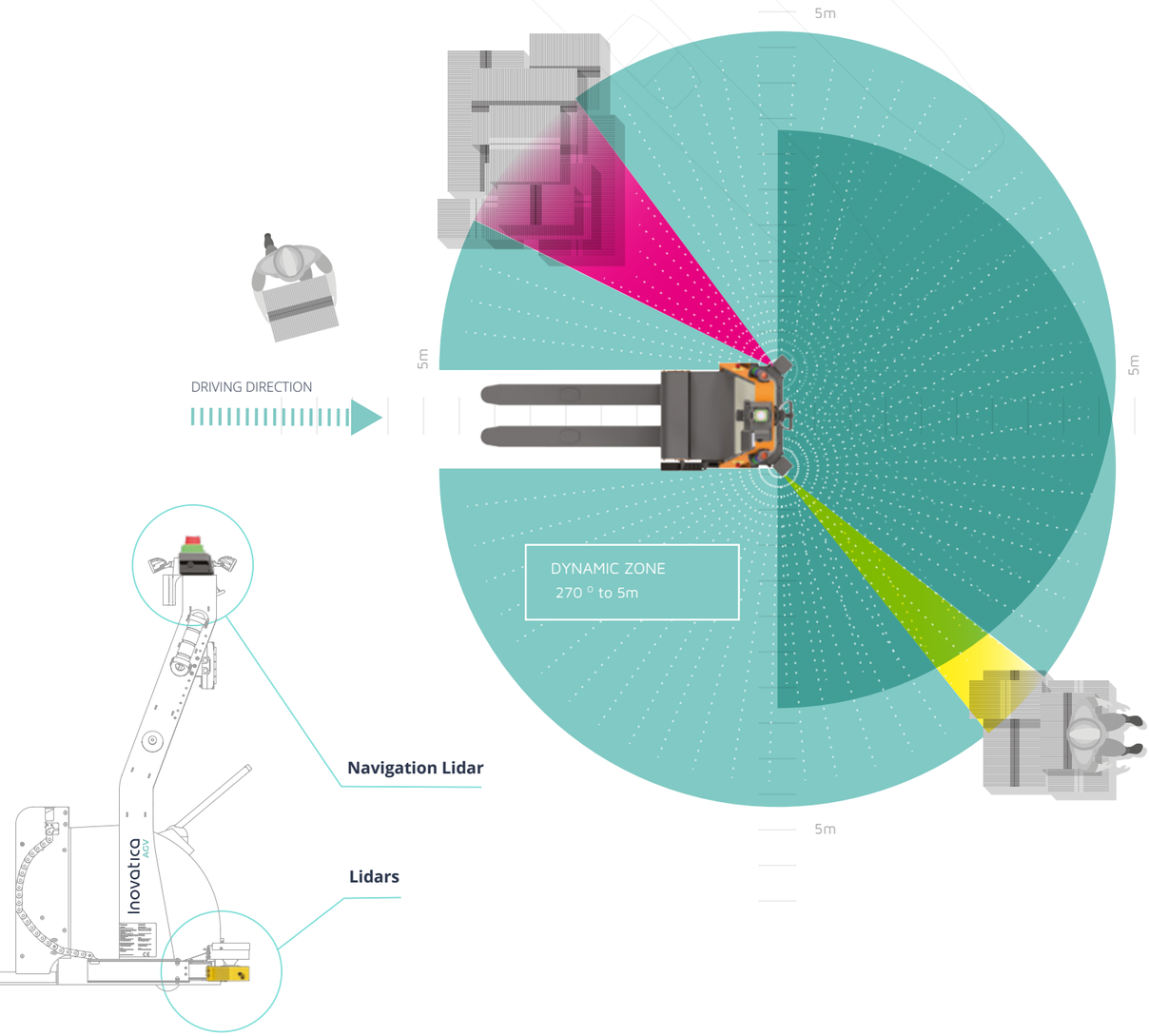


06.2 Protected zones

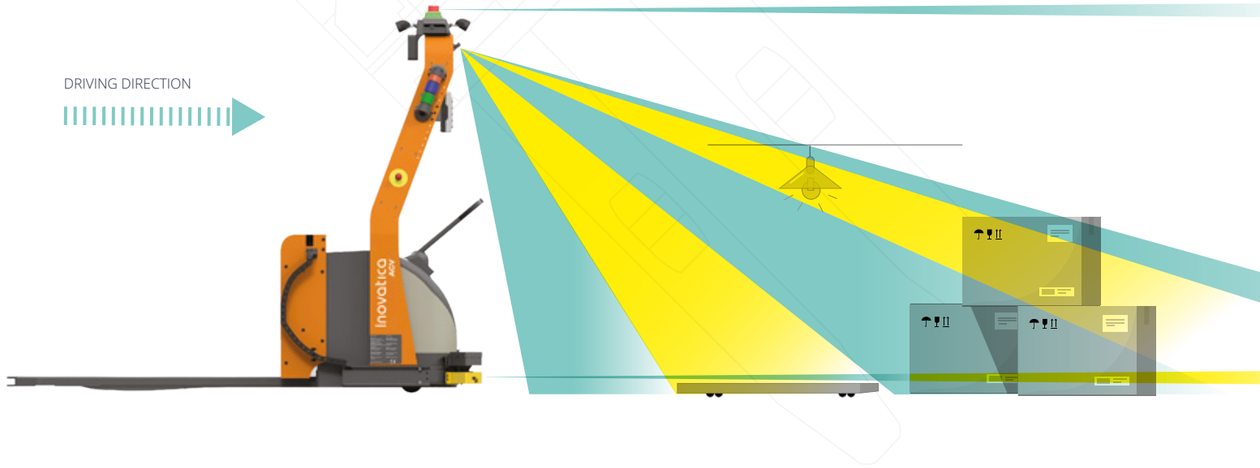
Sensors transmitting data for both safety systems allow you to protect the working space of the truck in many spatial zones:

Zones scanned by a 2D laser above the truck at a height of 2.2 m. The system is designed to detect obstacles in the plane above the truck, e.g. chains hanging from the crane.

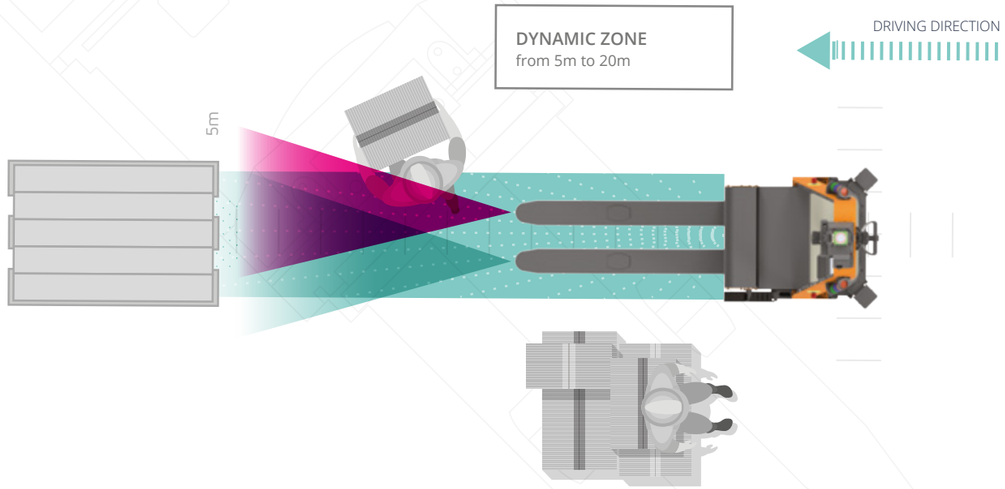
Zones scanned by 2D lasers monitor the plane 5 cm above the ground. They cover the area in front of the truck in the direction of driving, as well as next to the truck.



3D scanning zones supervised by 3D cameras. 3D cameras installed on an AGV monitor the „blind spot" area that is not supervised by 2D scanners, for example, a protruding towbar from the side or the forks of another forklift located more than 8 cm above the ground.



3D spatial zones in front of the forks. Sensors on the top of the forks are primarily used to monitor safety zones that may be temporarily invisible to other sensors. They are an additional complement to increase the three-dimensional protected areas, especially when the truck is maneuvering with pallets that reduce the visibility of other sensors.



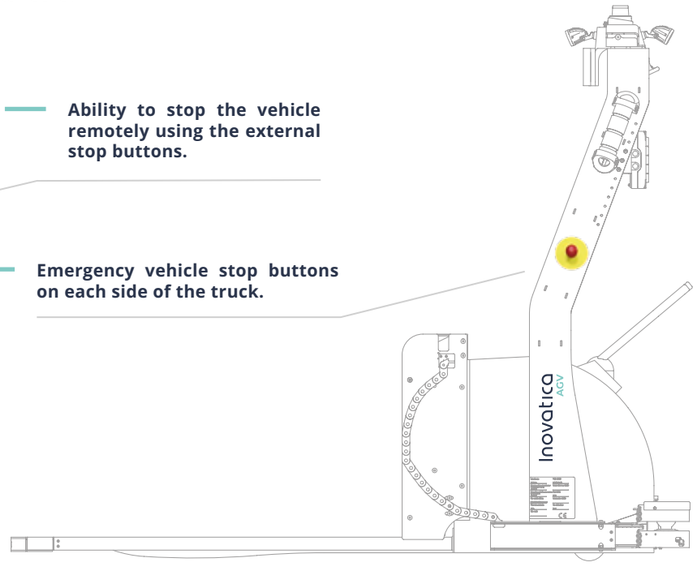
06.3 Emergency stop buttons

The emergency stop command may be given by the emergency stop button set. These buttons are mounted on the frame/body of the truck. Additional stop buttons can be installed in fixed places in the hall. Pressing the safety button starts the truck emergency braking.

Safety button panels used to stop the truck's operation are made in the form of industrial housings with safety buttons placed on them, also in the industrial standard.

Ability to stop the vehicle remotely using the external stop buttons.

Emergency vehicle stop buttons on each side of the truck.

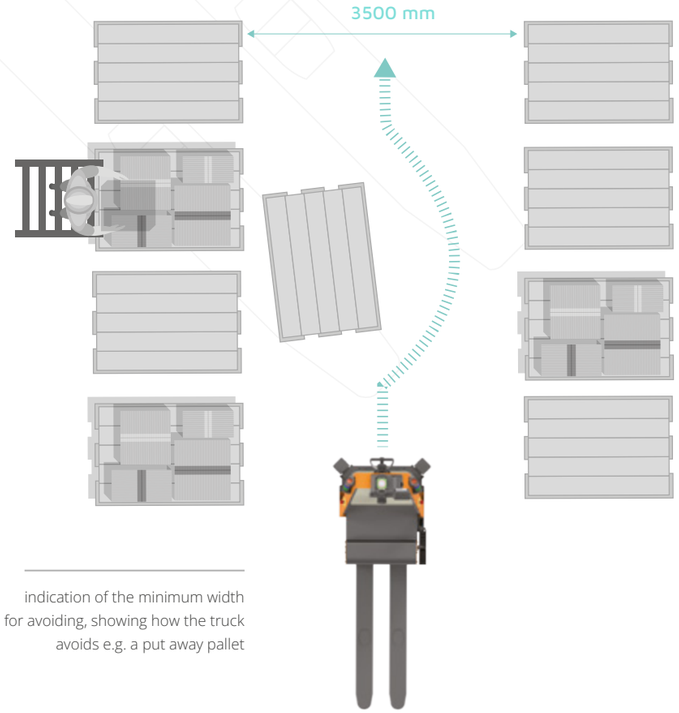


06.4 Avoiding obstacles

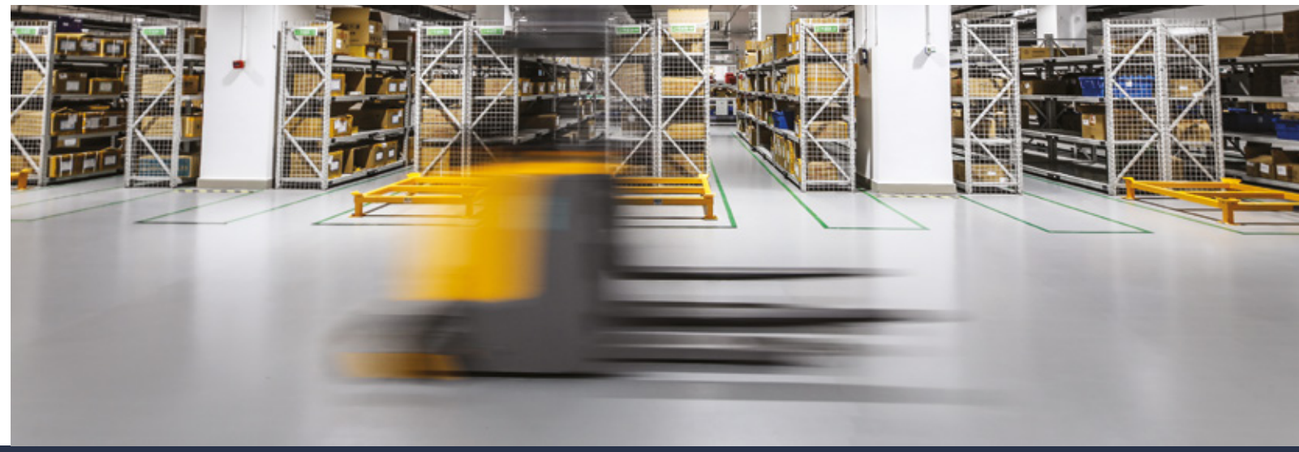
Inovatica AGV trucks move along predefined routes. In addition, route segments can be marked by the operator in the system as such, on which an autonomous truck can avoid an obstacle. The avoidable segment of the route must not be narrower than 3.5 m. After completing the maneuver to avoid the obstacle, the truck returns to its previously planned route.

Inovatica AGV vehicles which detect an obstacle on their route implement the following scenario:

1. **Reducing the speed**
2. **Stopping if the obstacle is not removed**
3. **Light and sound communication calling for the removal of the obstacle**
4. **Avoiding an obstacle if the route has been assigned the avoidance attribute**
5. **Continuing to follow the route.**



indication of the minimum width for avoiding, showing how the truck avoids e.g. a put away pallet



07 Implementation of Inovatica AGV vehicles

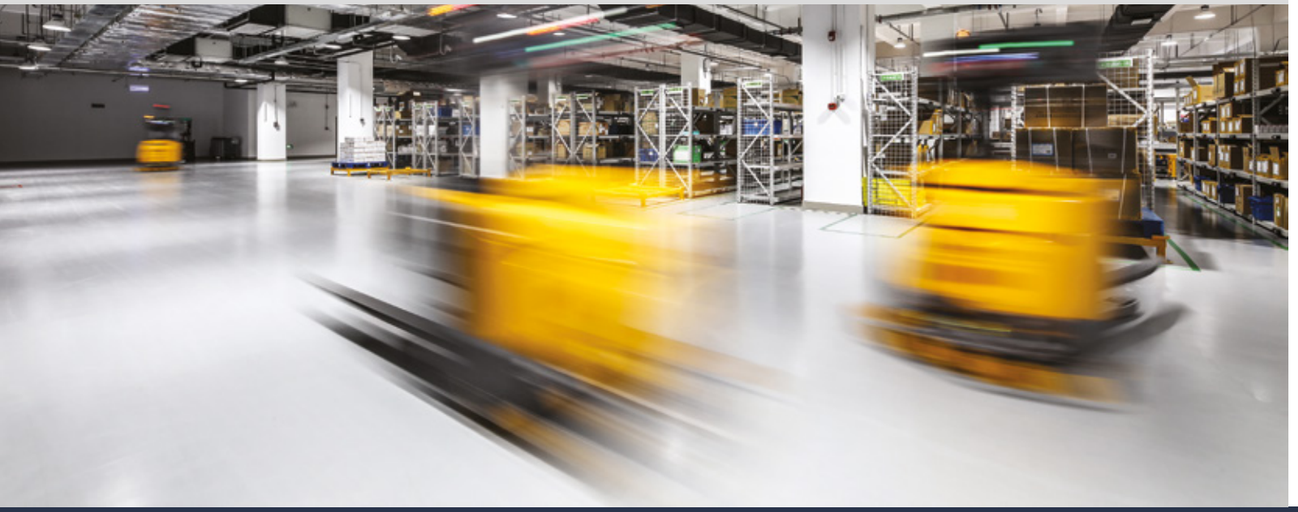
AGV truck task management

The AGV truck during the performance of tasks uses the map of the facility prepared during the implementation. It contains all the pallet pick-up and storage areas, paths, parking spaces, charging/battery rooms available for the truck.

Autonomous work

Operators responsible for AGV vehicles in the hall should initially undergo training in the field of safe human-robot cooperation and the use of each functionality. Only with the appropriate knowledge, they can start assigning tasks to the robot. The operator has the option of:

- **Establishing driving routes for the truck.**
- **Optimization and correction of already entered routes.**
- **Indication of the places where pallets are picked up and deposited.**
- **Determining parking spots, battery charging and other.**
- **Defining tasks to be performed by the truck and combining them into diagrams.**



07.1 Preparation of a map of the truck's working environment

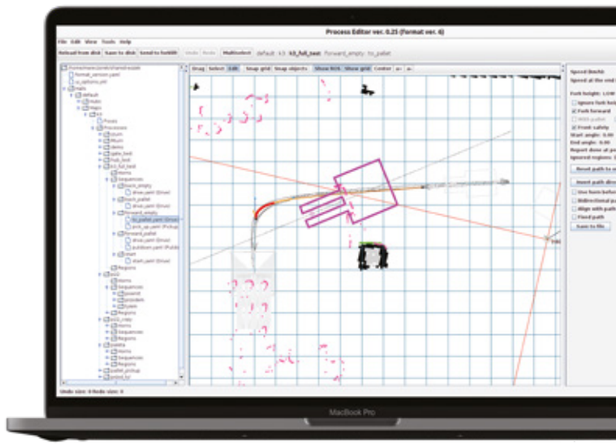
The autonomous Inovatica AGV truck is positioned on a previously prepared map of the work environment of the truck. This map is generated in the process of the so-called mapping, i.e. driving in manual mode with the mapping mode turned on in the working environment of the truck. A single trip is enough for the truck to collect scans of the surroundings and, on the basis of these scans, create a virtual map of the surroundings which is the basis for future positioning in the hall space.

07.2 Defining the paths of the truck's movement

The operator defines the paths of the autonomous forklift. These paths can be determined in two ways:

- Driving the truck in manual mode in the route recording mode. Then the paths of the truck are created on the basis of the truck's tracks, which are reproduced in digital form in the software for managing the fleet of trucks. Recorded tracks can be further edited in software for defining the processes.
- Drawing the paths on a map in software for defining the processes. Drawing these paths is similar to creating curves in popular graphics programs.

Defining of the paths is performed in software for defining the processes (the software is deliverde with the Inovatica AGV trucks).



07.3 Defining attributes of paths

The operator assigns the appropriate attributes of movement to the previously defined paths, i.e.:

- speed of movement on a given path
- permissibility of an avoidance/omission on a given path
- unidirectional/bidirectional way
- the height of the forks when traveling along a path

07.4 Defining process points

The operator determines the so-called process points on the map, i.e. points necessary in the context of defining intra-logistic process, i.e. places/spots of:

- putting away pallets
- parking lot
- picking up pallets
- truck starting point
- battery charging
- emergency stop buttons

07.5 Defining the intralogistic process

On the basis of previously determined elements, the operator starts defining the intralogistic process by creating transport tasks, and then arranging them in a sequence (possibly looping), adding the logic of appropriate triggers of a given process.

Software for defining the processes supplied with the Inovatica AGV truck system allows you to create tasks from the simplest activities to complex processes, e.g.

- Defining tasks, e.g. picking pallets from the warehouse and transporting them to a specific place in the production part of the plant.
- Combining simpler tasks into complex sequences to be carried out by the robot, e.g. “take the pallet from point A to point B, and then go to the foliar pallet in point C and put it back in warehouse D”.

In addition, the software allows you to define process priorities, as well as strategies for cooperation of multiple trucks, referred to in the section on the fleet management system.

08 Battery change

The truck monitors the battery charge level. In the event of a low battery condition requiring replacement of the battery, the truck first puts down the possibly transported load. Then it goes to the designated battery exchange area or to the battery room.
Replacing the battery consists in taking the discharged battery out of the truck onto the roller table, then connecting the charged battery with the extension cord, moving the truck under the table slot with the charged battery and placing it in the truck’s chamber. The last step is to disconnect the extension cord and plug the charged battery into the truck slot. The discharged battery should be charged using the charger provided in the set.

The operating time on the supplied battery is expected to be 8 hours of continuous operation and depends on the driving speed, number of maneuvers, and the weight of loads. The battery charging time is expected to be approx. 3-4 hours.

09 What is needed to implement an autonomous forklift truck?

The implementation of an autonomous forklift truck requires appropriate preparation from the customer. The following are necessary:

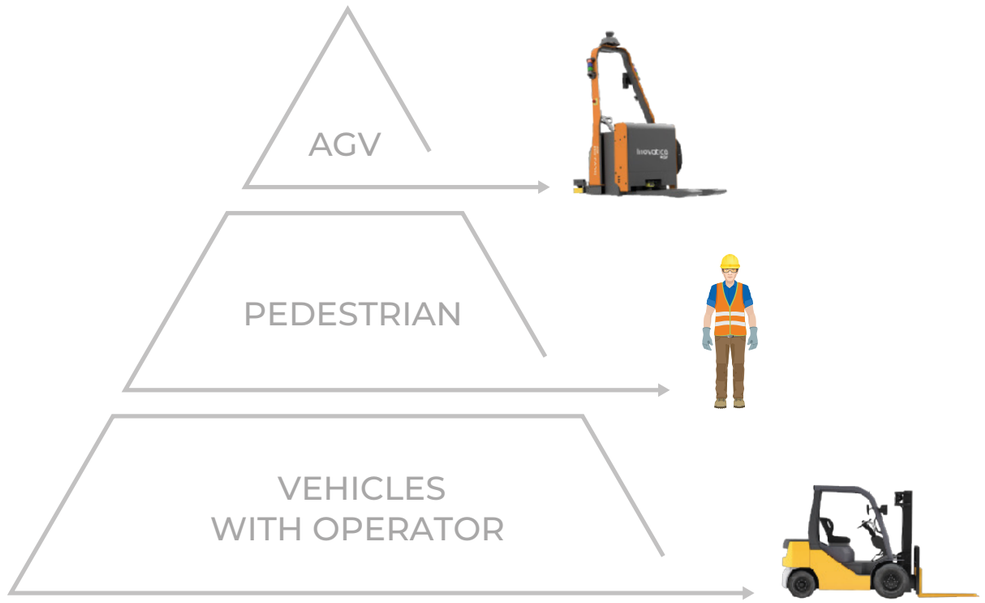
- Determining what internal transport processes we want to entrust to AGV service. They should be repeatable, predictable, allow to be included in a pattern that will then be mapped as a list of tasks for the robot.
- Providing a WiFi network in the area of the truck’s operation. For the correct operation of the AGV truck, communication with external infrastructure elements is required, for example integrated sensors for pallet pick-up/storage and safety systems.
- Preparing dedicated places in the hall:
  1. a place for charging and replacing batteries;
  2. at least 1 starting / parking space for each AGV truck;
  3. setting up routes in a manner that is safe for the surrounding.

In all of the above issues, the customer can count on the support of the Inovatica AGV engineering team.

10 Principles of operation of autonomous forklifts

10.1 Right-of-way rules

The rules of traffic in the hall, allowing for the highest possible safety and efficiency, assume that AGVs are given priority over pedestrians and other vehicles. This is due to the large safety buffer that accompanies AGVs, for which each, even potential collision risk, means a speed reduction or a stop. In addition, AGVs moving along strictly defined routes have a much more limited room for maneuver compared to other road users.



11 Construction of the forklift

Autonomous Inovatica AGV forklifts are made on proven constructions from reputable manufacturers. Thanks to this, the customer can be sure that the construction of the truck is solid, proven, and the product itself will be operational for years.
The production process of AGV trucks consists in the implementation of a new technology into an already existing device. A traditional truck is fitted with a dedicated frame with electronics responsible for navigation and communication. There are laser scanners located in the lower housing. On the other hand, at the front of the truck there are: a control cabinet containing an on-board computer, a safety system, a power backup system, and network connectivity devices. The final step is to upload the appropriate software that allows you to turn a traditional truck into a modern robot.

Navigation Lidar

For mapping and locating the forklift in the working area.

3D camera

Monitors the space in front of the moving truck.

Body

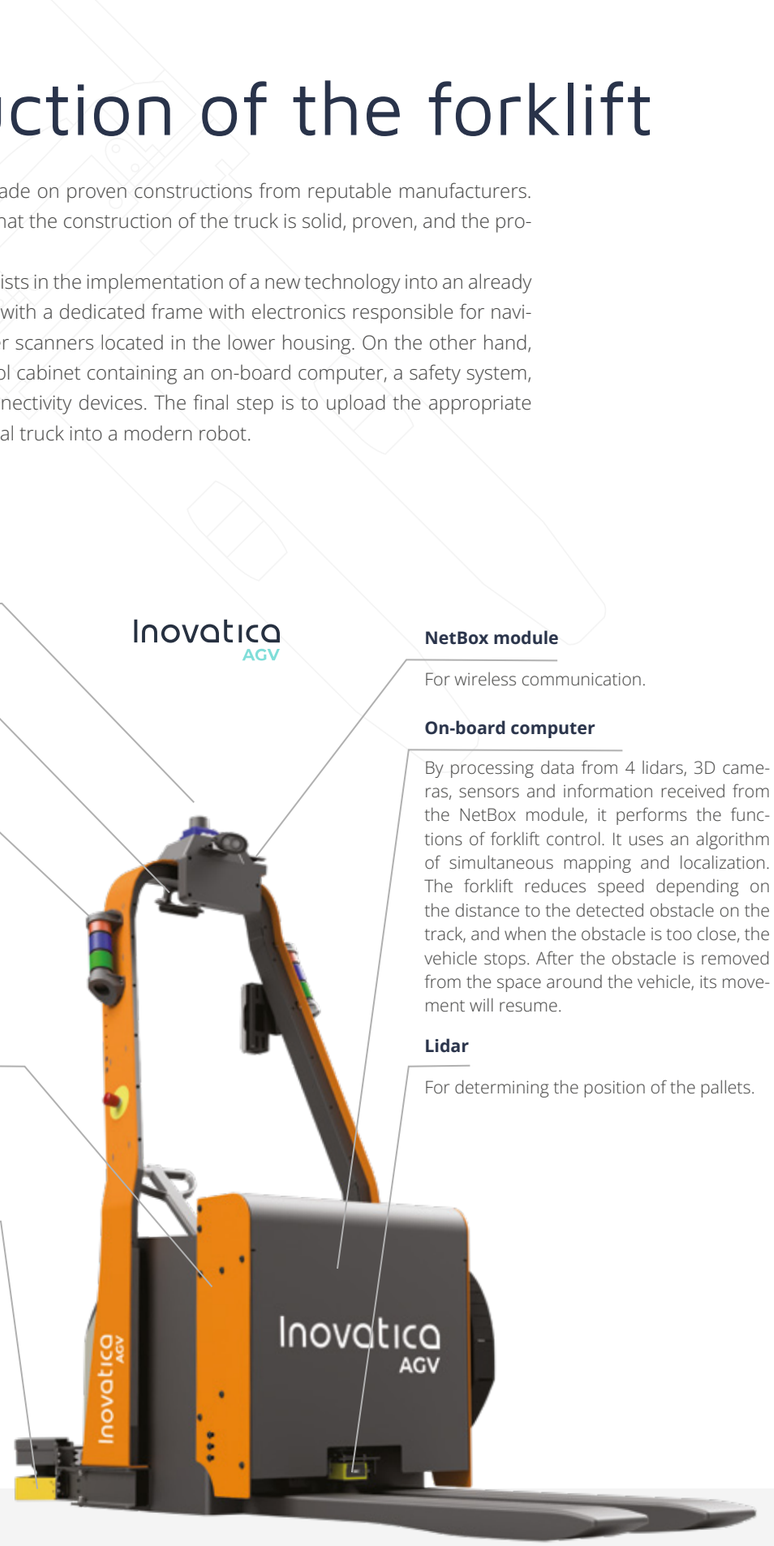
Containing the battery, motors and sensors responsible for the movement of the vehicle and the operation of the forks.

Frame

Frame mounted to the body. Lights, antennas and electronics necessary for autonomous operation are attached to the frame.

Lidars

All lidars (4 pcs.) scan the space around the forklift and also fulfill the safety function, detecting obstacles on the vehicle's path.



NetBox module

For wireless communication.

On-board computer

By processing data from 4 lidars, 3D cameras, sensors and information received from the NetBox module, it performs the functions of forklift control. It uses an algorithm of simultaneous mapping and localization. The forklift reduces speed depending on the distance to the detected obstacle on the track, and when the obstacle is too close, the vehicle stops. After the obstacle is removed from the space around the vehicle, its movement will resume.

Lidar

For determining the position of the pallets.

Signal lights

Three-position signal lights with an audible siren informing about the current state of the forklift. The sirens can, for example, inform about a low battery level, wireless communication status, obstacle on the track or other events and the technical condition of the vehicle.

Safety button

At least two safety buttons are placed on the frame for the purpose of emergency stopping the vehicle in the event of any danger, for example, a collision with another object or stopping a forklift truck, preventing it from being accidentally started. The truck includes a certified safety controller that acts as a safety system independent of the on-board computer.

Pendant station

Transport forks

Inovatica AGV truck can be equipped with standard length or extended forks to transport two pallets. It is also possible to equip the truck with forks for transporting goods on a roll.

Touchscreen

The screen with the user interface allows you to check the current status of the truck and / or the task in progress. In addition, the touch screen allows you to make changes to the tasks assigned to the truck.

Lidars

Scanning the space in front of and on the sides of the truck.

LEFT SIDE

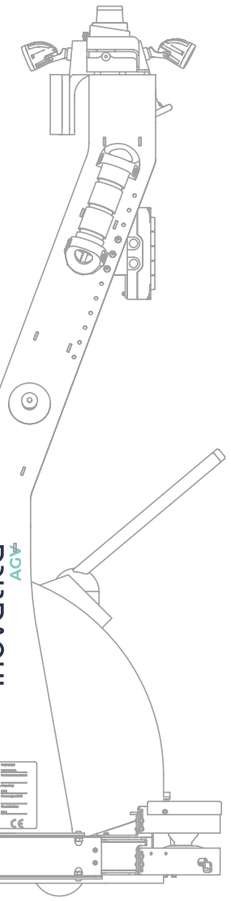
BACK

RIGHT SIDE

FRONT

11.1 Technical Specifications

	Capacity (at 600 mm nominal load center)	1900 kg
	Mast type:	frame
	Motor	Electric 4.0 kW
Available types of forks:	Straight forks (for pallets, pallet boxes)	working length in the range of 95-240 cm
	Prism forks (for paper rolls, etc.)	roll diameter: 55-150 cm working length: 125 cm
	Fork height	85 mm
	Initial lifting of the forks	125 mm
	Fork working length	1200 mm
	Carriage ground clearance	30 mm
	The width of the truck	1250 mm
	The height of the truck	2150 mm
	Front / rear tires	Vulkollan
	3D camera	YES



12 Frequently asked questions (FAQ)

12.1 Navigation and control

12.1.1 Does the technology require the installation of mirrors/magnetic tapes in the area where the truck moves?

No. Autonomous forklifts using SLAM laser navigation do not require any interference with the infrastructure to correctly locate and navigate in the hall.

12.1.2 What is the accuracy of laser navigation at Inovatica AGV.

The accuracy of laser navigation is 5 cm and 5 degrees.

12.1.3 Does laser navigation require additional service?

Yes. The service consists in wiping the glass of the lasers. Clean lidar covers are required for correct and safe operation. This activity is foreseen once per shift.

12.1.4 Does laser navigation require additional hall lighting?

For proper operation, laser navigation does not require visible light. This means that the truck can also be operated in complete darkness.

12.1.5 Can autonomous forklifts be used to load and unload trailers?

Currently, it is not possible due to the too small working area of semi-trailers or load boxes in delivery trucks. These are too small spaces for the AGV to maneuver freely in them. We conduct research and development works that will allow us to bypass this limitation in the future.

12.2 Battery change

12.2.1 What is the truck operating time per battery cycle?

8 hours of work, but it is worth remembering that the operating time of the truck is influenced, among others, by the weight of the pallets transported and the distances covered. So the actual battery life may be slightly shorter.

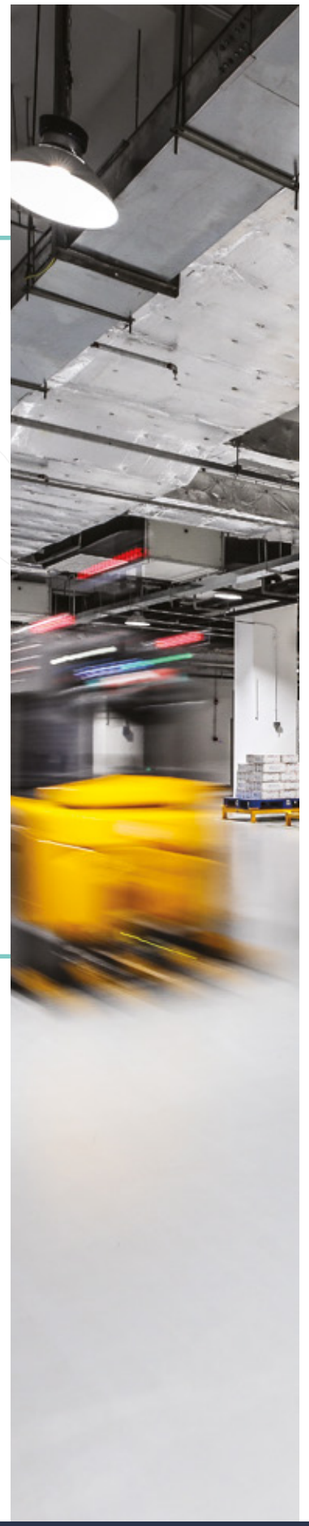
12.2.2 How long does it take to charge the battery?

Lead-acid and gel batteries charge up to approx. 4 hours and require great care during handling. It is also necessary to provide a room with appropriate dimensions and air circulation. In addition, in order not to reduce the efficiency of the battery, it should be charged only when it is about 20% charged.

Lithium-ion batteries, although more expensive, have many advantages. Their charging time is less than 2 hours. Importantly, when tilting the battery, there is no risk of leakage of any substance, and the battery can be recharged almost at any time.

12.2.3 How long does the battery replacement process take?

The hall staff trained in the operation of the AGV truck changes the battery within 15 minutes or less.



12.3 How soon the AGVs are ready to go.

If the map and the process are prepared, the implementation of the truck takes several minutes. The preparation of the map depends on the size of the hall and takes up to several hours. However, preparation of the process takes up to several weeks. Therefore, direct implementation is preceded by a pre-implementation analysis, during which, together with the client, we plan what processes should be entrusted to AGV trucks, where they will be parking, charging, their travel routes, etc.

12.4 Safety

12.4.1 Does the safety system detect objects located on the ground below 5 cm, e.g. forks of other trucks?

Yes, the safety system detects such objects where the forks of other trucks are a special case.

12.5 Intralogistic processes

12.5.1 What happens when an autonomous truck has no transport tasks?

Then the autonomous truck goes to the parking lot awaiting the next tasks.

12.5.2 What happens when an impossible task has been sent to an autonomous forklift truck, e.g. putting a pallet in an occupied pallet slot, i.e. one in which a pallet has already been put away?

The behavior of the truck depends on the adopted strategy of conduct, which is determined at the stage of pre-implementation analysis with the client. In this situation, for example, the truck can drive to the parking space and signal the impossibility of completing the mission by activating the appropriate signaling in the signaling column.

12.6 Connectivity

12.6.1 Is WiFi coverage required for the entire hall?

No, there is no such need. For the truck to work, it is not necessary to cover the entire working space of the truck with a WiFi network, but it is recommended. It is essential to cover the truck's parking area with wireless connectivity. When the truck completes all the scheduled tasks, it goes to the parking space and waits for the next tasks, which are sent to the autonomous truck via wireless means.

12.7 Return on investment

12.7.1 What is the expected return on investment for an autonomous forklift truck?

The expected return on investment is less than 24 months for three-shift work, taking into account the average earnings of forklift operators based on payroll reports in Poland.

12.8 Service

12.8.1 Is vehicle maintenance provided after the AGV start-up process?

Yes. As part of an additional contract, maintenance and post-warranty services are provided, as well as periodic maintenance inspections.

Glossary

Lidar/laser scanner

The name lidar comes from Light Detection and Ranging and reflects well the way the device works. Lidar illuminates the surroundings with laser light and, on the basis of the obtained reflection, generates a two-dimensional model of what is around. The distinguishing features of the lidar are independence from lighting conditions, high precision of up to 2 cm and lower production costs. Factors that reduce the efficiency of the lidar are high smoke or dirt on the glass housing.

Laser navigation, the so-called LGV (short for laser-guided vehicles)

Currently, it is the most accurate indoor navigation. It is based on the use of lidars that collect and analyze laser light reflected from the surrondings, creating a virtual map. This solution is more accurate and more resistant to measurement errors than navigations based on infrared sensors, gyroscopes or cameras analyzing the image.

SIL2 (Safety Integrity Level) and PL(d) (Performance Level)

SIL is the Safety Integrity Level. Whereas PL (Performance Level) stands for Integrity Assurance Level.
Both are parameters that define the safety level of machines in the context of their control systems. SIL levels are determined by electrical and electronic safety systems, and PL levels also apply to pneumatic, hydraulic and mechanical systems.
The SIL2 category means over 100 to 1000-fold reduction in the risk of a hazardous situation. On the other hand, category PL(d) means the probability of occurrence of a dangerous situation per hour, ranging from 1/10 000 000 to 1/1 000 000. The assessment of the risks of a given dangerous situation and the methods of reducing them are carried out already at the design stage of AGVs.

Products Inovatica AGV

Autonomous forklifts

Inovatica AGV autonomous forklift technology is extremely flexible. Thanks to this, it can be used in forklifts of almost any purpose. Below are the models that are already developed and available to customers.

Inovatica AGV **Single**

Load: **1900 kg** | Capacity: **1 pallet** | Motor: **electric**

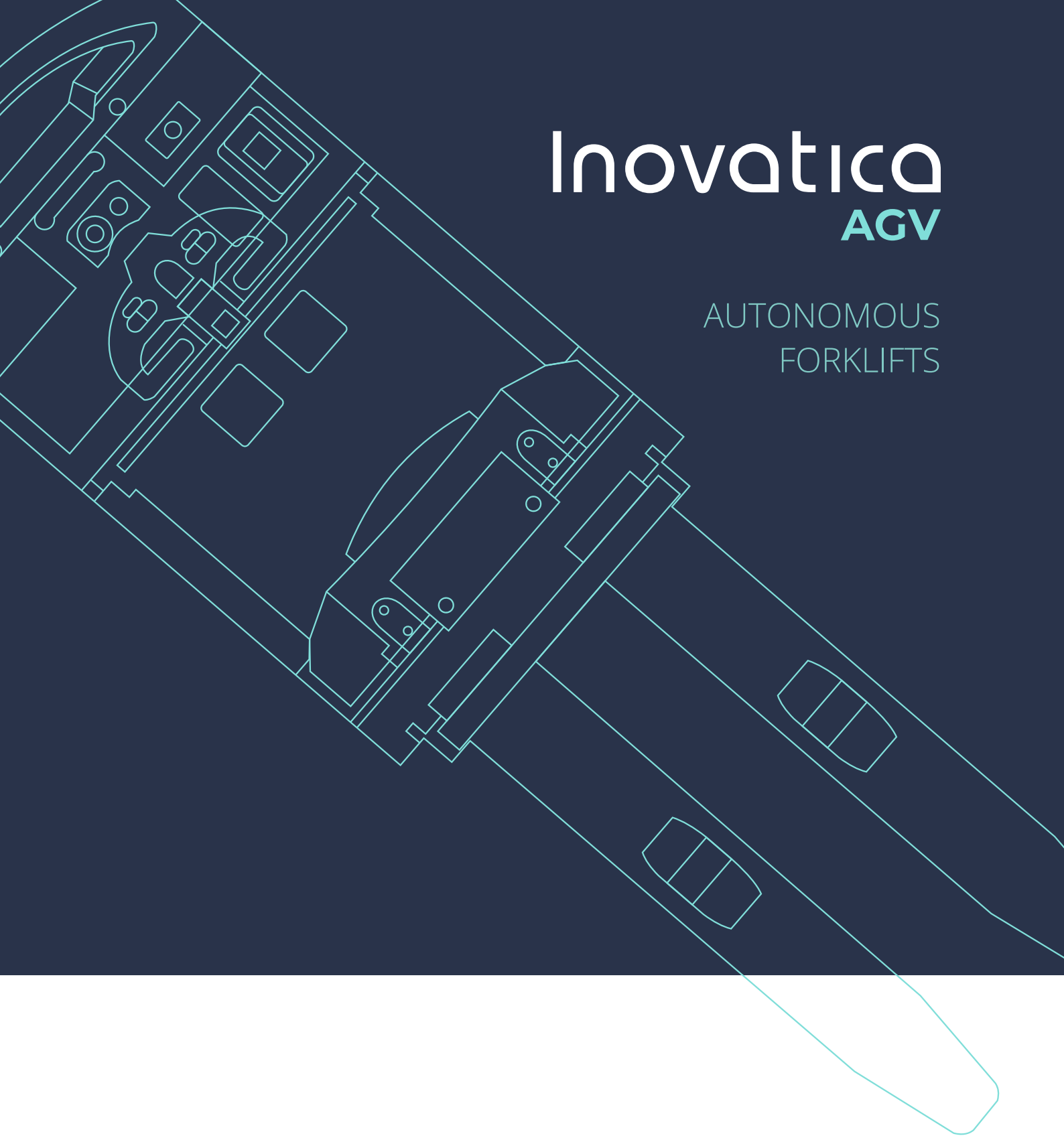
Inovatica AGV **Double**

Load: **1900 kg** | Capacity: **2 pallet** | Motor: **electric**

Inovatica AGV **Custom (special purpose)**

Load: **1900 kg** | Capacity: **1 roll** | Motor: **electric**

Inovatica AGV
agv.inovatica.com



Inovatica AGV

AUTONOMOUS FORKLIFTS

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Do you have additional questions?
Contact us, we will find a solution.