

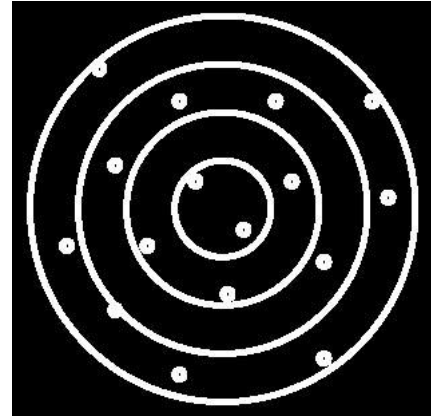
Indoor Positioning System

(with $\pm 2\text{cm}$ accuracy)

For autonomous vehicles,
robots, drones, forklifts
and humans



Problem to solve



Problem

- GPS does not work indoor:
 1. no direct view to satellites
 2. location precision is measured in meters rather than in centimeters (required indoor)
- Other indoor navigation systems - UWB, **Bluetooth beacons**, odometry, magnetometers, WiFi RSSI, laser triangulation, optical, etc. - have their own serious limitations - usually, either precision, or price, or size
- Without precise and timely knowledge of location, autonomous navigation is impossible

Solution



- Off-the-shelf ready-to-use indoor positioning system based on stationary ultrasonic beacons united by radio interface in license-free ISM band
- Location of a mobile beacon installed on a robot (vehicle, drone, human) is calculated based on the propagation delay of ultrasonic signal to a set of stationary ultrasonic beacons using trilateration

Indoor “GPS” ($\pm 2\text{cm}$)

- Starter Set configuration:
 - 1 mobile beacon – 129 EUR
 - 4 stationary beacons – 4*129 EUR
 - 1 modem/router – 129 EUR
 - All required SW included



Ready to use 3D (x, y, z) system for 599 EUR

Starter set covers up to $1,000\text{m}^2$

Get additional beacons to expand to $200,000\text{m}^2$ and beyond

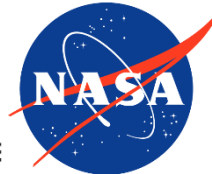
Selected customers

Customers in 50+ countries

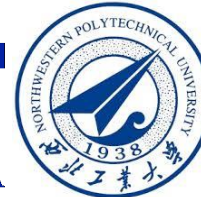
8+ years on the market



PORSCHE



MOTOROLA
SOLUTIONS

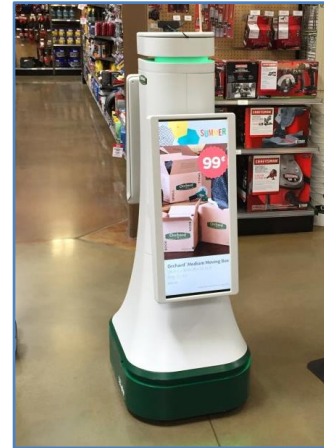


Use case: Autonomous robots



- 1) Automatic delivery (10-100kg) in warehouses and assembly plants
- 2) Modified versions for customized applications: scanning, spraying, inspecting, photometry, different types of repetitive measurements

Advertising robots with high-tech charm - shows, shopping malls, conferences, museums



Micro-delivery (1-10kg) in industrial environment: samples, gauges, cameras



Use case: Autonomous drones



Autonomous indoor drones
for inventory management
and inspection

Use cases: Vehicles

Use case:

- Tracking vehicles, buggies, trolleys, forklifts and other mobile assets in warehouses, in passenger and cargo areas of airports, in tunnels and mines

Problems solved:

- Accidents: collisions and speeding
- Broken equipment and goods
- Lost or underutilized mobile assets

Benefits:

- Precise knowledge of who is doing what and where => productivity increase
- Real-time data about speed, acceleration, position of the mobile assets => productivity increase
- Preventing accidents and decreasing insurance and other avoidable costs



Use cases: People

Tracking workers' location in factories, underground, in metro or tunnels, on construction sites, railways stations or under bridges

Use case:

- Underground / mining / metro
- Construction sites
- Factories
- Dangerous manufacturing
- Oil refineries and gas companies



- Increasing productivity
- Improving safety

Safety with working cranes and people

Mobile geofencing zone on crane boom

Ind Super-



Super-Modem



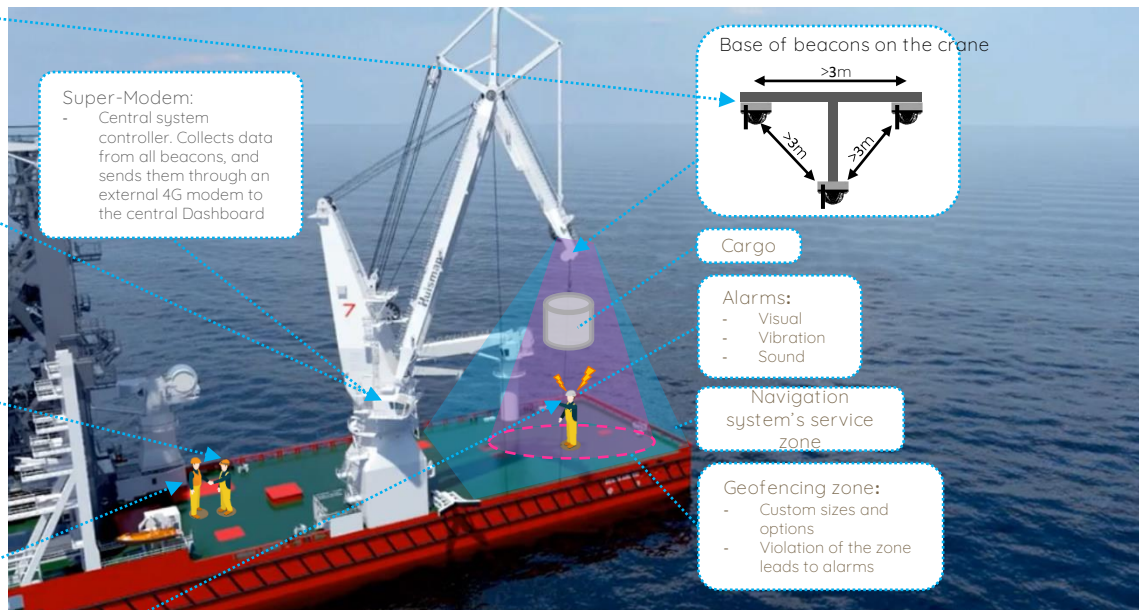
Marvelmind Headlight



Marvelmind Jacket



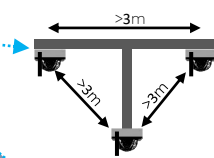
Marvelmind Helmet



Super-Modem:

- Central system controller. Collects data from all beacons, and sends them through an external 4G modem to the central Dashboard

Base of beacons on the crane



Cargo

Alarms:

- Visual
- Vibration
- Sound

Navigation system's service zone

Geofencing zone:

- Custom sizes and options
- Violation of the zone leads to alarms

Configuration:

- 3 x [Industrial Super-Beacon-Plastic](#) (placed on the crane)
- N x [Marvelmind Headlight](#) (1 per worker, placed on the helmet)
- 1 x Super-Modem (placed on the crane)

Principle of operation:

- In this configuration, the end of the crane boom is a card, the entrance to the Geofencing zone of which will warn the person and operator about a dangerous proximity

Result:

- High precision tracking Marvelmind Indoor GPS
- Alarm for workers and shift supervisor
- CSV file with recording of all movements during the shift
- Automatic recording of all violations in a file for further analysis (optional)

Task:

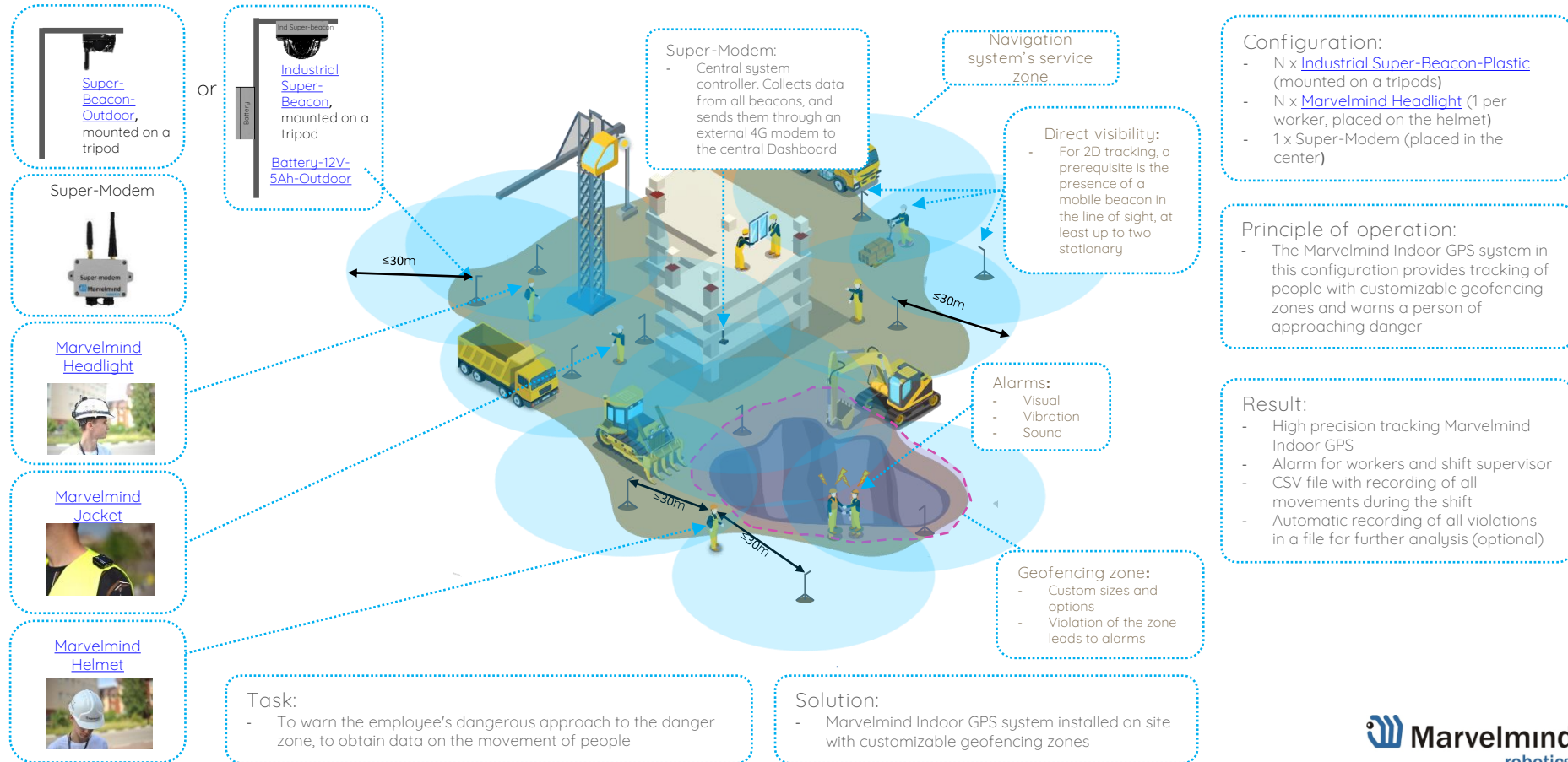
- Prevent dangerous approach and collision of cargo with a person

Solution:

- Marvelmind Indoor GPS system installed directly on the crane with a mobile geofencing zone, which moves after the crane's boom

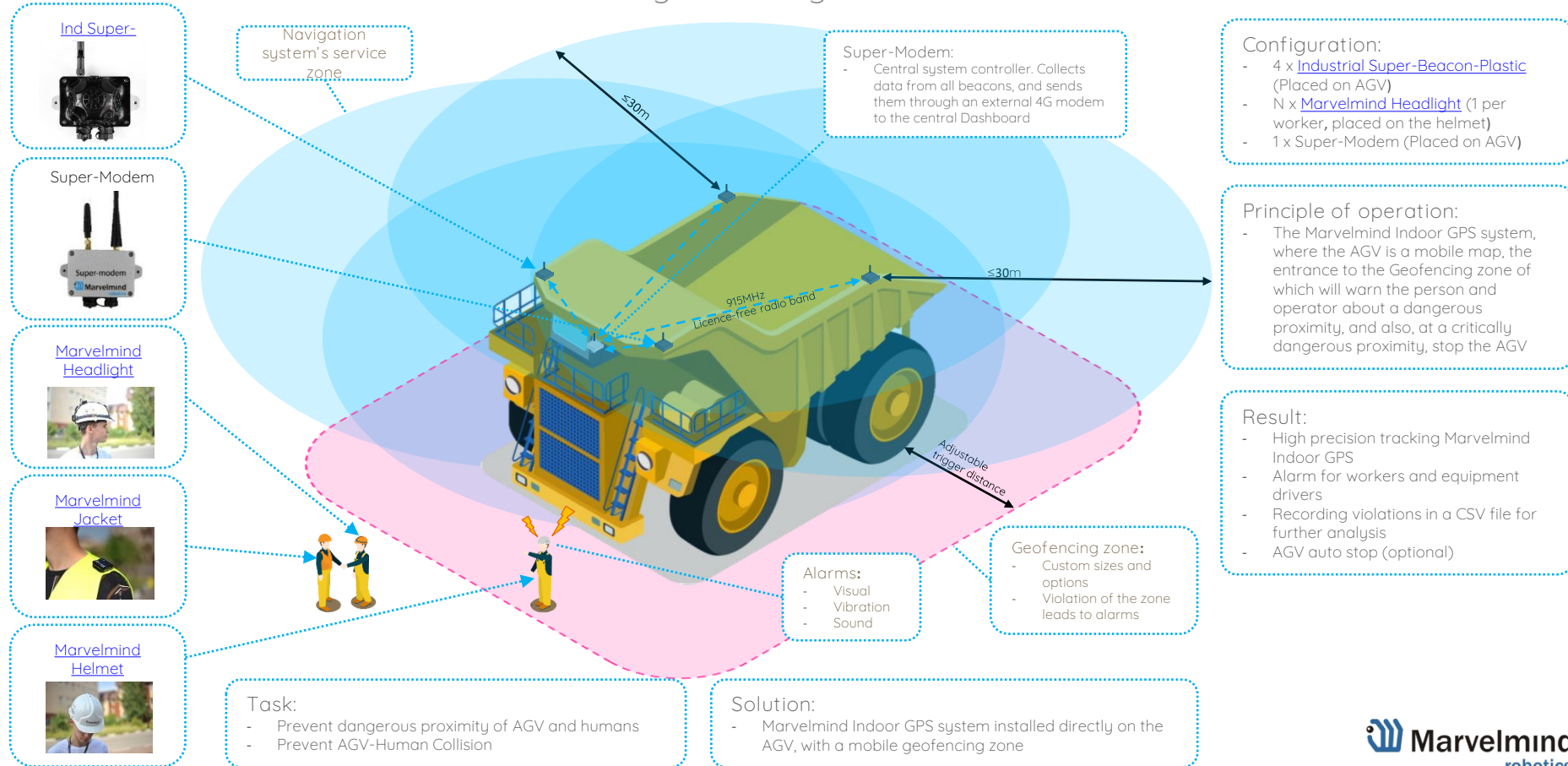
Safety at the construction site, people

Static and mobile geofencing zones at a construction site



Huge AGV, transport and people

Mobile geofencing zone on AGV



Construction safety, people and machinery

Type of one team: 1 excavator and 15 employees

Industrial Super-Beacon

- Fixed to the excavator and connected to the onboard network using [Converter-220V-12V-IP67](#)



Super-Modem

- Located in the interior of the excavator



Marvelmind Jacket

- Worn by an employee



Task:

- Track employee movements and violations of geofencing zones in 2D during work to improve safety and productivity
- Track the running time as well as the number of movements of the excavator boom in 3D to increase productivity

Super-Modem:

- Central controller of the system. Located in the salon. Collects data from all beacons and sends it via an external 4G modem to the Central Dashboard

4G modem:

- Located in the salon. Sends tracking data and data from the webcam to a remote server

Industrial Super-Beacon

- attached to the excavator and connected to the onboard network (2D tracking of people around the excavator)

Configuration for 1 team:

- 9 x [Industrial Super-Beacon-Plastic](#) (Located on the excavator)
- 1 x Converter (for connecting stationary beacons and [Super-Modem](#) to the onboard excavator network)
- 15 x [Marvelmind Jacket](#) (1 per employee)
- 1 x [Super-Modem](#) (Located in the cabin of the excavator)
- 1 x Webcam (1 on excavator)
- 1 x 4G modem (1 per excavator)

Principle of operation:

- The Marvelmind Indoor GPS system in this configuration provides 3D tracking of the excavator boom, as well as 2D tracking of people around the excavator within a radius of 30m. The system has customizable Geofencing zones and allows you to warn a person about approaching a danger, such as an excavator boom

Result:

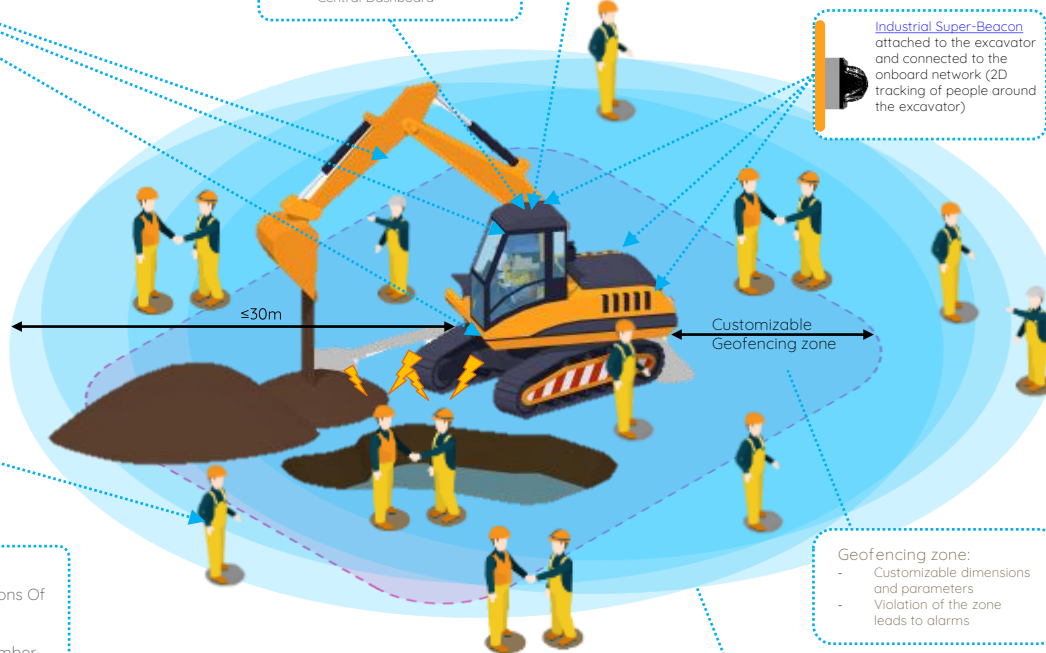
- High-precision tracking of Marvelmind Indoor GPS with customizable Geofencing zones
- Alarm to employees and shift Manager
- Transmitting data to the Central server via the REST API using JSOW
- Automatic recording of all violations in a CSV file for further analysis

Geofencing zone:

- Customizable dimensions and parameters
- Violation of the zone leads to alarms

Navigation system service area

- 3D tracking of the excavator boom
- 2D tracking of people around you



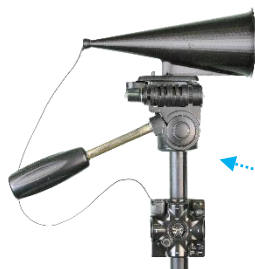
Precise 1D distance measurements for construction sites

Receiving beacon with Horn:

- Super-Beacon-Outdoor or
- Beacon Industrial-RX or
- Beacon Mini-RX-Outdoor or
- Ind. Super-Beacon

Task:

- Precise distance up to 100-150m measurements indoor or underground
- Precise distance measurements in fog, dust or through leaves with no direct line of sight, but with sound propagation
- Easy measurements without laborious laser tuning
- Easy to set up and inexpensive alternative to RTK GPS



Receiving beacon with Horn:

- Super-Beacon-Outdoor or
- Beacon Industrial-RX or
- Ind. Super-Beacon

Transmitting beacon:

- Super-Beacon-Outdoor or
- Industrial Super-Beacon or
- Beacon Industrial-TX

Alternative to:

- Laser distance meters
- RTK GPS

Pros:

- Multiple points simultaneously
- Attach & measure

Transmitting beacon with Horn:

- Super-Beacon-Outdoor or
- Industrial Super-Beacon or
- Beacon Industrial-TX

Configuration:

- 1 x [Super-Beacon](#) with [Horn](#)
- N x [Super-Beacons](#)
- 1 x Modem

Principles of operation:

- Precise ($\pm 2\text{cm}$) 1D distance measurement from an ultrasound transmitting beacon to an ultrasound receiving beacon using time-of-flight of ultrasound
- Streaming data with 3-16Hz update rate
- Multiple simultaneous trackers
- Various interfaces from UART, RS485 to BT

Result:

- cm-level accuracy 1D distance measurement without laser, for example, when it is not feasible: fog, smog, too bright, leaves, etc.
- cm-level accuracy distance measurement indoor or underground, when RTK GPS is not available or unpractical (expensive)
- High precision tracking Marvelmind Indoor GPS
- CSV file with all recording for analysis
- Automatic recording of all violations in a file for further analysis (optional)

Tracking service staff

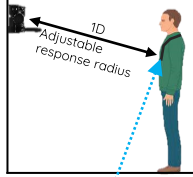
On the example of one floor of a shopping center

Super-Beacon



Restroom

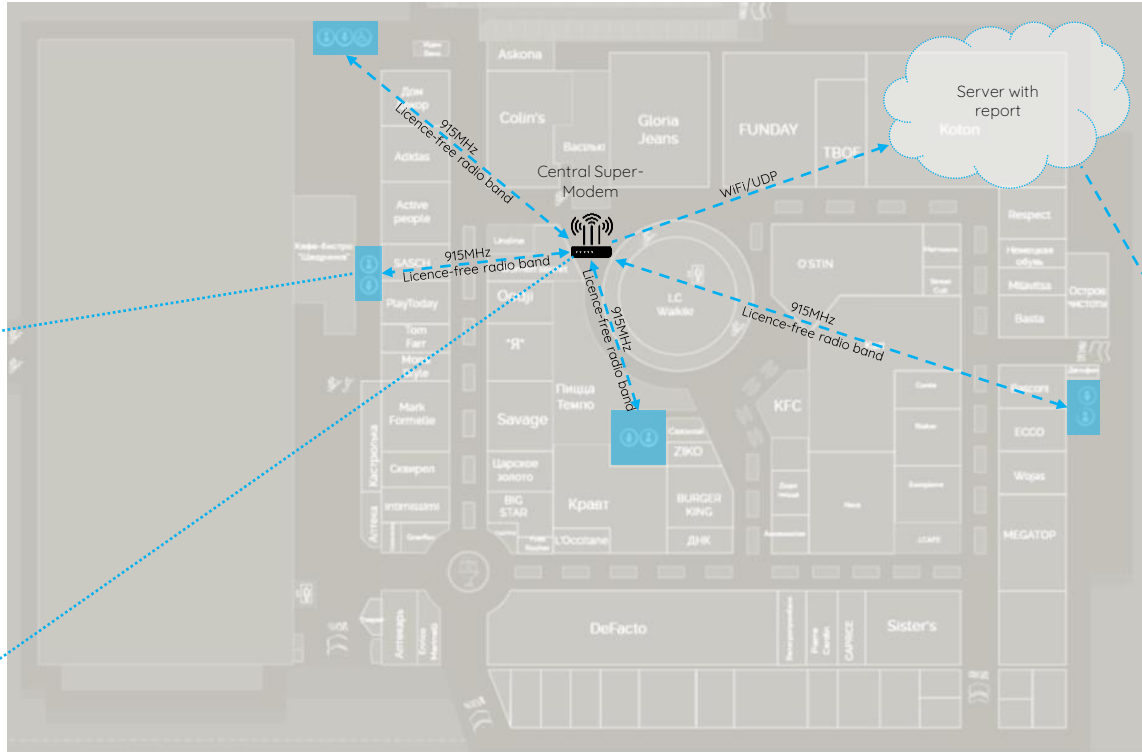
Side view



Badge



Super-Modem



Configuration:

- N x [Super-Beacon](#) (1 per restroom)
- N x [Badge](#) (1 per worker)
- N+1 x Super-Modem (1 per floor + 1 central)

Result:

- Automatic report on movements in the areas of responsibility of service employees (CSV file)
- Auto-fill table (optional)

Reporting Table (Marvelmind)

- The report is generated by the Central Super-Modem, and sent via Wi-Fi to your IP address on request or in a pre-set time (for example, nightly)

Time	Worker 1 (>80%)	Worker 2 (>50%)	Worker 3 (<50%)
8:00-8:15			
9:00-9:15			
11:00-11:15			
20:00-20:15			
21:00-21:15			
22:00-22:15			
23:00-23:15			

Task:

- Tracking service staff
- Performance monitoring

Solution:

- Marvelmind Indoor GPS system for monitoring and analyzing the work of service personnel in 1D configuration

Non-Inverse Architecture (NIA)



Stationary beacon 1

Stationary beacons:

- Mounted on walls or ceilings
- Distanced between beacons measured automatically
- Communicate with router wirelessly in ISM/SRD bands



Stationary beacon 2

Key requirement for the system to work - unobstructed sight by a mobile beacon of 2 or more stationary beacons simultaneously (like in GPS)



Mobile beacon:

- Installed on robot/forklift and interacts with it via UART or SPI or I2C or USB
- Receives location update from router up to 25 times per second
- May contain IMU (accelerometer + gyroscope + compass module)

Submaps:

- Advanced feature that allows building independent maps/clusters of beacons in separate rooms and thus covering large buildings (with area of thousands of m2) similar to cellular network coverage

Indoor Navigation System consists of:

- 2 or more stationary beacons
- 1 or more mobile beacons
- 1 central router

Router/modem:

- Central controller of the system
- Calculates position of mobile beacon up to 25 Hz
- Communicates via USB/virtual UART with Dashboard or robot



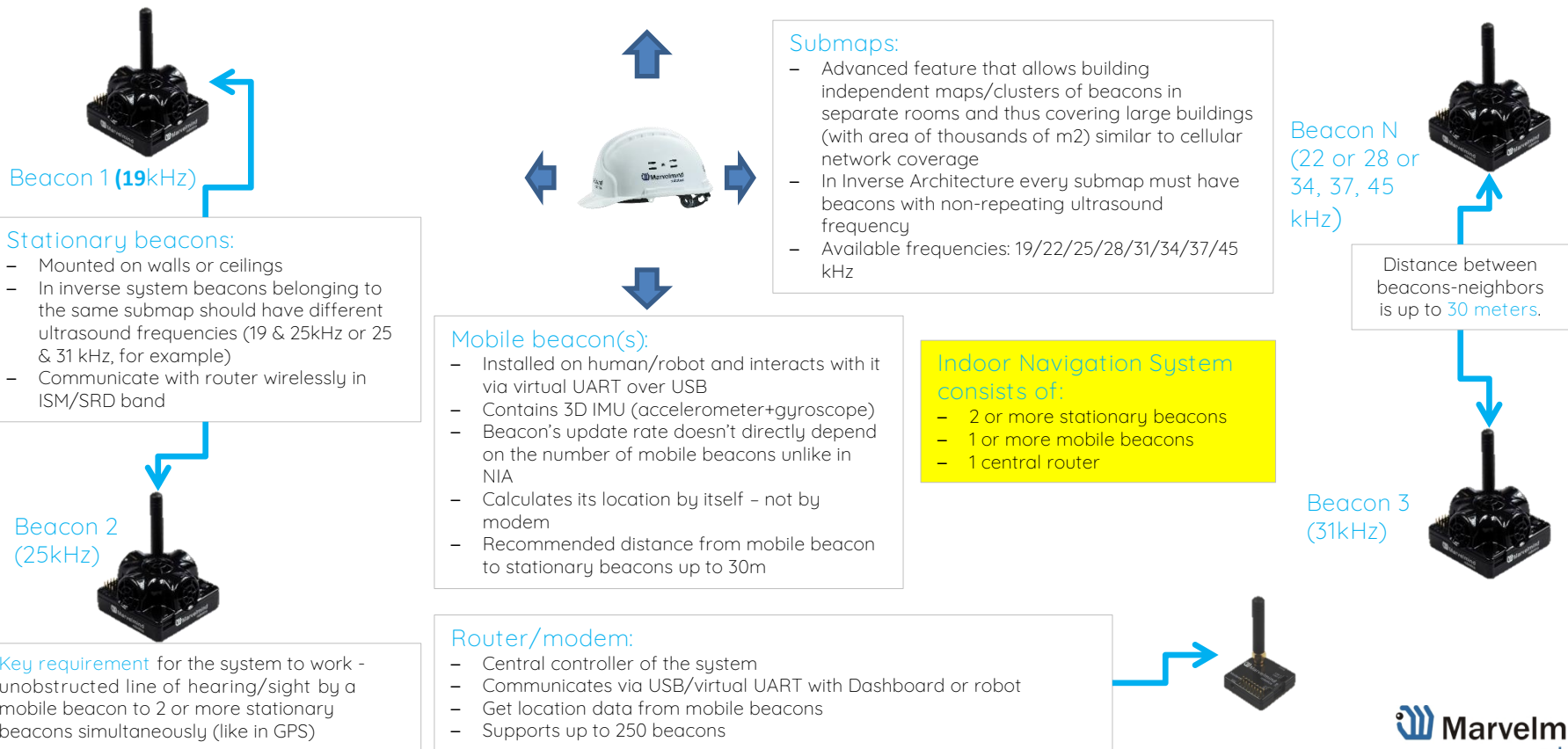
Stationary beacon 4

Distance between beacons-neighbors is up to 30 meters.

Stationary beacon 3



Inverse Architecture (IA)



Tunnel safety example for underground tracking



Beacons comparison



	Beacon Mini-RX/Mini-RX-Outdoor	Beacon Mini-TX	Super-Beacon / Super-Beacon-Outdoor	Industrial Super-Beacon-Metal / Industrial Super-Beacon-Plastic	Industrial-RX
Specialty and main use	Small RX-only beacon	Small TX only beacon	Universal dual-use beacon	Heavy-duty outdoor. Support of RS485 (CAN, Exp. Protected - optional)	Heavy-duty outdoor. Support of RS485 (CAN, Exp. Protected - optional)
Mode of operation	RX only	TX only	Dual-use (RX and TX)	Dual-use (RX and TX)	RX only
Range	- Up to 30m with Super-Beacons	- Up to 30m with Super-Beacon	- Up to 30m with Super-Beacons - Up to 100m with Horn	- Up to 30m with Industrial-RX - Up to 100m with Horn	- Up to 30m with Industrial-RX - Up to 100m with Horn
Ultrasonic frequencies	- 19/22/25/28/31/34/37/45 kHz	- 31kHz	- RX: 19/22/25/28/31/34/37/45kHz - TX: Only one frequency at a time	- RX: 19/22/25/28/31/34/37/45kHz - TX: Only one frequency at a time	- RX: 19/22/25/28/31/34/37/45kHz
Radio band	915/868MHz bands. Chinese bands - on request	915/868MHz	915/868MHz bands. Chinese bands (470/779MHz) - on request	915/868MHz bands. Chinese bands (470/779MHz) - on request	915/868MHz bands. Chinese bands (470/779MHz) - on request
Ext. power/int. battery	USB/750mAh	USB/250mAh	USB/1000mAh	Ext. +5V/+6.16V/Ext. battery	Ext. +5V/+6.16V/Ext. battery
Environmental conditions	- Indoor/Outdoor IP67 - t=0..40C ¹	- Indoor - t=0..40C ¹	- Indoor/Outdoor ² - t=0..40C ¹	- Indoor/Outdoor ² /Intrinsically Safe ³ - t=-40..60C ⁴	- Indoor/Outdoor ² /Intrinsically Safe ³ - t=-40..60C ⁴
Size and weight	47x42x15mm & 25g	35x35x26mm & 19g	55x55x33(64 ⁵)mm & 62/75g	83x58x65mm ⁸ & 250g	83x58x33mm ⁸ & 200g
IMU (3D gyroscope + 3d accelerometer)	Yes (6D)	Yes (6D)	Yes (6D)	Yes (6D)	Yes (6D)
Price, EUR	129/149	129	129/149	199/199	179

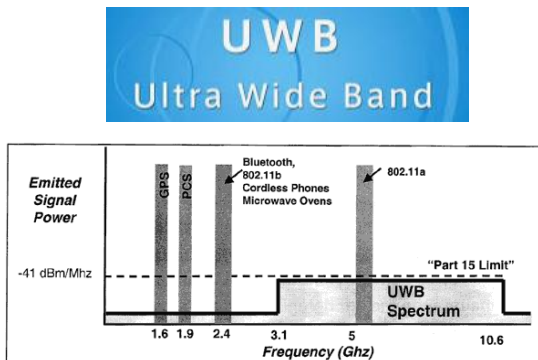
- 1) Withstand submersion to water on 1m up to 30m (IPx7 requirements)
- 2) IP56. Performance during this time is no guaranteed
- 3) 1D mode: RX4 to RX4 sensors; other sensors are disabled
- 4) Other power options available upon request
- 5) Exact type of certification shall be discussed separately

- 6) Temperature range down to -40C is available with external power supply only and upon request
- 7) With antenna
- 8) Sizes without mounting holes
- 9) 6.3g without housing

Competition

Accuracy: 10-30 cm

Compete



There are a few dozens of players in UWB globally.
Thus, majority UWB solutions are very similar in performance



Accuracy: $\pm 2\text{cm}$ vs. 10-30cm – we are 10 times more accurate
Price: even less expensive than UWB at the same time

Complement/compete

LIDAR
Inertial
Optical flow
Structured light
Laser triangulation
Odometry
GPS
Magnetic field

Accuracy: 2-5 meters

Partially compete



There are hundreds of players in Bluetooth and WiFi navigation.
They have the same limitations of any RSSI-based technologies

Summary



Thank you!

Marvelmind Robotics

Marvelmind OÜ
Ahtri tn 12, Kesklinna linnaosa,
Harju maakond,
Tallinn, 10151
Estonia

info@marvelmind.com
<https://marvelmind.com>

Additional slides



Marvelmind Robot v100

An autonomous delivery robot for smart warehousing and industrial applications

Up to 100 kg payload
>16h drive time
4,990 EUR

Idea

- Fully autonomous, economically viable, and safe delivery robot of small-size goods for warehouse, retail and industrial applications
- Flexible, modular and pragmatic approach
- Predictable and reliable delivery from point A to point B just in time
- Reduced dependence on labor



Problem to solve



- Usual autonomous guided vehicles (AGVs) are bulky, expensive, complex to integrate and rather dangerous to use. If an AGV is not expensive, then it is, usually, very inflexible in terms delivery routes (magnetic wires on the floor)
- **Many companies simply don't find it economically viable to employ advanced AGVs => market remains unserved and untapped**

Solution: Autonomous Delivery Robot



Key benefits of Marvelmind Autonomous Delivery Robot



Fully autonomous delivery:

- Navigation and collision avoidance based on combination of Indoor “GPS” and several other systems and sensors. Solid and reliable autonomous delivery of cargo from point A to point B

Cost efficient solution by design with little or no integration cost:

- Inexpensive Indoor “GPS” + IMU + odometry + optical for navigation and positioning instead of costly LIDARs
- Multiple inexpensive 1D LIDARs as proximity sensors collision avoidance and safety
- No expensive 3rd party elements, no 3rd party SW or licenses or IP – only inhouse solutions

Small size and modular architecture:

- Simple and very customizable frame (“Ikea style”) with possibility to choose between different shelves structure in minutes. Optional additional battery capacity. No dangerous fork
- Suitable for different robot’s height/width/length and cargo boxes/baskets’ sizes

Use cases

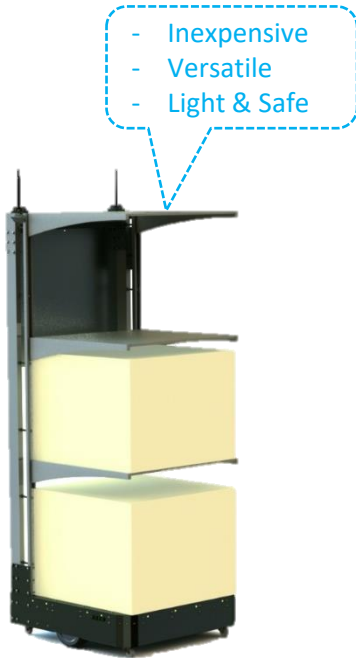
Warehousing:

- Hassle-free delivery of goods between different parts of the warehouse or between storage areas and loading/unloading/assembly areas. Reliable and fast goods delivery from point A to point B, C, D, etc. An assisting person puts loaded baskets or boxes into the robot, press a single physical button B for address B and the rest of inhouse delivery is done fully automatically by the robot

Industrial applications:

- Just in time and reliable delivery on assembly plants (automotive industry, factories, hospitals, chemical or pharmaceutical plants, food industry, etc.) of small and medium size cargo of different size and shape

Competition



- Only partial competition with AGV – more complementary co-existence. AGVs have different capabilities and serve different needs
- Many regular AGVs players: Kuka/Swisslog, Egemin, AGVE, Ward, JBT etc. Relatively few established competitors in autonomous delivery robots. Some made for own usage only (Amazon/Kiva)
- Very little real competition in small-size delivery robots
- Price and complexity of the total solution is the decisive factor for adoption

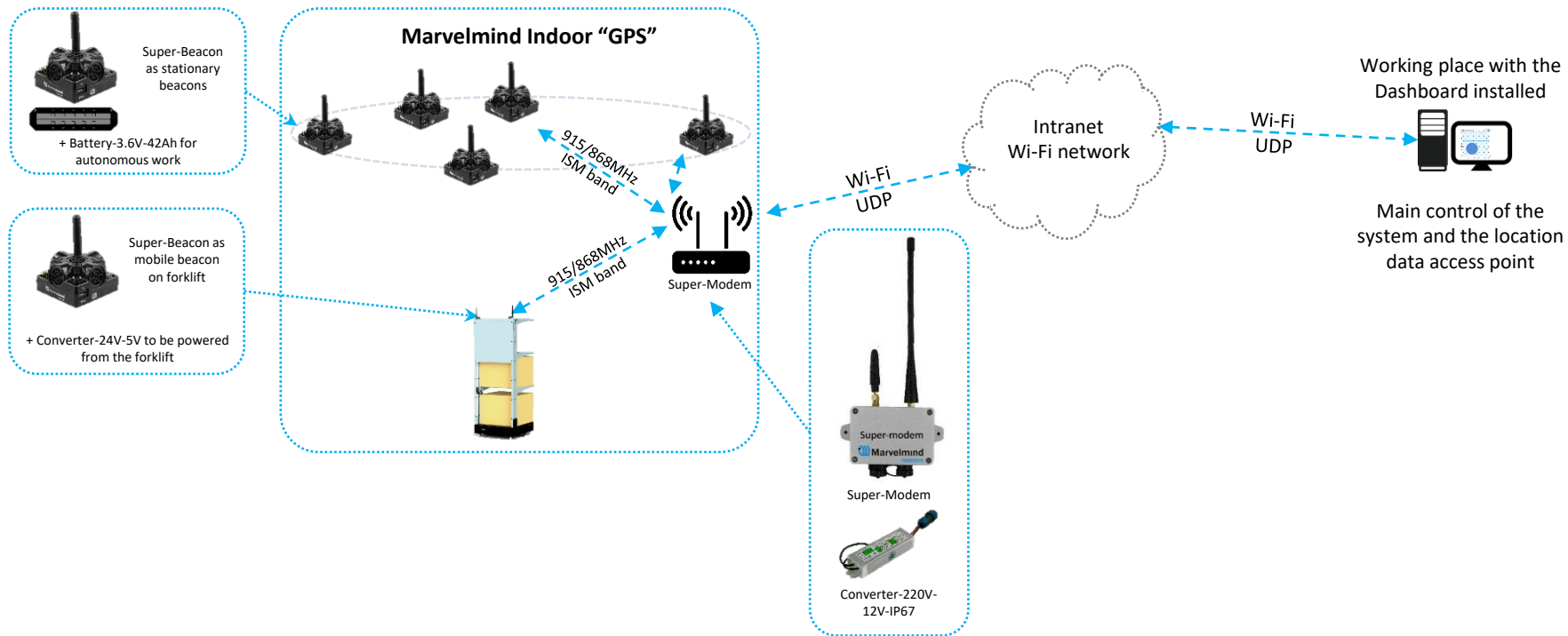


Price: as low as 4,990 EUR instead of 20,000 – 100,000 EUR for regular AGV – **10-20 times less expensive**

Size: much smaller and more versatile than regular AGV – **human size or smaller**

Usage: can be used where regular AGVs are simply not viable

Marvelmind Robot v100 + Indoor “GPS”



Thank you!

Marvelmind Robotics

Marvelmind OÜ
Ahtri tn 12, Kesklinna linnaosa,
Harju maakond,
Tallinn, 10151
Estonia

info@marvelmind.com
<https://marvelmind.com>