

# Precise ( $\pm 2\text{cm}$ ) Indoor "GPS"

for autonomous robots, drones and VR

## Selection guide

v2019\_06\_16

# Intro






There are many ways and starting points for creation or selection of a particular configuration of Marvelmind's Indoor "GPS". Most of them interlink with each other. In the guide, we cover only some starting points and some use cases – to clarify questions that, as we hope, will help you to build a Precise Indoor "GPS" configuration the most suitable for your specific requirements and applications.

Selection can be done based on:

- Available Starter Sets: for example, you have a set and you need to understand what you can do with it
- What you track: forklift vs. autonomous robot vs. autonomous drone vs. VR helmet vs. warehouse worker vs. stationary asset
- Use case: warehouse on forklifts vs. robotics research vs. VR for industrial applications vs. show of drones
- Your environment: indoor or outdoor
- The number of mobile: 1-4 robots/drones vs. a hundred of workers
- Used radio band or your region (EU vs. US)

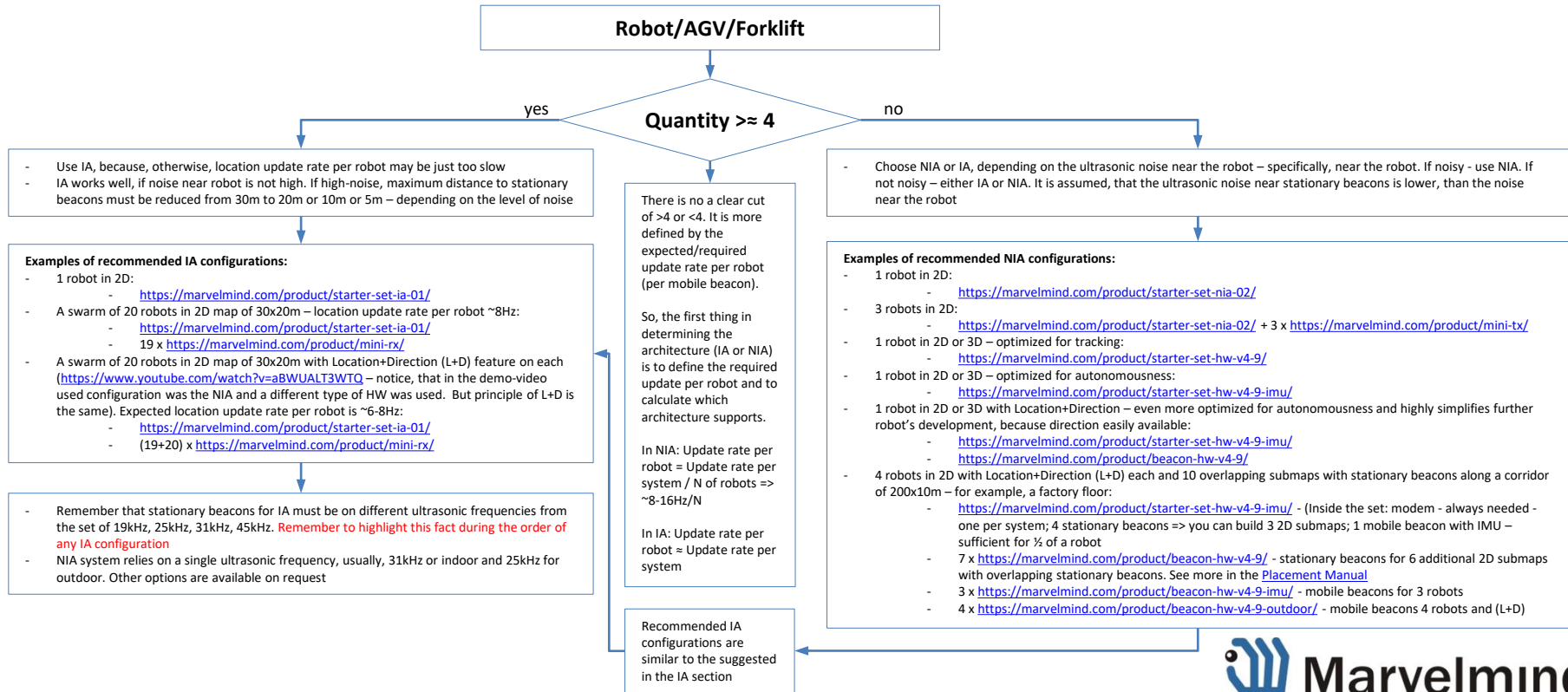
If questions remain or you want that we expand the guide, send us email to [info@marvelmind.com](mailto:info@marvelmind.com).

# Selection guide – table of Starter Sets

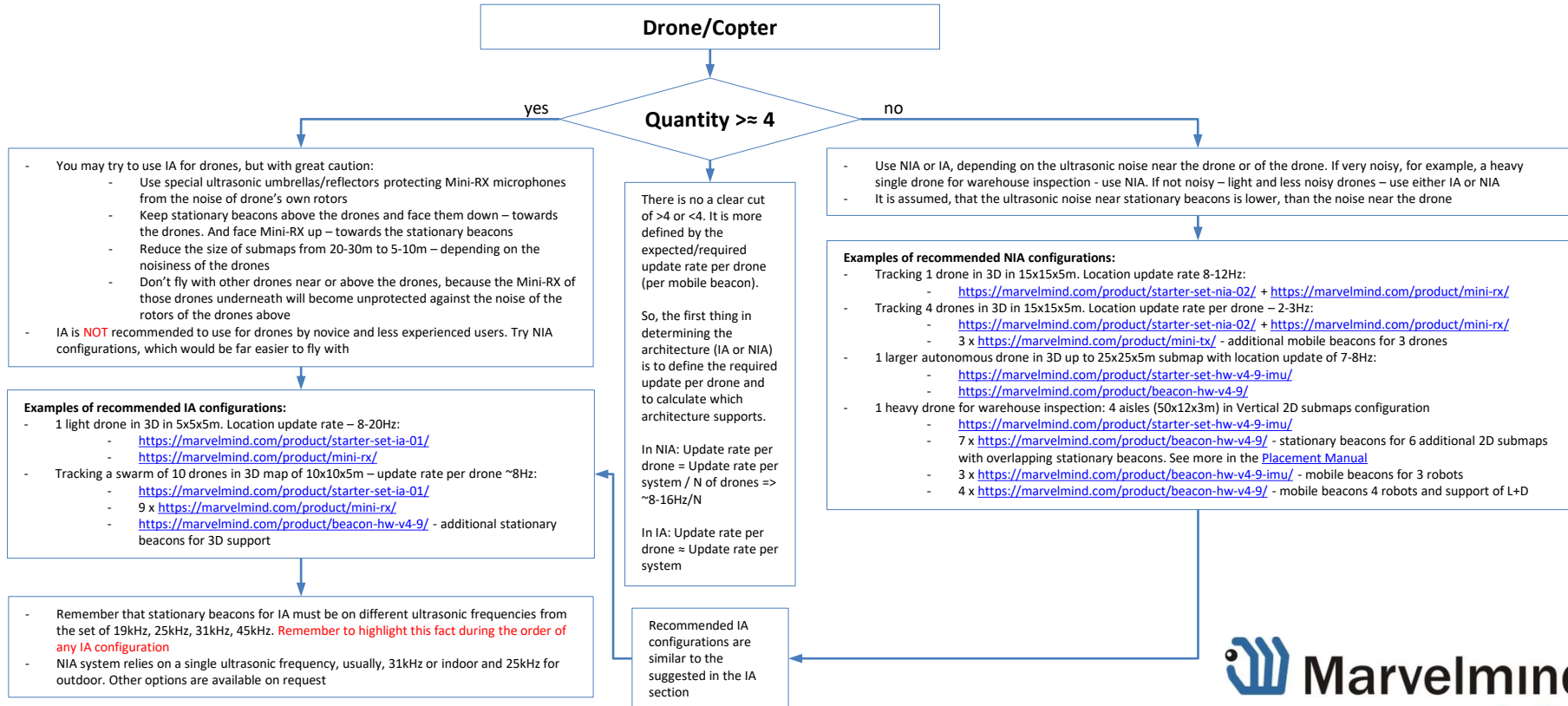
Set	Starter Set HW v4.9	Starter Set HW v4.9-IMU	Starter Set Industrial-NIA-01	Starter Set NIA-01	Starter Set IA-01
					
<b>Typical application</b>	<ul style="list-style-type: none"> <li>- Universal, general purpose, low cost set</li> <li>- Tracking a single robot/drone/forklift</li> <li>- Guiding a single autonomous robots/drones</li> </ul>	<ul style="list-style-type: none"> <li>- Focus on autonomous robots/drones because of IMU-enabled mobile beacon</li> <li>- Guiding a single autonomous robot/drone</li> </ul>	<ul style="list-style-type: none"> <li>- Industrial and other harsh environment</li> <li>- Tracking a single robot/drone/forklift</li> <li>- Guiding a single autonomous robot/drone/forklift</li> </ul>	<ul style="list-style-type: none"> <li>- Ultrasonic-superior version of Starter Set HW v4.9-IMU</li> <li>- Guiding a single autonomous robot/drone</li> </ul>	<ul style="list-style-type: none"> <li>- Tracking people/VR/forklift in 2D</li> <li>- Particularly designed when multiple mobile beacons without location update rate reduction – thanks to IA</li> </ul>
<b>Architecture</b>	- NIA	- NIA	- NIA	- NIA	- IA
<b>Range / Area</b>	- Up to 1000m <sup>2</sup>	- Up to 1000m <sup>2</sup>	- Up to 1000m <sup>2</sup>	- Up to 1000+m <sup>2</sup>	- Up to 1000m <sup>2</sup>
<b>Ultrasonic frequencies</b>	- 31kHz (other – on request)	- 31kHz (other – on request)	- 19/25/31/45kHz RX and 19 or 25 or 31 or 45kHz TX (other – one request)	- 19/25/31/45kHz RX and 31kHz TX (other – one request)	- 19/25/31/45kHz RX and 19 & 25 or 31 or 45kHz TX (other – one request)
<b>Radio band</b>	- 915/868 MHz or 433 MHz	- 915/868 MHz or 433 MHz	- 915/868 MHz or 433 MHz	- 915/868 MHz	- 915/868 MHz
<b>Power/LiPol battery</b>	- USB/1000mAh embedded	- USB/1000mAh embedded	- +5/12V ext. Optional ~220V converter. Optional external +12V IP67 battery	- USB/1000mAh (TX)/750mAh (RX)	- USB/1000mAh (TX)/750mAh (RX)
<b>Environmental conditions</b>	- Indoor only (Outdoor – optional) t=0..+40C	- Indoor only (Outdoor – optional) t=0..+40C	- Indoor and outdoor (beacons) t=-20..+40C (-40C and Ex – optional)	- Indoor only (Outdoor – optional) t=0..+40C	- Indoor only (Outdoor – optional) t=0..+40C
<b>IMU</b>	- No	- Yes (mobile beacon)	- Yes (all beacons)	- Yes (mobile beacon)	- Yes (mobile beacon)
<b>Link / Price</b>	- <a href="#">Starter Set HW v4.9</a>	- <a href="#">Starter Set HW v4.9-IMU</a>	- <a href="#">Starter Set Industrial-NIA-01</a>	- <a href="#">Starter Set NIA-01</a>	- <a href="#">Starter Set IA-01</a>

- 19/25/31/45kHz RX and 19 or 25 or 31 or 45kHz TX - means that the beacon's ultrasonic receiver can receive any frequency in 19/25/31/45kHz ultrasonic bands at the same time (SW selectable) and transmitter can be bought for any frequency in 19 or 25 or 31 or 45 kHz bands, but only one at a time, because TX ultrasonic frequency is defined by HW of ultrasonic transducers and cannot be changed by SW
- You can expand to track more robots/drones with more mobile beacons – the rule is applicable to all sets. You can get more coverage area with more stationary beacons. Up to 250 beacons per modem is supported right now. Only single-modem configurations are supported at the moment. Multi-modem are in the R&D phase and coming H2/2019

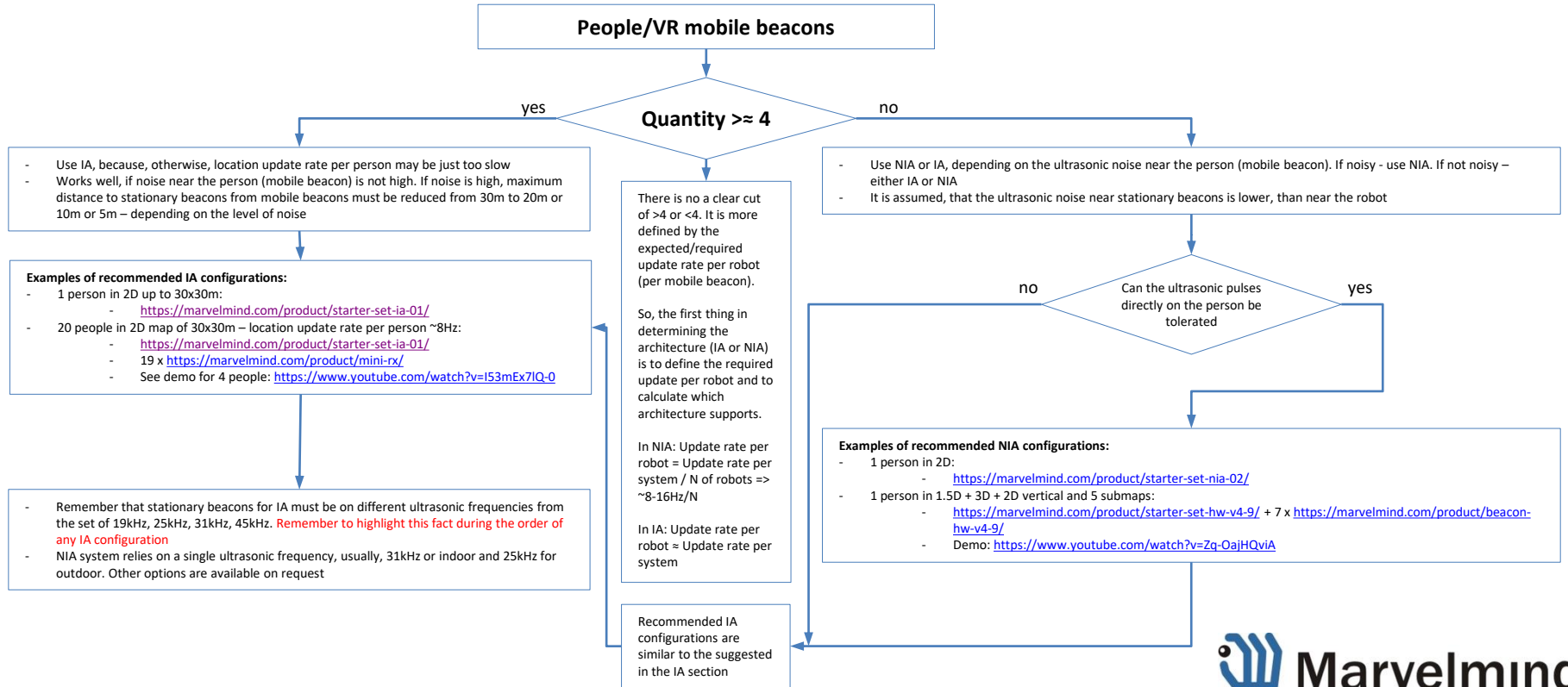
# Selection tree – for robots/AGVs/forklifts



# Selection tree – for drones/copters



# Selection tree – for tracking people/VR



# Selection guide – region vs radio band

Different countries have different license-free bands. The regulation is pretty complex and may even differ for indoor vs. outdoor, fixed vs. mobile, research/amateur vs. commercial use, etc. Always consult with your regulator about it. There is plenty of data online as well. Good starting points:

- [https://en.wikipedia.org/wiki/ISM\\_band](https://en.wikipedia.org/wiki/ISM_band)
- [https://en.wikipedia.org/wiki/Short-range\\_device](https://en.wikipedia.org/wiki/Short-range_device)
- <https://www.itu.int/en/ITU-R/study-groups/workshops/RWP1B-SRD-UWB-14/Presentations/International,%20regional%20and%20national%20regulation%20of%20SRDs.pdf>

The key parameters of Marvelmind's Indoor "GPS" radios:

- Emitting power  $\leq 10\text{mW}$  ( $\leq 10\text{dBm}$ ) – which meets requirements for ISM and SRD devices
- Duty cycle depends on many parameters (mostly, update rate, but not only) and settings (for example, radio profile 500kbps would give much smaller band occupation time than the 38kbps radio profile) and the device (mobile beacon vs. stationary beacon vs. modem) and varies a lot – 0.01% to 20% or more. So, you can nearly always choose the setting so that you let you meeting duty cycle requirements, if there are in your country/band

Type of set	Use the 433MHz HW for these bands/countries		Use the 915MHz HW for these bands/countries		
	<ul style="list-style-type: none"> <li>- <b>315 MHz SRD band</b> – can be used with potentially significant radio performance reduction due to significant difference from the original 433MHz central frequency.</li> <li>- Just select the band in the Dashboard's radio settings</li> </ul>	<ul style="list-style-type: none"> <li>- <b>433MHz ISM band</b> – <a href="#">the EU and Region 1</a> – native band of this HW</li> </ul>	<ul style="list-style-type: none"> <li>- <b>SRD860 band</b> – can be used with low/middle or no radio performance degradation</li> <li>- Just select the band in the Dashboard's radio settings</li> </ul>	<ul style="list-style-type: none"> <li>- <b>915MHz ISM band</b> – <a href="#">US and Region 2</a> – native band for this HW</li> </ul>	<ul style="list-style-type: none"> <li>- Other SRD or ISM bands in 779-928MHz range – can be used for mild radio performance degradation depending on the frequency distance from the central frequency of 915MHz</li> <li>- Some manual radio settings may require in the Dashboard's menu</li> </ul>
<a href="https://marvelmind.com/product/starter-set-hw-v4-9/">https://marvelmind.com/product/starter-set-hw-v4-9/</a> <a href="https://marvelmind.com/product/starter-set-hw-v4-9-imu/">https://marvelmind.com/product/starter-set-hw-v4-9-imu/</a> <a href="https://marvelmind.com/product/starter-set-industrial-nia-01/">https://marvelmind.com/product/starter-set-industrial-nia-01/</a>	Supported		Supported		
<a href="https://marvelmind.com/product/starter-set-nia-02/">https://marvelmind.com/product/starter-set-nia-02/</a> <a href="https://marvelmind.com/product/starter-set-ia-01/">https://marvelmind.com/product/starter-set-ia-01/</a> <a href="https://marvelmind.com/product/starter-set-nia-01/">https://marvelmind.com/product/starter-set-nia-01/</a>	Not supported natively. Only optional on request due to default embedded small-size ceramic antenna that wouldn't work in this band. An external wired antenna would be provided.		Supported		

# Selection guide – indoor vs. outdoor

	Conditions	Outdoor
<b>Indoor</b>	<b>Indoor:</b> office-like environment: no rain, no dust; t=0..+40C	<a href="https://marvelmind.com/product/starter-set-ia-01/">https://marvelmind.com/product/starter-set-ia-01/</a> <a href="https://marvelmind.com/product/starter-set-nia-02/">https://marvelmind.com/product/starter-set-nia-02/</a> <a href="https://marvelmind.com/product/starter-set-hw-v4-9/">https://marvelmind.com/product/starter-set-hw-v4-9/</a> <a href="https://marvelmind.com/product/starter-set-nia-01/">https://marvelmind.com/product/starter-set-nia-01/</a> Nearly all of these sets can converted to Mild Outdoor or Heavy Outdoor variants upon request. Lead time – several days
<b>Outdoor &amp; Ex</b>	<b>Mild outdoor:</b> protection of electronics by sealing compound against a surprise rain. Ultrasonic sensors and USB are not protected (less likely to be damaged by a rain). DIP switch and Reset buttons are sealed/protected and not available. t=0..+40C.	<a href="https://marvelmind.com/product/beacon-hw-v4-9-imu-outdoor/">https://marvelmind.com/product/beacon-hw-v4-9-imu-outdoor/</a> <a href="https://marvelmind.com/product/beacon-mini-tx-outdoor/">https://marvelmind.com/product/beacon-mini-tx-outdoor/</a> <a href="https://marvelmind.com/product/modem-hw-v4-9-outdoor/">https://marvelmind.com/product/modem-hw-v4-9-outdoor/</a>
	<b>Heavy outdoor:</b> can withstand up to IP67 conditions. However, the system is designed to survive the conditions – not to work in them. So, performance in rain and heavy dust is not guaranteed; t=-20..+40C – by design. Not tested. Negative temperatures are applicable to battery-less configurations only	<a href="https://marvelmind.com/product/starter-set-industrial-nia-01/">https://marvelmind.com/product/starter-set-industrial-nia-01/</a> <a href="https://marvelmind.com/product/industrial-tx/">https://marvelmind.com/product/industrial-tx/</a> <a href="https://marvelmind.com/product/industrial-rx/">https://marvelmind.com/product/industrial-rx/</a> <a href="https://marvelmind.com/product/mini-rx-ip67/">https://marvelmind.com/product/mini-rx-ip67/</a> <a href="https://marvelmind.com/product/converter-220v-12v-ip67/">https://marvelmind.com/product/converter-220v-12v-ip67/</a>
	<b>Explosion protected:</b> different flavors for explosion protected specifications and Intrinsic safety requirements	Customized versions of the following systems are available on request: <a href="https://marvelmind.com/product/starter-set-industrial-nia-01/">https://marvelmind.com/product/starter-set-industrial-nia-01/</a> <a href="https://marvelmind.com/product/industrial-tx/">https://marvelmind.com/product/industrial-tx/</a> <a href="https://marvelmind.com/product/industrial-rx/">https://marvelmind.com/product/industrial-rx/</a>



# Selection guide – general Q&A

Questions	Answers
<ul style="list-style-type: none"><li>- How large a swarm of robots/drones can Marvelmind's Indoor "GPS" system support?</li></ul>	<ul style="list-style-type: none"><li>- Our systems (IA and NIA) currently (06/2019) supports up to 250 beacons – stationary + mobile combined. So, if you have, for example, 50 stationary beacons to cover the territory, there could be up to 200 mobile beacons</li><li>- You may be more limited with the location update rate. For example, location update rate per mobile beacon for the NIA in the configuration above would be 8/200Hz, i.e. pretty slow. For IA, it would be ~8Hz</li></ul>
<ul style="list-style-type: none"><li>- Can your system work through walls or metal or glass?</li></ul>	<ul style="list-style-type: none"><li>- No, it cannot. The most fundamental requirement for the system to work – a direct line of hearing/sight from a mobile beacon to 2 or more stationary beacons for 2D and from a mobile beacon to 3 or more stationary beacons for 3D</li><li>- However, you can still hide the mobile and stationary beacons under "breathable" materials, for example, cloth. Such materials do not really block ultrasound and doesn't affect on the system</li><li>- Yes, even a basic sheet of paper can significantly disrupt or completely block the system</li><li>- There several options to overcome the challenge:<ul style="list-style-type: none"><li>- To build TDMA submaps in IA</li><li>- To use N+1 redundancy in IA – to have more beacons, so that, if one is blocked, the remaining would still serve and the system would try to recover and calculate the location</li><li>- To place stationary beacons and build submaps so that obstructions are minimized or not affecting on the tracking</li><li>- To use sensor fusion – we highly recommend the approach for autonomous robots, drones, AGVs – to combine, for example, Marvelmind's Indoor "GPS" with odometer+IMU and use Kalman filter for determining the most probable location</li></ul></li></ul>
<ul style="list-style-type: none"><li>- What is the highest update rate or the lowest latency?</li></ul>	<ul style="list-style-type: none"><li>- Exact delay / latency depends on many factors. Among them:<ul style="list-style-type: none"><li>- IA or NIA</li><li>- From modem or from beacon</li><li>- IMU sensor fusion or regular ultrasonic only</li><li>- Radio profile</li><li>- Realized update rate in submap</li><li>- Any sort averaging or Real-time player enabled or not</li></ul></li><li>- The range of latency is from (1) ~12ms for data from a mobile beacons via USB with IMU fusion enabled and not averaging at all to (b) ~150ms with 30m-submap and update rate in ultrasonic of 7Hz and not averaging to (c) 2 seconds with the same settings as in (b), but the Realtime player with settings 16 enabled, i.e. it takes into account up to 16 previous readings before giving out the new one. Tracking in (c) will be very smooth, but for the expense of increased latency</li></ul>
<ul style="list-style-type: none"><li>- Do you have outdoor versions?</li></ul>	<ul style="list-style-type: none"><li>- Yes, we have several HW variants, for example:<ul style="list-style-type: none"><li>- <a href="https://marvelmind.com/product/starter-set-industrial-nia-01/">https://marvelmind.com/product/starter-set-industrial-nia-01/</a></li><li>- <a href="https://marvelmind.com/product/mini-rx-ip67/">https://marvelmind.com/product/mini-rx-ip67/</a></li></ul></li></ul>

# Dictionary

- **AGV** – Autonomous guided vehicle
- **HW** - Hardware
- **IA** – Inverse Architecture  
([https://marvelmind.com/pics/architectures\\_comparision.pdf](https://marvelmind.com/pics/architectures_comparision.pdf))
- **IMU** – Inertial Measurement Unit – a set of sensors that usually consists of 3D accelerometer and 3 gyroscope. In some beacons, additionally, 3D magnetometer. We strongly suggest not to use magnetometers indoor because there are many magnetic fields, currents generating magnetic fields that make determining of direction based on magnetometer and magnetic field of the Earth nearly impossible. Outside of the building – easier and magnetometers can be used with caution and taking into account own robot's and drone's currents that can generate strong magnetic fields – i.e. keep the mobile beacon with magnetometer farther from the sources of any magnetic fields
- **ISM band** - [https://en.wikipedia.org/wiki/ISM\\_band](https://en.wikipedia.org/wiki/ISM_band). We support 433MHz and 915MHz. Choose wisely depending on your region – the EU or the US. For other regions, check the location requirements. In many cases, the same HW can support other ISM/SDR bands without or with some radio performance degradation. If you have smaller maps or open area without much non-radio transparent walls, other bands, for example, 868MHz SRD band can easily work the 915MHz beacons/modems
- **L+D** – Location + Direction – a SW/HW feature that returns not only a location, like a GPS does, but also a direction, which a regular GPS doesn't provide. It is extremely simplifies development of autonomous robots, drones, VR. Demo: <https://www.youtube.com/watch?v=aBWUALT3WTQ>
- **NIA** – Non-Inverse Architecture  
([https://marvelmind.com/pics/architectures\\_comparision.pdf](https://marvelmind.com/pics/architectures_comparision.pdf))
- **R&D** – Research and development. Basically, it means that we work on the product/architecture, but exact schedule of commercial availability is not defined yet
- **SRD** - [https://en.wikipedia.org/wiki/Short-range\\_device](https://en.wikipedia.org/wiki/Short-range_device). We support 868MHz for the EU. Other bands – with some radio degradations on 433MHz or 915MHz HW
- **SW** - Software
- **TDMA submaps** – A special use of submaps, where not all stationary beacons emit at the same time. The TDMA submaps allow having a more robust and reliable tracking in a challenging environment with multiple obstructions and not guaranteed direct line of sight/hearing between stationary and mobile beacons