

# **ARGOS: a solution to increase security and safety of ships**

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## **ABSTRACT**

In the last years, the leisure vessels market had a very positive trend and, every year, more and more ships will be present in our waters. This is giving a push to the demand and needs of increased security, in the protection against theft, and safety, in the protection against losing the mooring while anchored with the risk of having accidents against rocks or other vessels. The ARGOS Solution is offering the capabilities and performance to answer those needs with easy plug-in installation of a device in the boat.

The ARGOS Solution is under development in the frame of the ARGOS (Anti-theft Robust Galileo-based Operational System) project co-funded by the EU Agency for the Space Programme (EUSPA) within its Fundamental Elements funding programme.

The ARGOS Solution, leveraging the services provided by Galileo and thanks to its scalable and modular architecture, provides timely alerts in case of theft or risk of losing the mooring of the anchor point. It also provides high robustness against environmental conditions, e.g. multipath, shadowing of the GNSS signals, etc..., and external factors that can be unintentional (e.g. interference sources) or intentional (e.g. jamming or spoofing attacks in order to support a theft attempt).

These differentiating capabilities are based on the new features of Galileo, the European GNSS system, specifically the Open Service Navigation Message Authentication (OSNMA) that will increase the robustness against certain types of spoofing attacks, and the I/NAV Message improvement that will increase the performance of the GNSS signal processing in harsh environments (e.g. ports, natural harbours, etc...).

These capabilities are integrated in the solution and improved with an advanced Navigation Engine in the ARGOS device by fusing the GNSS information with data from other on-board sensors (e.g. Inertial Measurement Unit) in order to provide timely alerts with high performance detection of risky conditions.

## **1 CONTEXT AND USER NEEDS GATHERING (GEA)**

The ARGOS project, co-funded by the EU Space Programme Agency (EUSPA) of the European Commission (EC), in the frame of the Fundamental Elements Funding Programme (Grant Agreement contract GSA/GRANT/03/2019/01) started its activities the 1<sup>st</sup> of October 2020. The objective of the project is to develop an innovative Solution to provide security (i.e. anti-theft protection) and safety (i.e. mooring at anchor monitoring) functions and to develop an innovative technology in vehicle tracking, addressing a wide list of target applications and market verticals while becoming a reference low-cost solution in its field.

The solution is strongly based on the use of the European Global Navigation Satellite System (EGNSS): Galileo. Thanks to its services and capabilities (e.g. Open Service Navigation Message Authentication and the I/NAV improvement capability), ARGOS can provide to the users a reliable, robust, accurate and timely solution to their security and safety.

Today, the use of GNSS enables a wider set of applications, from autonomous driving to autonomous boats, tracking of goods and citizens when natural disasters take place, along with elder people assistance or smart-agriculture and citizens security and control as well. Different addressable markets and applications for the use of the ARGOS Solution have been identified, specifically for anti-theft purposes, like, for example:

- Leisure Vessels

- Electric-Bikes (e-Bikes)
- Earthmoving Machines
- Motorbikes
- Trucks

The above listed markets are to be considered as an initial estimation of the potential target applications of the ARGOS Solution. Among them, the Leisure Vessels have been considered as the first addressed Use Case because it presents less limitations for the HW implementation than the others (e.g. possibility to have continuous power supply, no need of small dimensions) and because a potential client expressed an interest and is part of the ARGOS Consortium (PerMare Group).

In order to develop the right solution that answers to the needs of the users, an initial activity to gather the user needs and, therefore, the ARGOS Solution requirements, have been carried out.

In order to gather a feedback from potential users, clients and service operators in the domains addressed by the ARGOS Solution, a session of interviews with them has been set up.

The objective was to have their indication on which are the main capabilities and performance that will make the ARGOS Solution attractive in the market. This translates to the effort to identify the **key elements** of the product that will fit the market demand in the different domains.

When speaking about products that provide services based on position information, several key capabilities shall be analysed including their importance from the user perspective.

These key capabilities are, for example:

- ✓ **Accuracy of the Position Information:** how far is the estimated and provided position information with respect to the real one.
- ✓ **Availability of Position Information:** this is not only saying if the position information is given or not but also if the Position information is given but not within the declared/expected “Accuracy”.
- ✓ **Robustness against potential attacks:** of course, it would not be possible to have a product robust against all the possible attacks, but we have to understand which level of attack cost and complexity will be possible in the proposed use case. For example, the spoofing attack cost that could be considered, by the attacker, to steal a Yacht is considered high. So, with this “capability” we intend to understand how much is the level of robustness to be implemented in our solution with respect to the cost/complexity of the attack.
- ✓ **Time to Alert:** it is another key parameter that applies to our solution. How long it will take to detect and communicate through an alarm the theft attempt to the user.
- ✓ **Probability of False Alarms:** this is going together with the Time to Alert and represent the reliability of the Alarm information. We also want to know from the users if having a higher False Alarm probability could be too much annoying or tolerated.
- ✓ **Easy to Use:** last but not least, the installation and use simplicity can be a strong driver



Further than the key capabilities, other key elements to be considered and assessed are relevant to the Commercialisation Strategy and, in particular, the:

- ✓ **Need/Awareness:** the need is clearly defining the demand of what the ARGOS Solution is going to propose while the awareness is representing a key element for the commercialisation strategy: if there is no awareness on the technology included in the ARGOS Solution, there could be a preconceived

distrust that can disrupt the potential ARGOS Solution business. In this case, the Commercialisation Strategy shall foresee actions to increase the awareness among the potential users/clients.

- ✓ **Pricing approach:** together with the Awareness, also the pricing approach is key for the Commercialisation Strategy. With pricing approach it is not only considered the “cost” of a product but also if it is bought as a stand-alone product/solution, if it will be subscribed with a Service contract or if it will be a leasing contract, etc... An analysis of what is the users/clients preferred approach is also a key element for the success.

## 2 THE ARGOS USE CASE (MODIS)

As described in the Section **Error! Reference source not found.** the Leisure Vessels have been considered as the first addressed use case and has been chosen for the demonstration activities of the project ARGOS. In this context, two scenarios have been considered:

- Vessel at anchor in a pier
- Vessel at anchor in a natural harbour

### 2.1 VESSEL AT ANCHOR IN A PIER

No one is safe from boat theft, regardless of where your vessel is stored. The Marine Insurance files are full of reports of boats that have been stolen from backyards, front yards, the street in front of the house, the brokerage or dealer lot, secured storage with video-surveillance equipment and barbed wire, and other typical areas that we believe are "safe."

This use case is related to a vessel that is at anchor in a pier. This scenario leads to different conditions due to bumpers, waves (roll, pitch), wind (roll, pitch) and limited lateral movement that impact on the vessel.

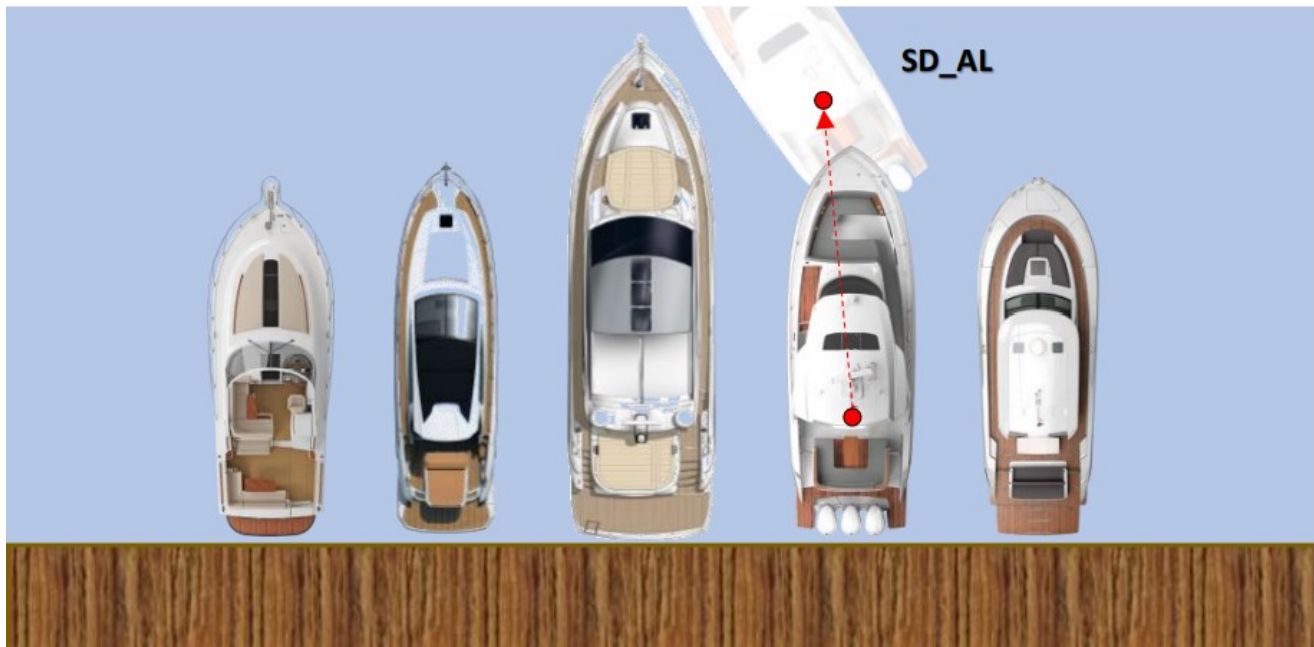


Figure 1 – Anti-Theft Protection

Comparing movements between normal behaviour of a vessel at anchor in a pier and those of a vessel on which a theft is taking place, the ARGOS solution will be able to identify suspicious theft situations.

## 2.2 VESSEL AT ANCHOR IN A NATURAL HARBOUR

Any time a vessel is at anchor, the anchorage point is chosen considering all possible dangers around, declaring a virtual Safe Distance around the anchorage point.

When a vessel is at anchor in a natural harbour, it is exposed to waves (roll, pitch), wind (roll, pitch) and limited movement due to the anchoring.

Anchor dragging, for example, could bring the vessel towards collision with natural constraints or with other boats or obstacles. Dragging the anchor often happens in rough weather conditions (typhoon, hurricane, etc.).

Anchor dragging would not cause serious accidents if there is enough space in the sea for manoeuvring and enough time to regain control of the vessel. But in most cases, there is not sufficient space or enough time as the speed of anchor dragging under wind pressure force is approximately 3 - 4 knots.

The ARGOS solution shall be able to identify abnormal situation on which the boat is dragged out the Safe Distance Circle.

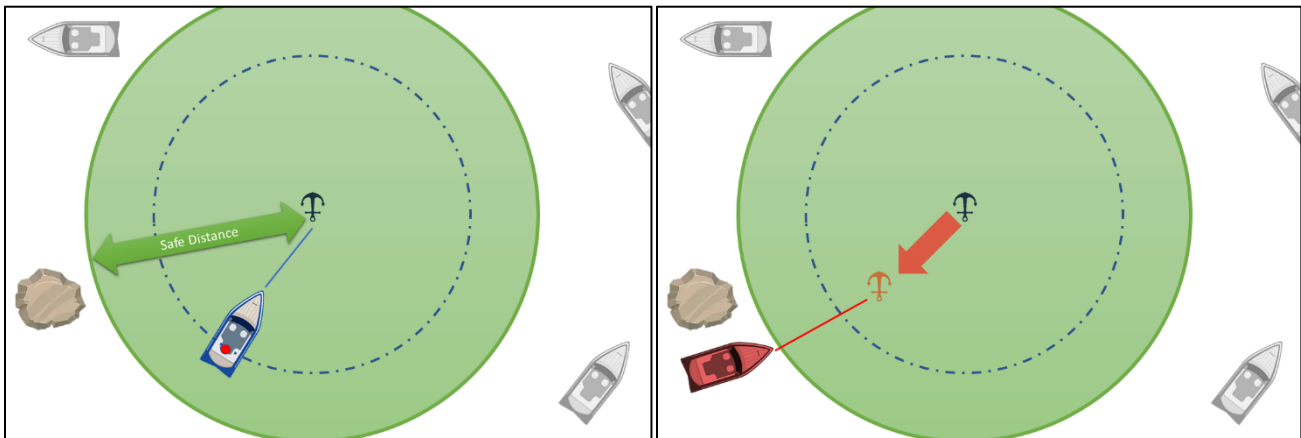


Figure 2 – Mooring at anchor monitoring

Defining the safe distance limits or the safe area within which the vessel is in a safe condition it will be possible to monitor the behaviour of the boat around the anchor point and in case of abnormal behaviour, detect it and notify the vessel owner about the anomaly.

In some cases, it is important to intervene in a timely manner to avoid collisions. Think of anchoring at night when you may not be able to realize, for various reasons, any dragging of the anchor, ARGOS allows you to have a big brother who keeps an eye on our boat with respect to the original anchor point

## 3 THE ARGOS SOLUTION

The idea at the base of the ARGOS Solution is to take advantage both of the new Galileo services like the OSNMA or the I/NAV message improvements and of the innovative elements brought by the partners of the project.

The ARGOS Solution aims, then, to answer the user needs identified with the activities described in section 1 and in the Use Cases identifies in Section 2.

In the following picture, the high-level physical architecture is presented.

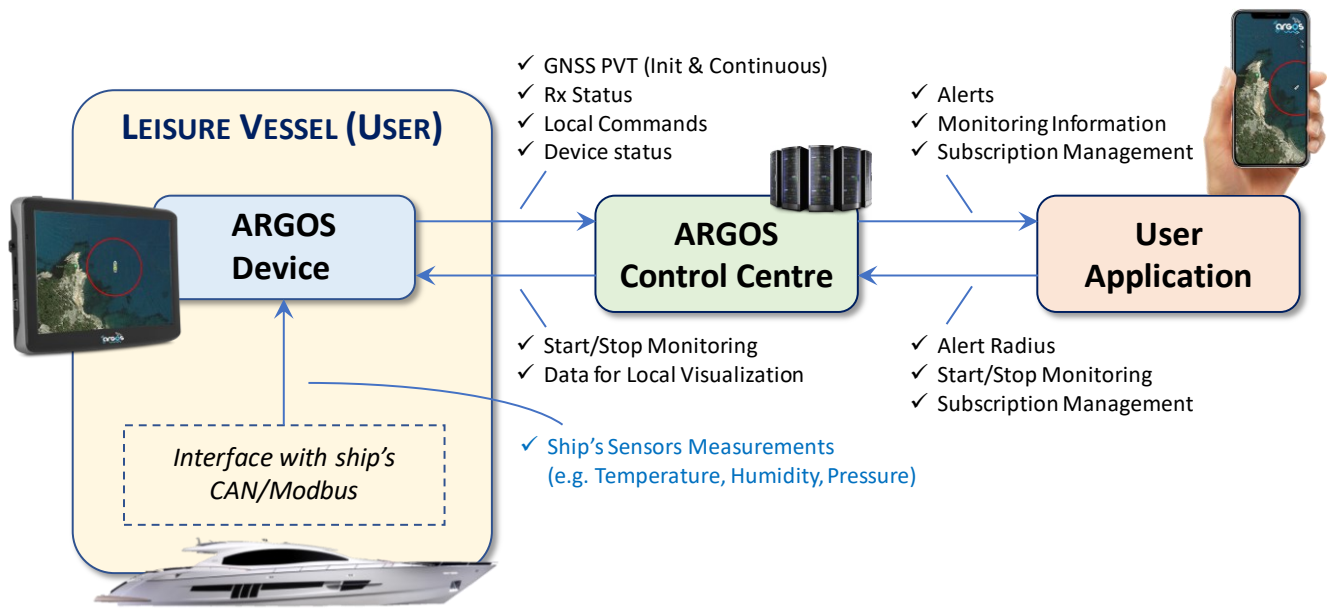


Figure 3 – ARGOS Physical Architecture

The need of two of the subsystems foreseen for the ARGOS Solution have been derived from the user needs:

- The **ARGOS Device** to be installed on-board the ship
- The **User Application** to be installed on the User device (e.g. smartphone, tablet, laptop, ...)

In order to manage all the functions identified in the Section **Error! Reference source not found.**, it has been foreseen another key subsystem to manage all the interfaces and to provide the required monitoring and control capabilities:

- the **ARGOS Control Centre** to implement all the monitoring & alerting capabilities and all the external and internal interfaces.

The only external interface not provided by the Control Centre is the interface between the ARGOS Device and the Ship (i.e. through the CAN/Modbus).

Hereafter the 3 main subsystems of the ARGOS Solution are described, with particular focus on their functionalities.

### 3.1 ARGOS DEVICE

The device is responsible for the detection of anomalous behaviours of the boat and of the tampering attempts both in terms of power supply interruption and device integrity.

In particular the device offers protection from the following threats.

- **Spoofing attack Detection:** the ARGOS Device, and in particular the GNSS Chipset, by implementing Galileo signals reception, can be protected with the use of the OSNMA in order to trust the Galileo-based PVT solution instead of the GPS-only based solution. The use of the Galileo OSNMA allows the device to be robust against simple spoofing attacks (with "Simple Spoofing Attacks" it is meant the attacks performed by an attacker not expert on GNSS and with a low complexity equipment). Once that the attack has been identified the device generates an alert to the Control Centre to inform the final user about the event.

- **GNSS signal interruption:** a malicious person could attempt the theft of a boat by blocking the reception of the GNSS signal from the ARGOS device. When the ARGOS device do not receive anymore the GNSS signals, the ARGOS Control Centre would not be able to detect a theft attempt because by using GNSS positions (not available anymore due to the lack of signals). Therefore, the ARGOS Solution implemented a function that will be able to transmit an alert to the ARGOS Control Centre when an interruption of the reception of GNSS signals is detected.
- **Power supply interruption:** the device has been designed to be robust to detect low voltage or power supply interruption for the device. The device is designed to measure the electrical voltage, in input to the power supply of the ARGOS Device, and verify if it drops down under a configurable "Min Voltage" threshold. If this happens, the device will raise a "Low Voltage" alert that will be immediately forwarded to the ARGOS Control Centre and communicated to the User. This can be another possible type of attack carried out to perform a theft attempt.
- **Physical Anti-Tampering:** one possible strategy to steal a boat, equipped with the ARGOS Device, could be to destroy or physically manipulate the device and, then, steal the boat. The ARGOS Device is designed to be anti-tampering. In case of tentative of manipulation, an Alarm will be triggered and sent by the Control Centre to the User application.

### 3.2 ARGOS CONTROL CENTRE

The Control Centre monitors and controls the inputs coming from the ARGOS device's interfaces. Its main functionalities consist in User's & System's Management, Monitoring and Alarming. The former is related to user's functionalities initialization and processing as well as the system's ones. The latter ones are related to the monitoring of the ARGOS device status and detecting possible problems in order to provide alarms in case of necessity. This is done through the innovative implementation of a **Dynamic Geofencing system**.

The ARGOS control centre shall fulfil the following functionalities during its operation:

- Reception from the users of the monitoring parameters;
- Monitoring of the ARGOS Board/Device (i.e., availability and data);
- Watchdog system;
- Messaging system (push of data through the User device mobile application) that will update owners on the state of their monitored vehicles.

Below a quick overview of the monitoring functionalities.

- **Communication availability monitoring:** the Control Centre finds eventual holes in data transmission or not ordinary time gaps between consecutive observations. When an anomaly is detected, it realises a flag identifying the possible problem and the level of awareness that should be communicated to the user.
- **Dynamic Geofencing monitoring:** it checks if the last positional status of ARGOS device is inside of the associated Alarm Limit (AL). Besides, it analyses consecutive status observations in order to derive the possible path of the boat, verify if it is approaching the AL boundary and eventually give an estimation of the Approaching Time (AT). This parameter determines the level of awareness of the notification according to the Time to Alert definition.

### 3.3 USER APPLICATION

The Mobile and Web application allows the user to monitor its vessel and to receive alerts in case of anomalous behaviors or tampering attempts.

It provides several functionalities, below the most important ones:

- Authentication & Authorization - identity server 4 via JWT token;
- Notifications & Alerts – in case of anomalous behaviour or tampering attempt the user is informed by the system through alerts and notifications;
- 2D navigation map – the map allows to
  - draw polygons and circles to define the secure area around the boat (for theft or safety reasons)
  - define the mooring at anchor radius
  - visualize the boat position
- Turn on/off alarm - the interaction with the ARGOS device system is required because it allows the user to come into contact with his own alarm system. Therefore, features are provided to support this such as alarm activation and monitoring of data coming from the ARGOS device

#### 4 INITIAL RESULTS

The ARGOS project is still on-going, and its Demonstration will be carried out during this summer. Therefore the final results will be available only after summer. But some interesting initial outcomes from the subsystem integration and testing activities have been collected.

As part of the Integration and test activities some preliminary results show that the performance achievable in position determination by the ARGOS solution are very promising.

As it is possible to see from the figure below, the accuracy of the position it's around 2m (95% confidence level) considering also that the docked vessel was slightly and slowly moving on the horizontal axis. This level of accuracy will grant a reliable monitoring of the ship movements. This performance is only preliminary because it has been achieved in a nominal (i.e. not degraded) environment but it is still a very promising accuracy level.

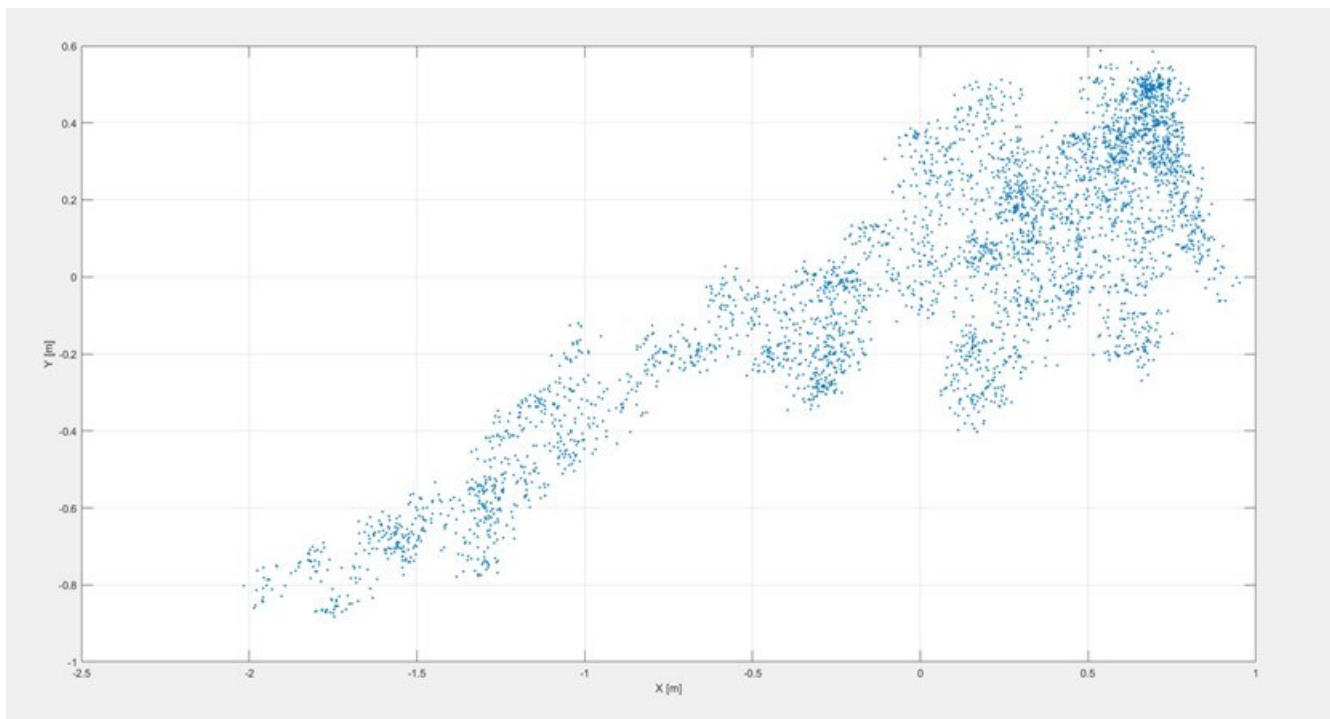


Figure 4 – ARGOS Solution Position Accuracy Test



The tests have been carried out in an AMER 110 SuperYacht of Permare Group with a length of 33 meters (see Figure 5) with the ARGOS Device connected to a Tallysman Dual Frequency L1/E1-L5/E5a Antenna.



Figure 5 – ARGOS Solution Testing Vessel

Another important achievement verified during the Testing Activities in Laboratory using simulated realistic scenarios, including open sky as well as impaired environments, was the benefit provided by the use of the upcoming Galileo new capability called **I/NAV Improvements**<sup>1</sup>.

Thanks to the Reed-Solomon code, the capability to decode the Galileo Navigation Message Ephemeris is improved and the advantage is even bigger in difficult environments (e.g. in a natural harbour with vegetation).

Relative signal level [dB]	% of decoded ephemeris		Ephem. Decod. Abs. Improv.	Ephem. Decod. Rel. Improv.
	Legacy Msg	I/NAV Improv.s		
-60	0%	4%	4%	∞
-59	3%	10%	7%	233%
-58	1%	26%	25%	2500%
-57	11%	46%	35%	318%
-56	26%	51%	25%	96%
-55	32%	56%	24%	75%
-54	35%	67%	32%	91%
-53	44%	69%	25%	57%

Table 1 – Absolute and Relative Improvement on the Galileo Navigation Message decoding with I/NAV Improvements

<sup>1</sup> See <https://www.euspa.europa.eu/newsroom/news/euspa-launches-testing-campaign-inav-improvements-implementation>



As it is possible to see from the Table 1, the improvement on the availability of the receiver ephemeris is also to an absolute value of 25-35% and with a relative improvement from 50% to 300% better than the standard GNSS-based solution.

This is directly reflected in the availability of the GNSS Position information and, therefore, this is a great advantage of the ARGOS Solution implementation.

Unlike the I/NAV improvements, the **OSNMA** signal is currently available, for testing, over the air, then, we were able to carry out testing activities in realistic conditions. Although the OSNMA signal is a subject of Public Observation Test Phase and is not fully operational, promising results have been achieved. The analysed OSNMA accuracy (static condition) results, show 1.61m horizontal and 2.61m vertical errors (95% confidence level) with respect to 1.61m horizontal and 2.55m vertical positioning accuracy without OSNMA. As a conclusion **OSNMA is not degrading the positioning accuracy** and **99.82% of navigation solution availability has been achieved**. This means that **the ARGOS Solution equipped device exploits cryptographically protected position fix** and can resist simple attack scenarios including artificially generated Galileo constellation as well as using recorded signal.

It has also to be noted that these results of the OSNMA performance testing has been achieved with a GNSS-only configuration, without the improvements granted by the integration of the GNSS data with the IMU data within the Navigation Engine of the ARGOS Device (that has been tested separately with synthetic data).

## 5 CONCLUSIONS AND WAY FORWARD

The ARGOS Solution, thanks to differentiating capabilities based on the new features of Galileo (OSNMA & I/NAV Message Improvement) and thanks to a scalable and modular architecture, is able to provide protection against thefts or risk of losing the mooring of the anchor point. Furthermore, it provides high robustness against environmental unintentional or intentional conditions and external factors.

In the scope of the ARGOS project, two scenarios have been identified in the use case of the Leisure Vessels: vessel at anchor in a pier (anti-theft) and vessel at anchor in a natural harbor (safety).

The ARGOS services have been implemented through an ARGOS Device that is responsible for the detection of anomalous behaviours, a User Application to receive alerts in case of anomalous behaviors, and a Control Centre to monitor the vessel and that merges and controls the inputs coming from the ARGOS Device.

The initial results reported show that the performance achievable in position determination by the ARGOS solution are very promising and that there are significant benefits provided by the use of the upcoming Galileo capability I/NAV Improvements.

The ARGOS services will be demonstrated during this summer with the system deployed on a boat at anchor in the Sanremo pier. The demonstration activities will be focussed on the alerting capabilities to detect anomalous movements of the vessel.

The intention of the ARGOS Consortium is to realize a commercial product starting from the work done during the project. The Leisure Vessels use case will be the first commercialization of the ARGOS Solution and the targeted date will be the 3<sup>rd</sup> Quarter (Q3) of 2023. The versioning approach we target for the ARGOS Solution is depicted in the figure below.

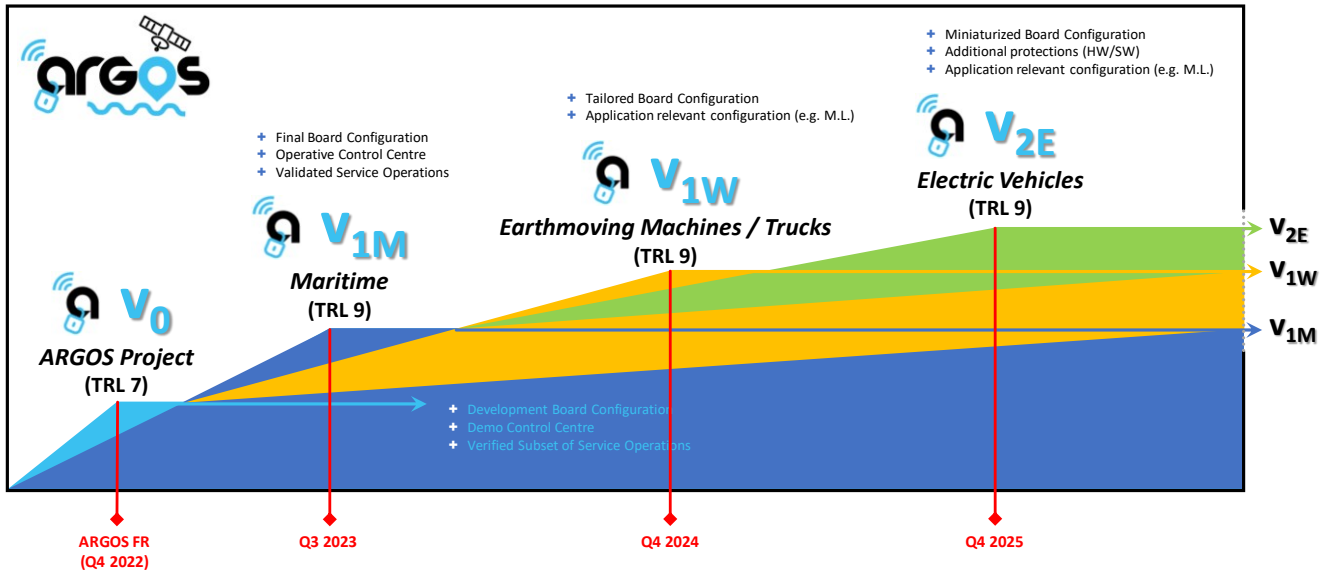


Figure 6 – ARGOS Solution Versioning Approach

## AUTHORS SHORT BIO



**Franco Gottifredi** has a Master degree in Aerospace Engineering and 27 years of experience in GNSS relevant activities: e.g. receiver D&D, complex system technical coordination (i.e. Galileo System), etc. He is author of 3 patents: one on complex and distributed networks synchronization technique, another on an autonomous planetary navigation system and the last one on a method for data cryptography for low computational power devices (e.g. IoT). He is founder and director of GEA Space with activities in Navigation, SatCom and Earth Observation and of WAY4WARD with main focus on NewSpace solutions based on innovative algorithms (e.g. AI).



**Marco Cappella** has a Master degree in Computer Engineering, almost 13 years of experience in analysis, design, development, testing and integration of desktop, web, mobile applications with a strong knowledge of Service Oriented Architectures (SOA) and Microservices Architectures. He has 8 years of experience as technical leader and 4 years as Project Manager in European and regional co-funded projects. He worked also as tendering engineer in the context of European and regional calls and experienced several projects in the following domains: aerospace, ATM, maritime, emergency and cultural heritage. . Unfo



**Krzysztof Marcinek** has a Master degree and the Ph.D. in Electronic Engineering. He has a 10+ years of experience in design and development of electronic devices and application-specific integrated circuits. In 2016 he co-founded ChipCraft private company, where he is leading a digital design team responsible for development of custom microcontrollers including RISC-V and GNSS navigation processors and microcontrollers. He has authored or co-authored over 20 works including: book chapters and papers published in conference proceedings or journals. He is also a co-author of 10 registrations of physical layout of production photomask set of integrated circuits in Polish Patent Office.



**Alina Anton** has a Ph.D. in International Relations and Security Studies and more than 10 years of experience in business consultancy, development and commercialization of innovative products on the market. She is co-founder of ARIA UNITED company, leading a team of experienced consultants specialized in drafting business plans, testing and validation of new product ideas, obtaining financing for innovative companies, including startups and spin-offs. Previously, Alina Anton has lead the research and development team of a leading IT company of Romania for 5 years.



**Barbara Amerio** is an Italian superyacht builder. In the family business for more than 30 years. Italian Marine Industry Association board member and for the second time President of superyacht sector. First woman with this rule. President of nautical sector till 2019 of the General Confederation of Italian Industry in the territorial section of Imperia. First woman with this rule. Italian design ambassador in Kuwait for the Italian design day. Brand Ambassador for Italy at Dubai expo 2020 for yachting. Amer Yachts Eco-sustainability manager for creating a green attitude in superyacht sector in synergy with Volvo Penta Swedish company. Involved in projecting innovative vessels with the brand Amer Yachts. All the production has been awarded or nominated in several international competitions concerning design and innovation and has obtained the best votation in Green plus certifications by Rina register. Amer Yachts has introduced the concept eco-design in yachting in 2013. A deep knowledge about technical rules in superyacht sector, sales and charter fields.