AGIS4RAIL

Assisted GNSS with Imaging sensors for Rail applications

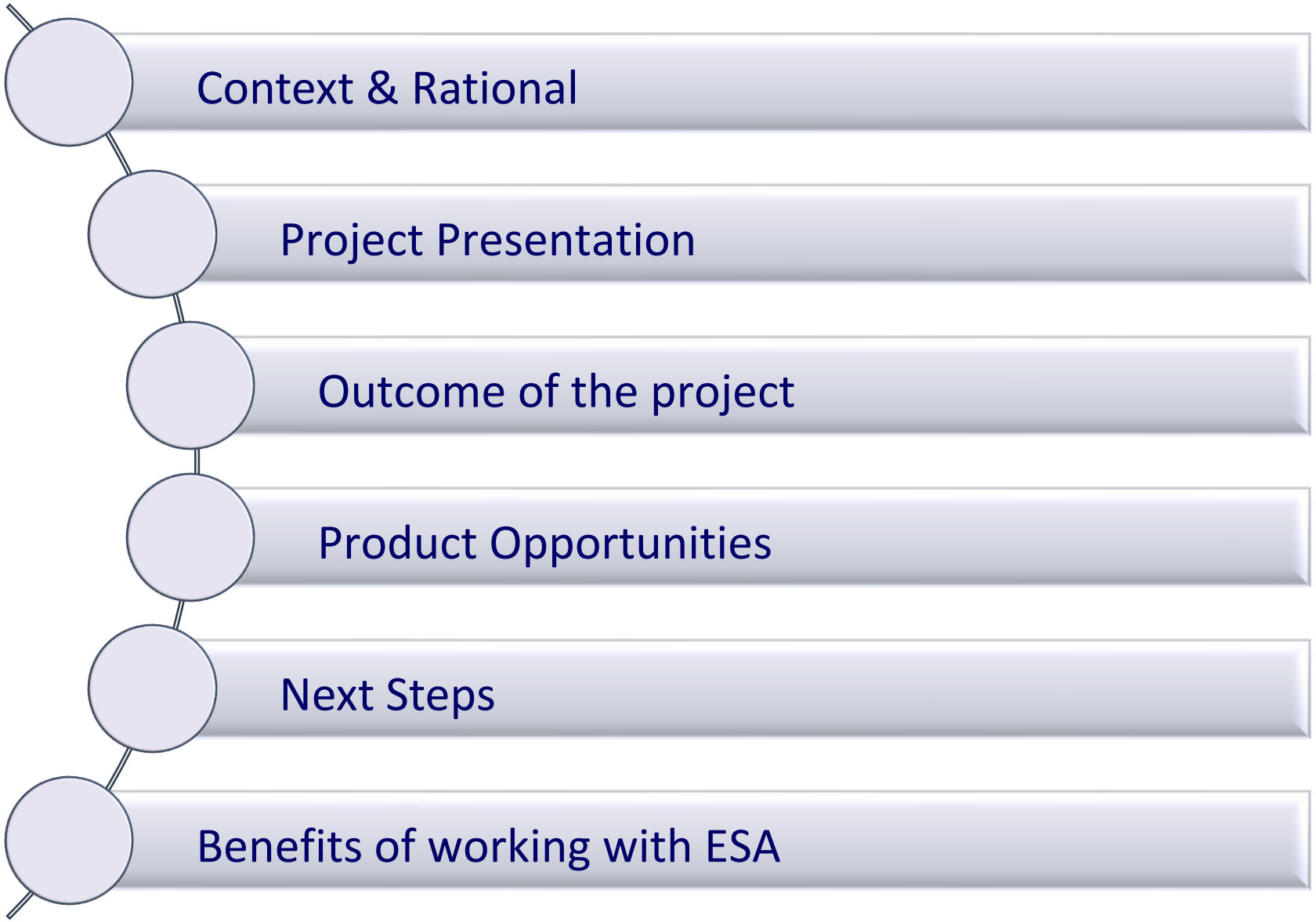
FINAL PRESENTATION

NAVISP ELEMENT 2 – ESA AO/1-10516/20/NL/MP (Issue 1.0)

18 January 2024 – Videoconference

Speakers: *P. Nencioni , S. Esposito Mocerino*

Agenda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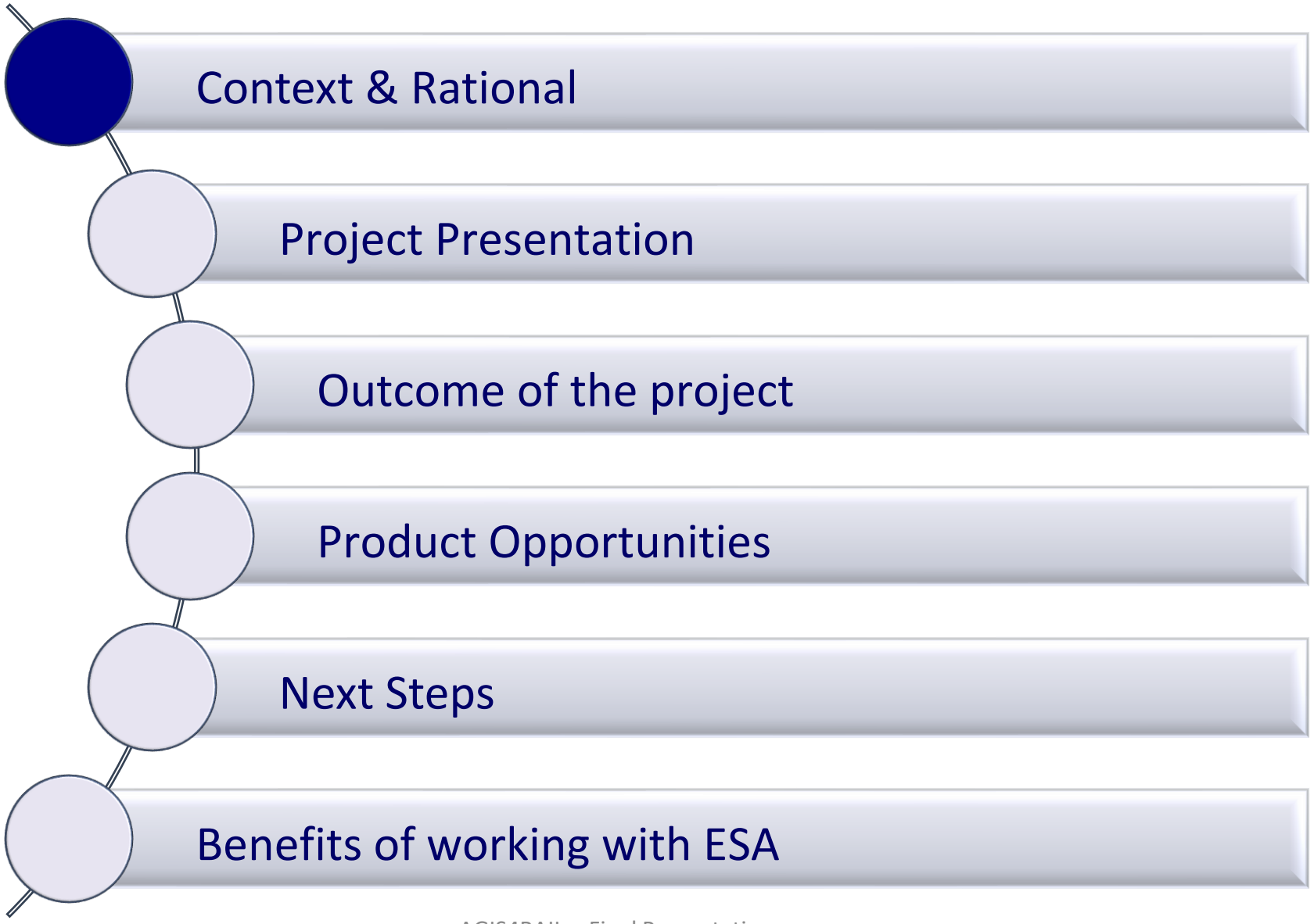
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Introduction

Subject: NAVISP Element 2, CALL FOR PROPOSAL

Ref: ESA AO/1-10516/20/NL/MP (Issue 1.0)

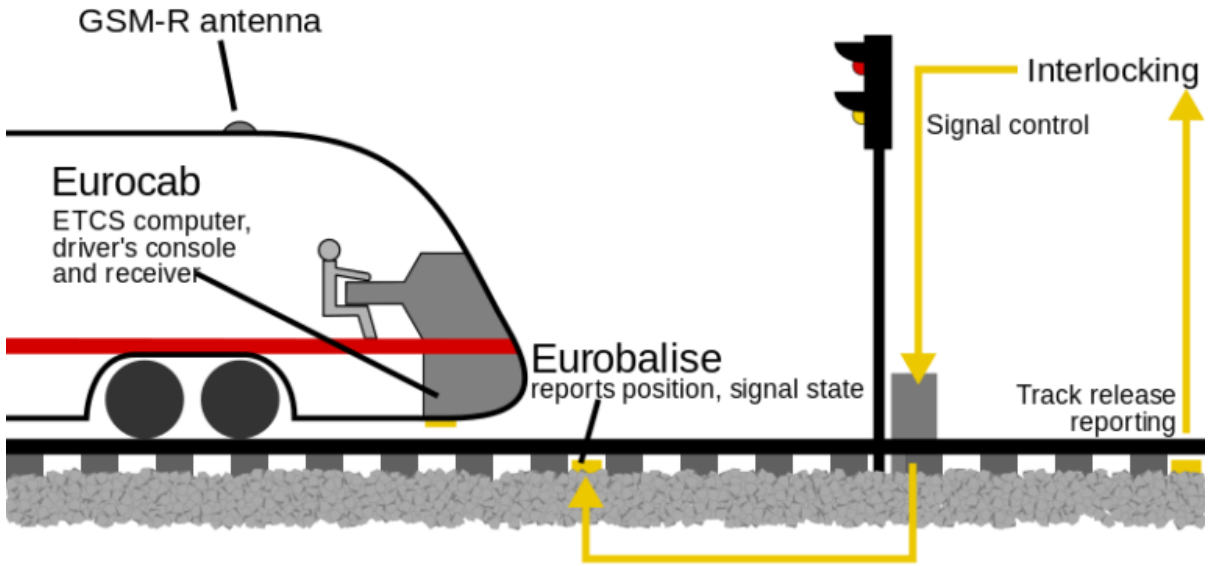
Proposal Title: Assisted GNSS with Imaging sensors for Rail applications (AGIS4RAIL)

Proposal Ref: No. 019-22-AS-V1.0 (dated 25th April 2022)

With reference to the above Call for Proposals, INTECS Solutions S.p.A. is pleased to present our project: **AGIS4RAIL**.

AGIS4RAIL aims at obtaining the train absolute position exploiting the fusion among GNSS and imaging sensors. The latter are cameras that have the objective of reading QR codes deployed in the track area. The data fusion is performed through a robust voter.

Context & Rational: ERTMS



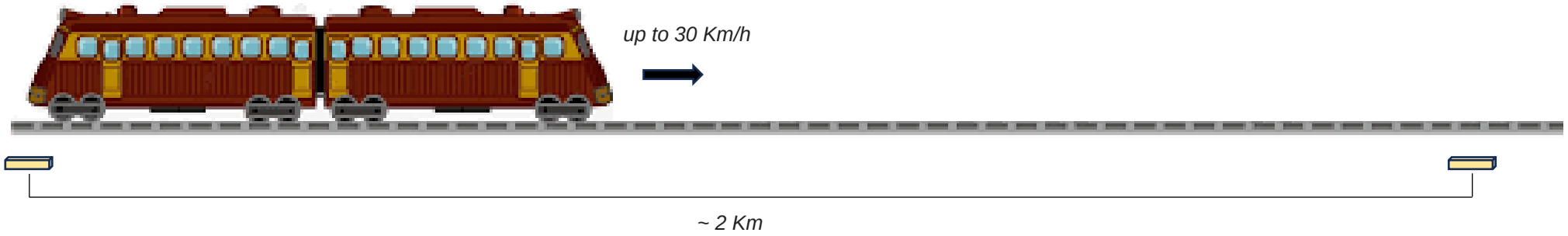
Eurobalise

Rail signalling system aims to regulate the rail traffic, keeping trains away from each other and avoiding accidents.

In a railway signalling system, knowing the position of the train has vital importance for correct and safe traffic control.
The European standard for achieving railway interoperability is currently the ERTMS, which make use of **balises** to determine the train's position.
A balise is an electronic beacon or transponder placed between the rails of a railway as part of an automatic train protection (ATP) system

Context & Rational: SoM problem

Unscheduled Start of Mission



Railway lines have availably problem especially when a train loses its position between two balises, for example when the on-board system needs to be restarted and a new mission starts (SoM).

In this scenario, the train is forced to proceed on sight until the next balise (that could be some kilometres away) reducing the capability of the line and causing delays on all the schedule of the line.

Context & Rational: Our Solution

A cheap alternative to the eurobalise could be based on GNSS Receivers, but…

… the European ERTMS regulation applies strict safety standards that do not allow the use of the GNSS system as the only positioning system for railway signalling.

The promising railway signalling market cannot currently be faced with products that exploit satellite positioning.

AGIS4RAIL is a useful solution for the train positioning when it has to identify its absolute positioning after that the ERTMS signalling system loses these information thanks to the integration of positioning information provided by a **GNSS** receiver and the **image sensors.**

AGIS4RAIL will be useful also in other market applications with common requirements like undergrounds, trams, buses, cars, trucks or drones

Intecs Background

Intecs technological background required for the development of AGIS4RAIL project is summarized below:

- Extensive experience with embedded system and development of safety critical applications.
- A solid background in the Railway sector, achieved with the development of systems such as SIRIO-LX.
- A GNSS expertise, acquired through several project, such as GIASONE, G-PASSION and SPACE4LIFE.
- The ownership of Microsek, a certified OS, already employed in existing Railways' systems.

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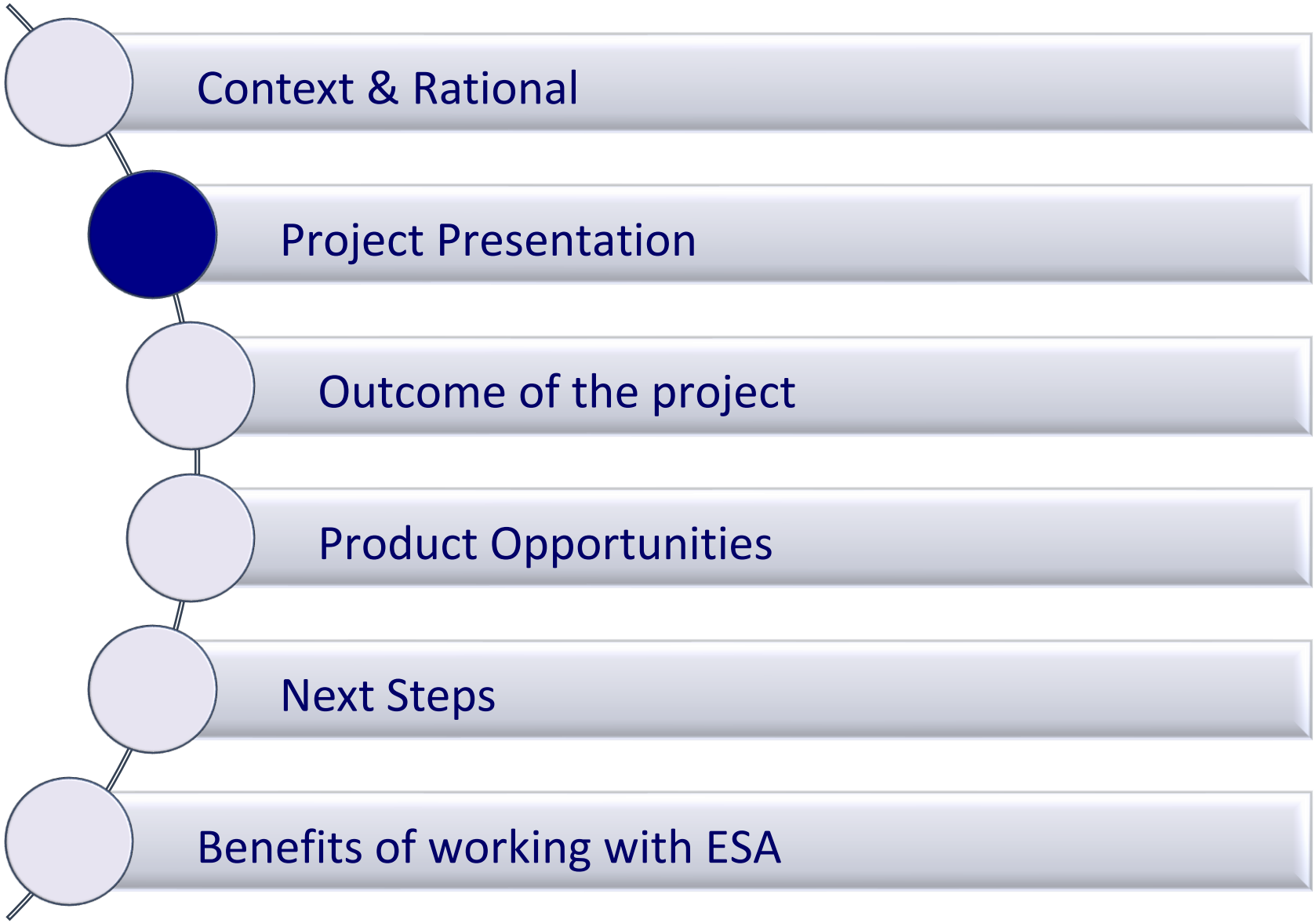
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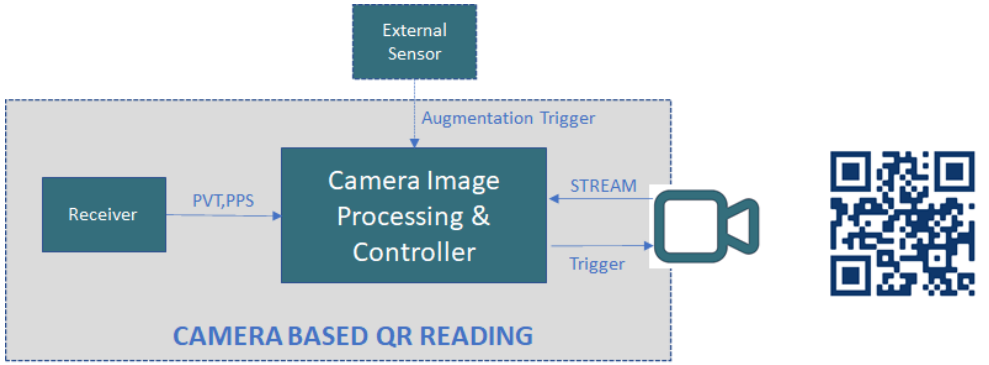
Project Presentation: System Overview

The train localization function of **AGIS4RAIL** is based on GNSS positioning aided by imaging sensors.

The additional positioning information is provided through a camera-based navigation system that makes use of QR-codes along the tracks, in predetermined and known position.

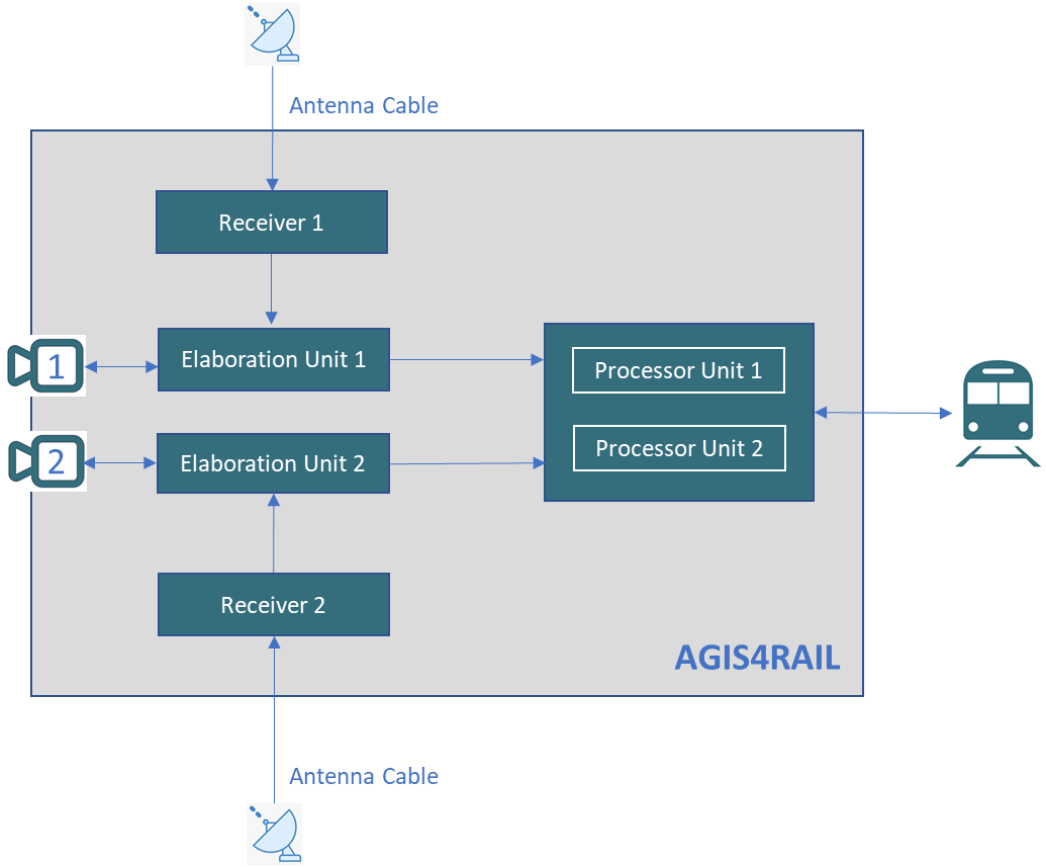
For identifying the fiducial point crossing time and to allow the comparison among the PVT solution provided by a GNSS receiver, the output of the camera frames is timestamped.

AGIS4RAIL exploits the data from the GNSS receiver (PVT and PPS) to generate the trigger for the camera. To augment the trigger generation, the system includes an external clock synchronizer.



Project Presentation: Processing Chain

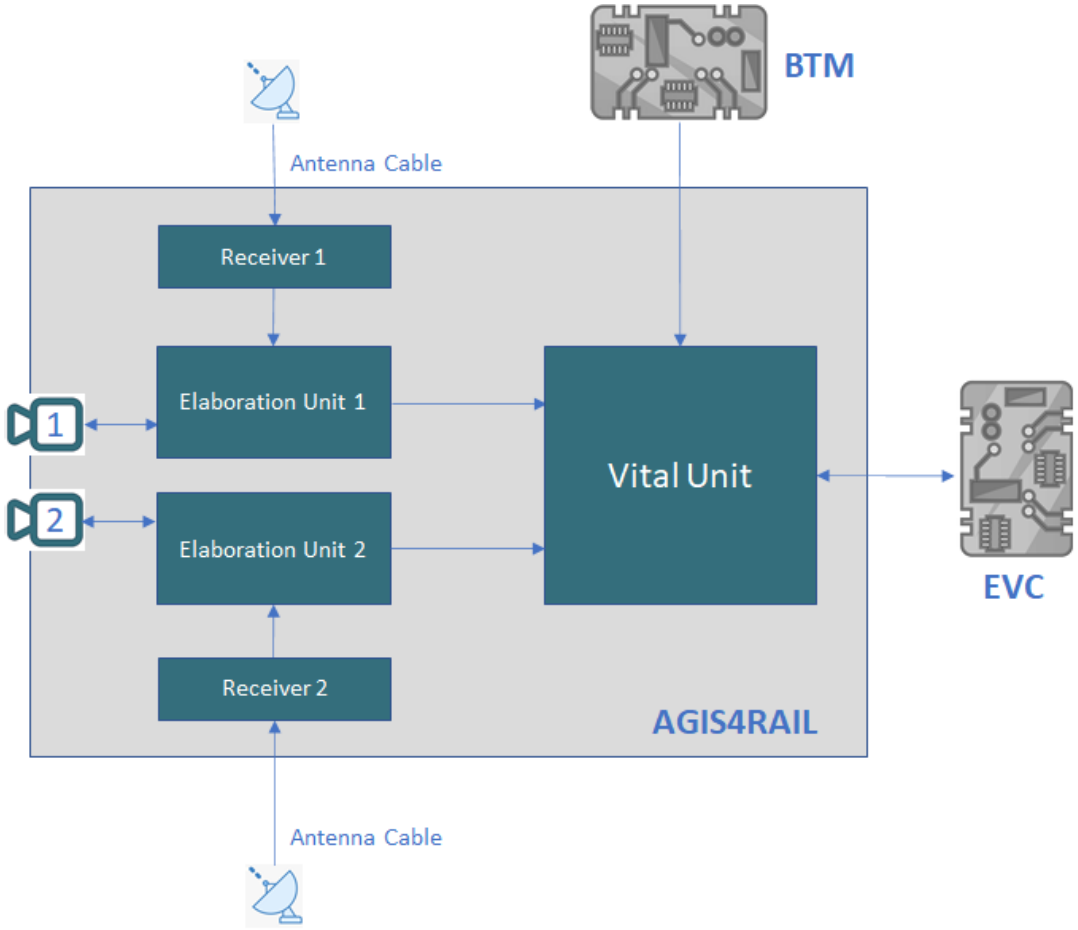
The architecture of **AGIS4RAIL** involves the use of a “2 out of 2” redundant processing unit.



The components that are not natively designed as 2oo2 will be duplicated. Therefore, in addition to this 2oo2 processing unit, there are 2 GNSS receivers, 2 Cameras and 2 Elaboration units.

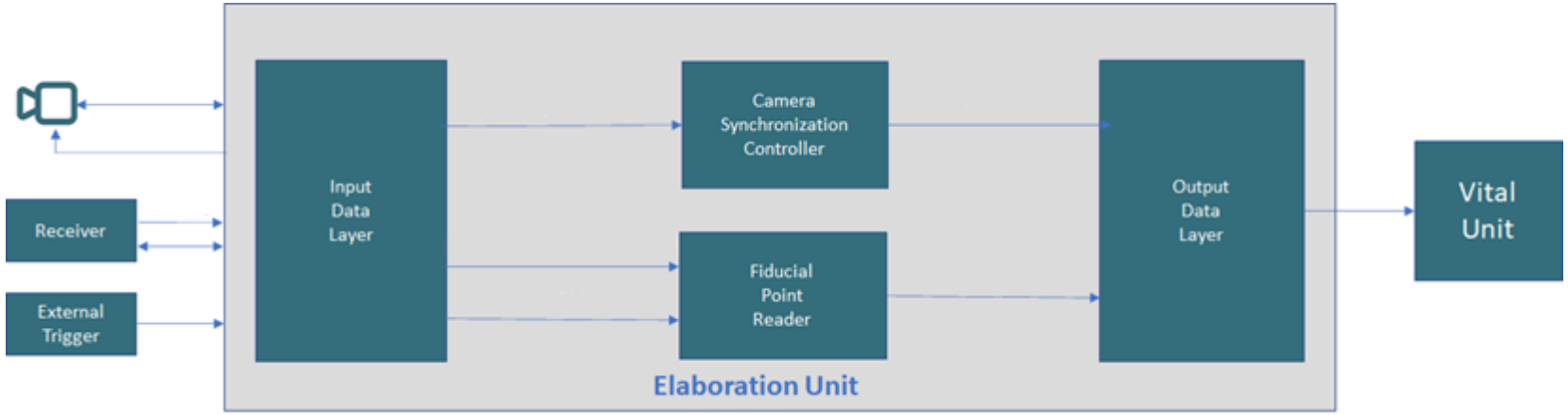
Project Presentation: System Boundary

AGIS4RAIL interfaces with the BTM (Balise Transmission Module) and the EVC (ERTMS Vital Computer). Under this perspective, AGIS4RAIL interacts with the EVC as a BTM.



Project Presentation: Elaboration Units (1/2)

The Elaboration Units oversee the interface with the sensors and the preliminary processing of the raw streams, executed by the camera synchronization controller and the Fiducial point reader. The output of this preliminary process is then sent to the vital unit.

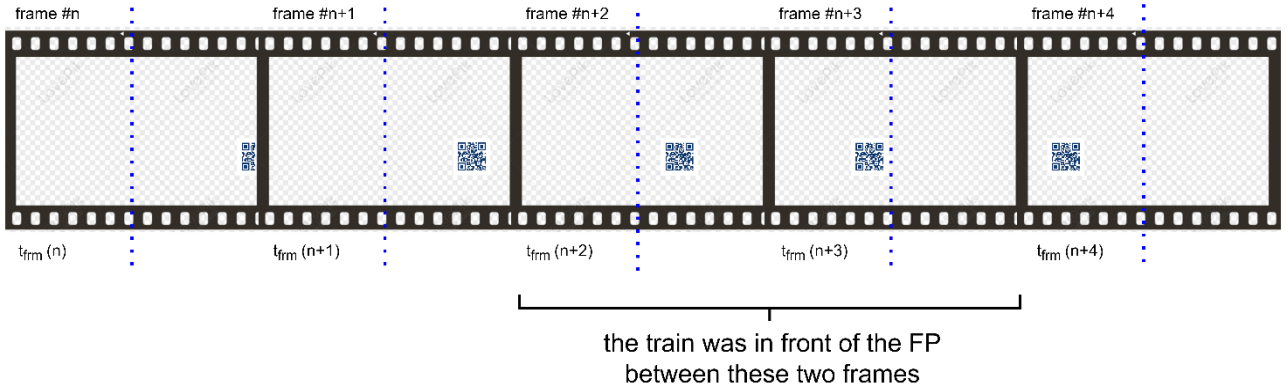


The Elaboration Units have four main components:

- The input data layer, implementing the communication interfaces to the GNSS Receiver and Optical sensor.
- The Output Layer, implementing the communication interface to Vital Unit.
- The Camera Synchronization Controller, responsible of the camera synchronization using a clock signal.
- The Fiducial Point Reader, which parses the GNSS and Optical sensor inputs.

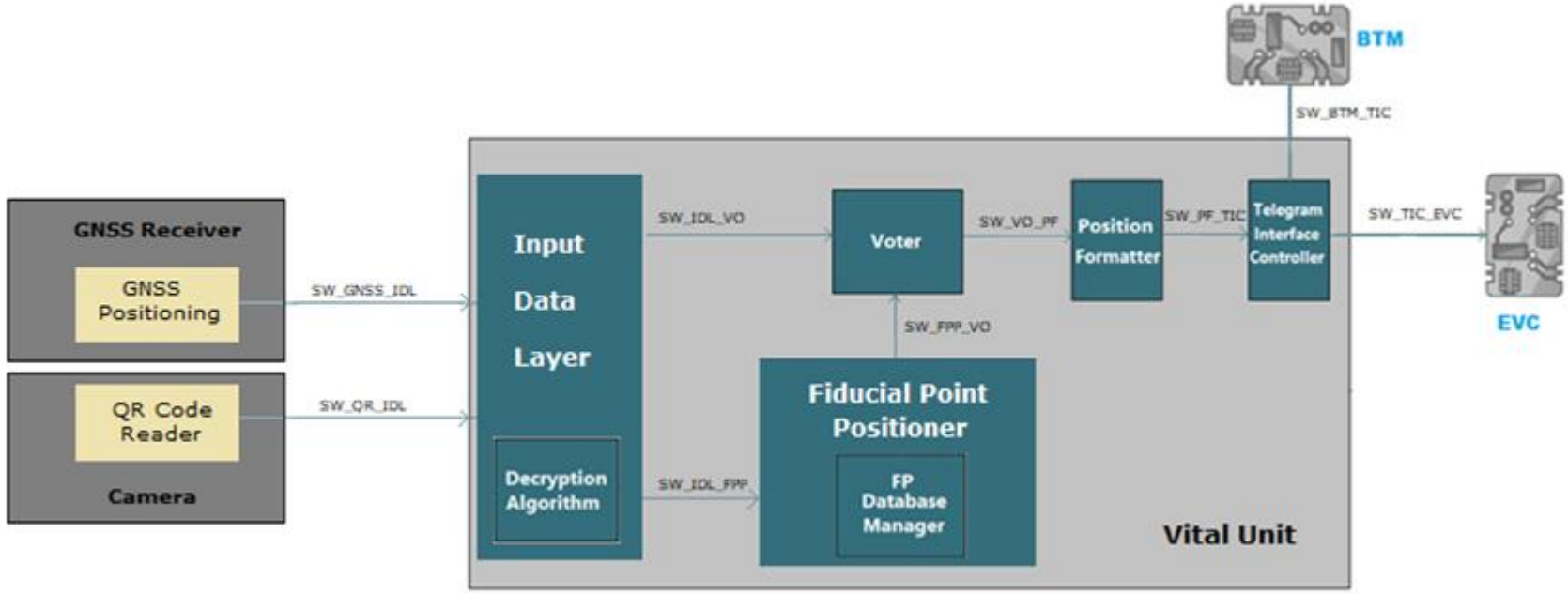
Project Presentation: Elaboration Units (2/2)

The Elaboration unit also manages the Camera input, and particularly the estimation of the fiducial point trespassing timestamp.



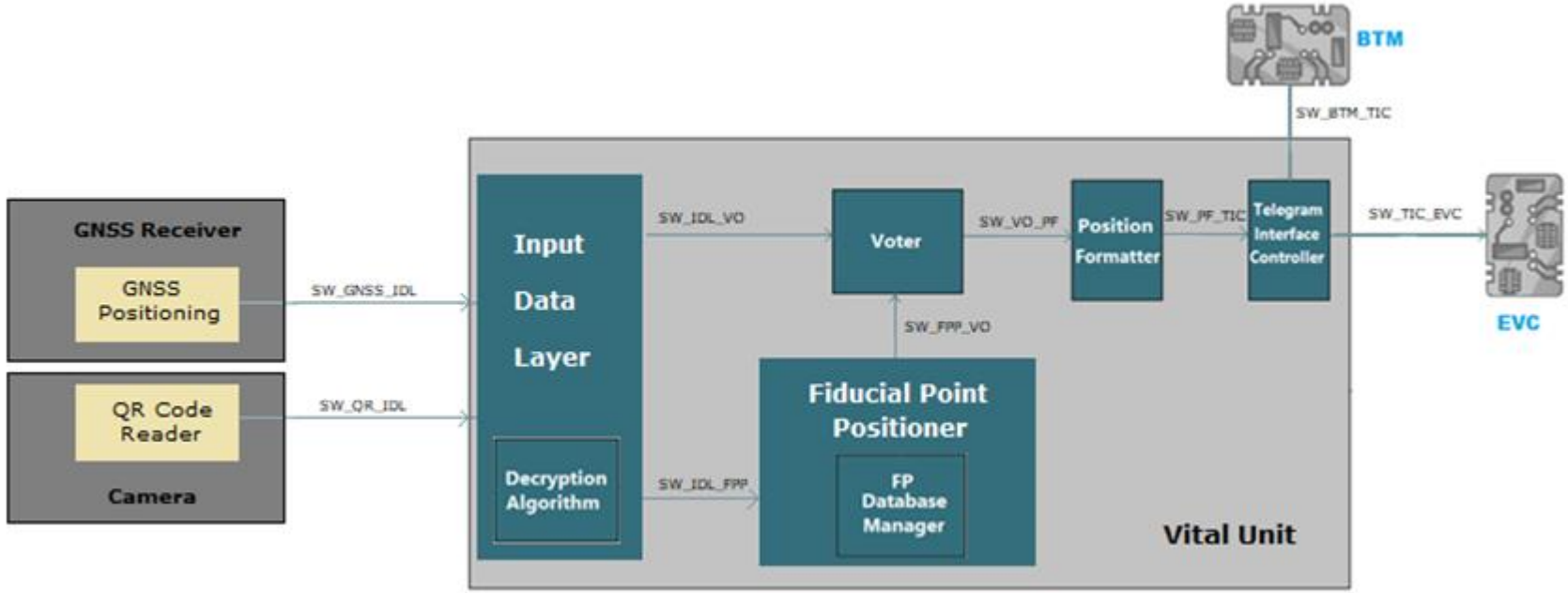
The Elaboration unit accepts the Camera Input only if the same code is read at least two consecutive times, in order to estimate the timestamp at which the sensor has passed over the fiducial point, otherwise the data are discarded and the system waits for the next input.

Project Presentation: Vital Unit



The Vital units is a platform implemented following the 2oo2 logic. This unit implements the core software of AGIS4RAIL system. It will process the data received from the Elaboration Units to perform the position estimation through the fiducial points and return the formatted output to the EVC.

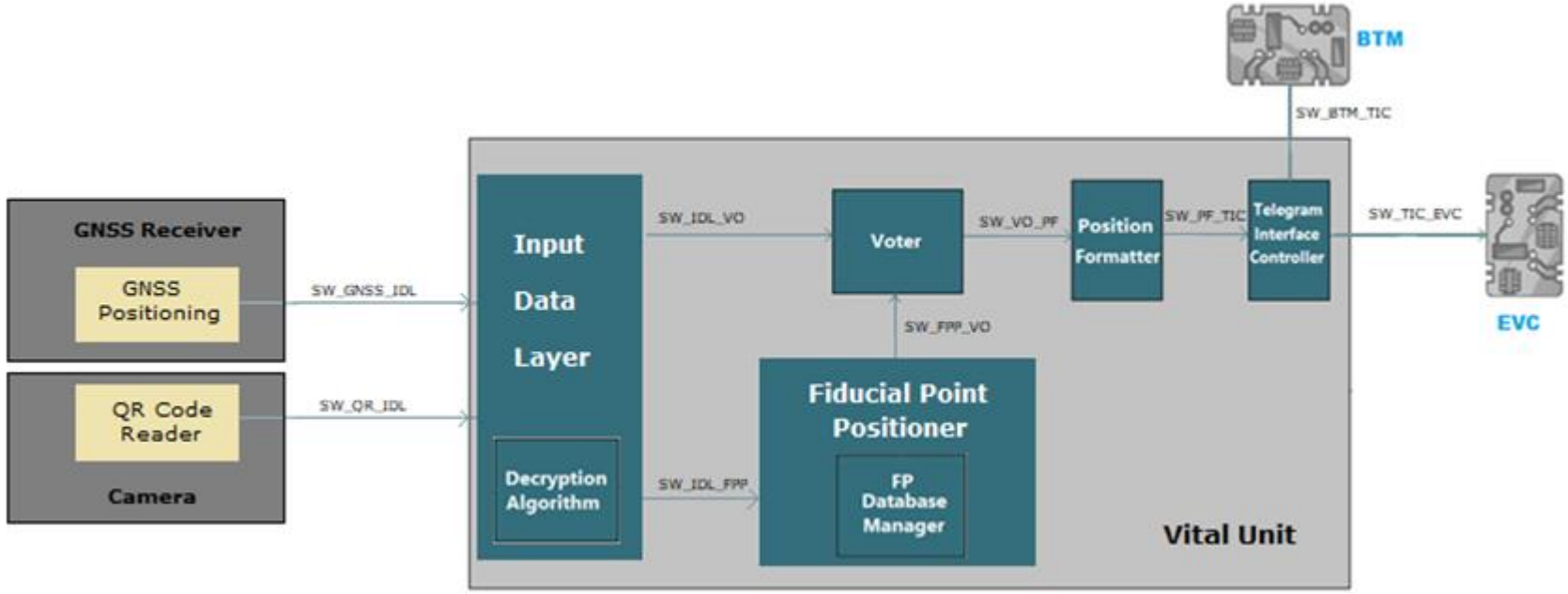
Project Presentation: Vital Unit Software



The Software running on the Vital Unit includes five different subcomponents:

- The Input Data Layer, implementing the interfaces toward the Elaboration Unit and also the decoding algorithm for the data received by the optical sensor.
- The Voter, which estimates the train position.
- The Fiducial Point Positioner which checks the optical sensor input against an internal database.
- The Position Formatter, which format the output following the train standard.
- The Telegram Inteface Controller, which read the balise telegram during the normal train functions and send the system generated BTM to the EVC when AGIS4RAIL is enabled.

Project Presentation: Data Processing



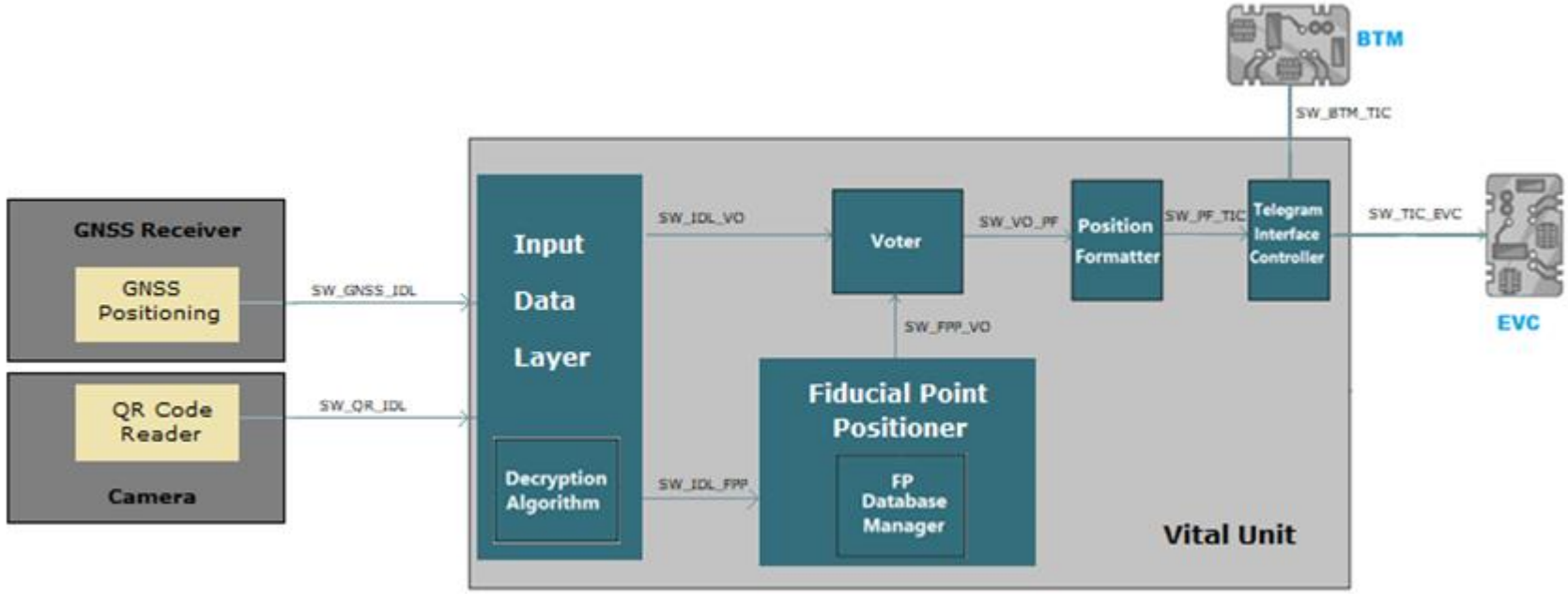
The Vital Unit will receive at fixed intervals the GNSS data and the QR Code data, if they are available.

QR Code data is decoded, then checked against an internal database.

The Voter periodically checks for inputs and, when available, calculates the position and the accuracy.

When the Voter has a minimum number of inputs and the estimated position error is lower than the threshold of 5 meters, then the output is formatted as a BTM telegram and sent to the EVC

Project Presentation: Idle and SoM Modes (1/2)



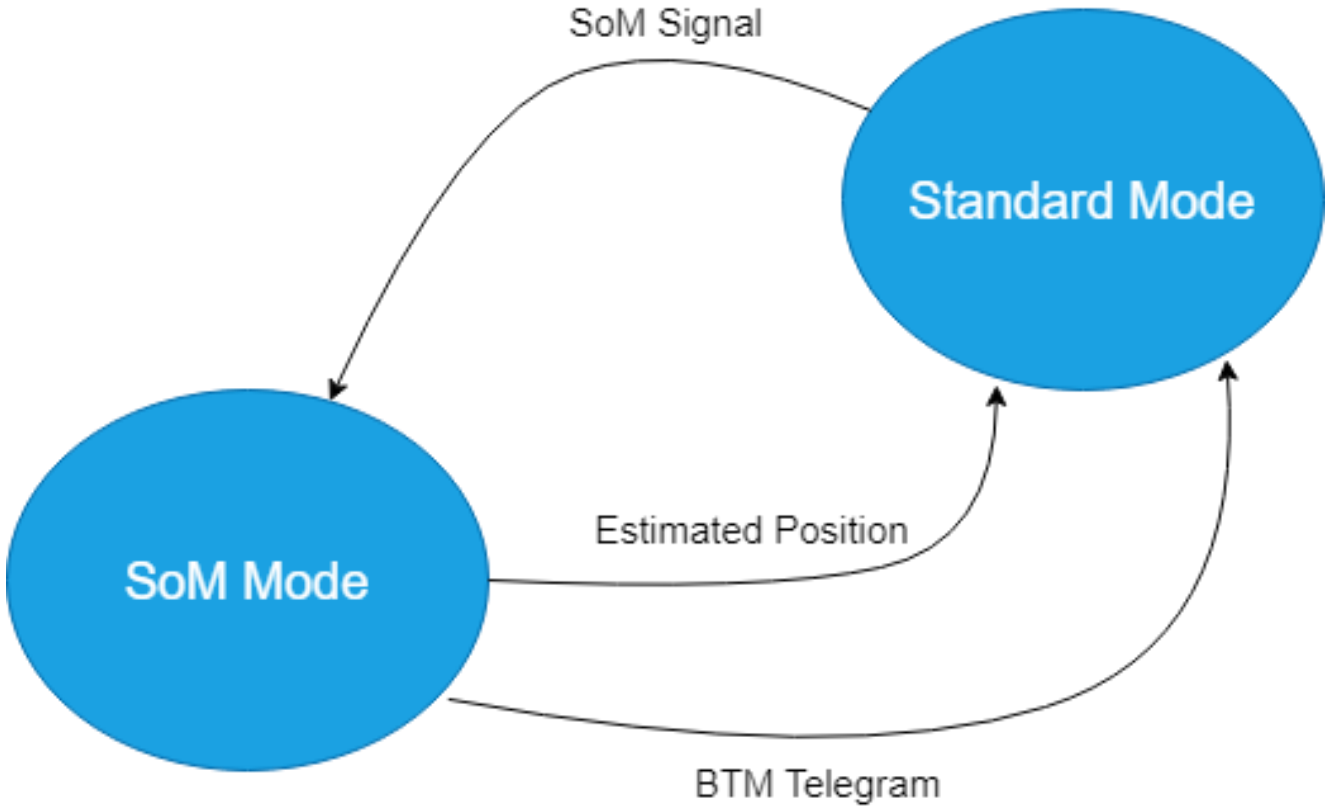
AGIS4RAIL foresees two operative modes: Idle Mode and SoM mode.

It usually works in Idle Mode, acting as a relay of the balise telegram.

This way, AGIS4RAIL can be installed seamlessly on a train control system, no alteration needed.

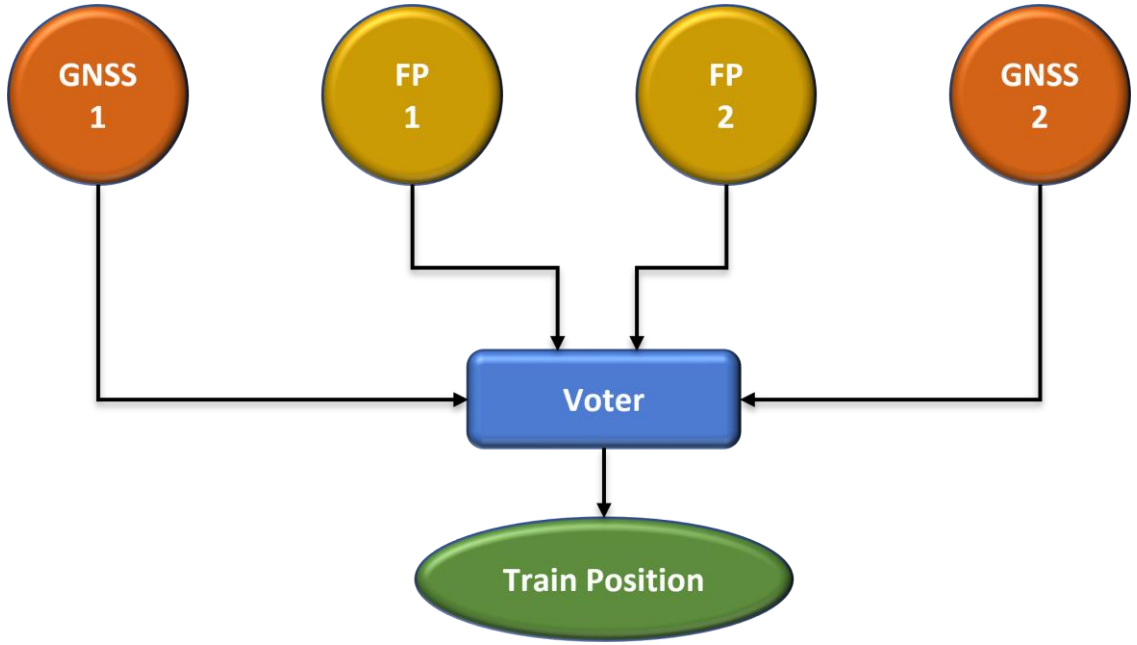
When a SoM event is registered and the signal is sent to AGIS4RAIL, it starts scanning for inputs and returns in Idle Mode after the first output.

Project Presentation: Idle and SoM Modes (2/2)



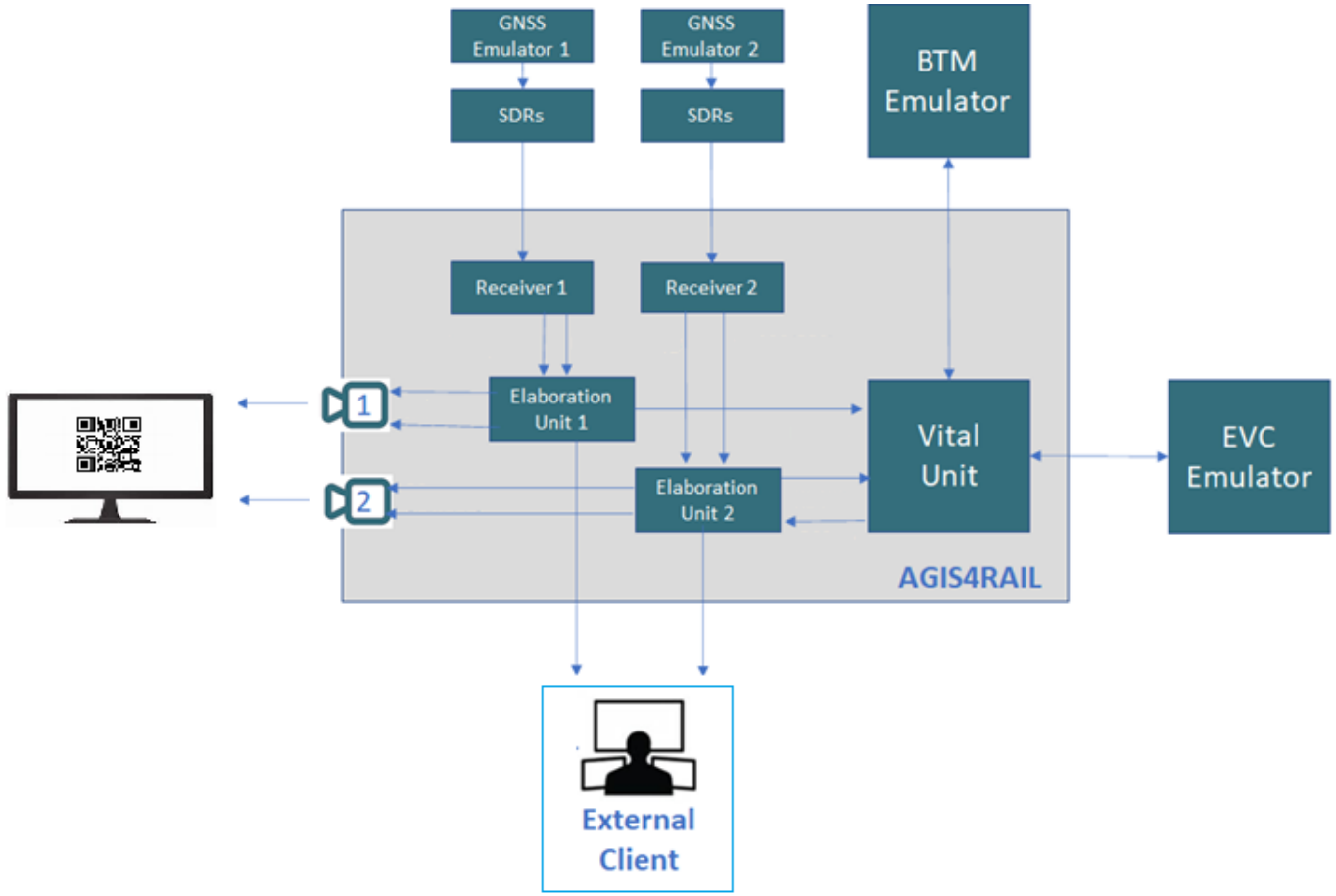
Project Presentation: Voter

The voter implements a consistency check among the data taken as input by the four processing chains: two GNSS receivers and the two FP Positionings. The check is implemented through a set of logics that accounts for different factors including the temporary unavailability of some of the sensors and the correct sequence of detected FPs.



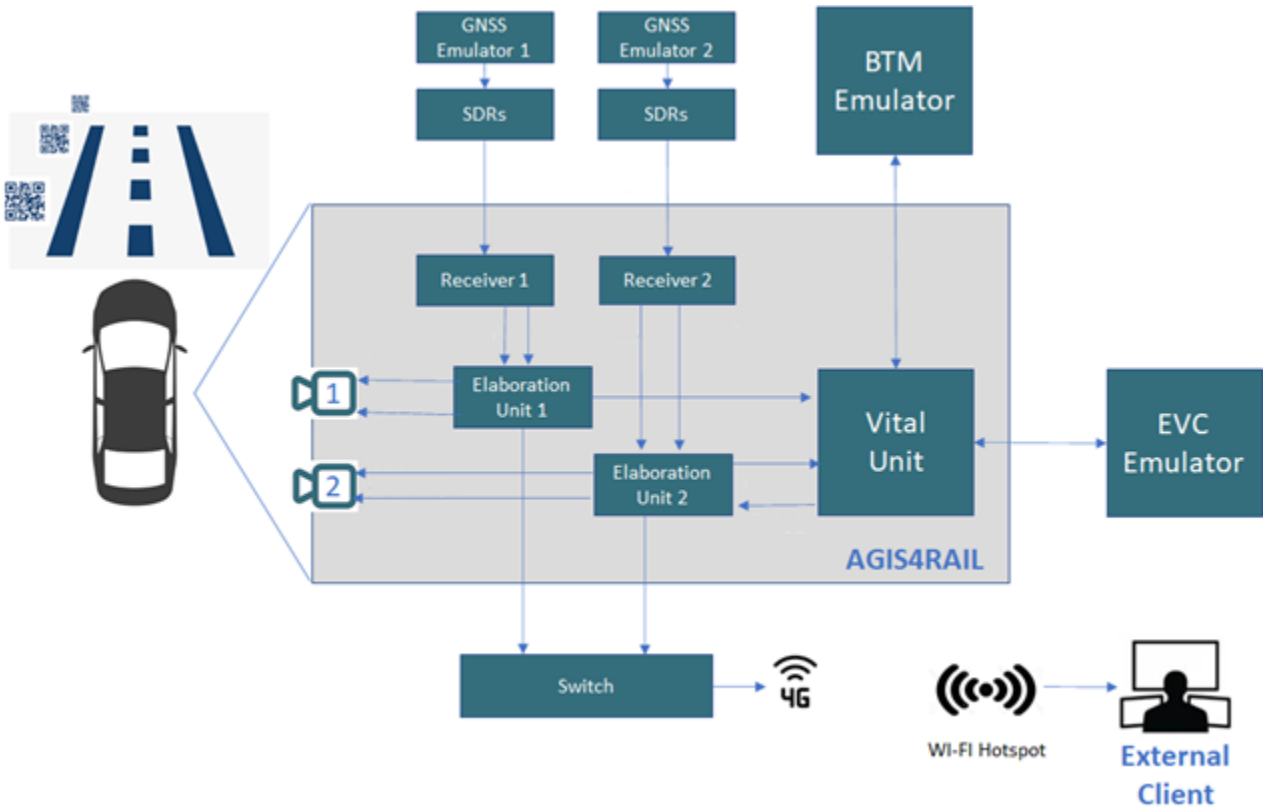
Project Presentation: In-Lab Verification

The first test environment is recreated in lab with the cameras in a fixed position pointing to a monitor with a high refresh rate. The monitor is programmed to show a QR Code for a fixed interval, which can be configured to simulate a travel speed from 10 to 30 Km/h.



Project Presentation: On-Field Validation

The second test environment consists of a car on a track. The prototype is mounted on the vehicle, with the cameras pointed to the side where the QR code are set, while the GNSS antennas are on the roof.



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Outcome of the Project: Testing

AGIS4RAIL foresaw three test campaigns:

- Unit Test Campaign, to verify the correct behavior of the single components.
- Integration Test Campaign, to verify the interfaces between each component
- System Test Campaign, to verify the system behavior in a controlled environment and on the field.

Outcome of the Project: Unit Tests

ID	Name	Description
AGIS4RAIL-TC-01	GNSS Receivers and Antennas	The objective of this test case is to verify the functionalities of the GNSS Receivers Component. The test case will cover the following functionalities: • The correct connection to the antenna for both receivers. • The correct connection to the computer for both receivers. • The correct reception of data for both receivers.
AGIS4TAIL-TC-02	Clock Synchronizer	The objective of this test case is to verify the functionality of the Clock Synchronizer Components. The test case will cover the following functionality: • Correct operation of the component. • Correct synchronization of clock with predetermined signal.
AGIS4RAIL-TC-03	QR Readers Test	The objective of this test case is to verify the functionality of the Camera Component related to acquiring new QR codes. The test case will cover the following functionality: • Correct scanning of QR codes. • Correct output format.
AGIS4RAIL-TC-04	Microcontroller Test	The objective of this test case is to verify the functionality of the microcontroller to correctly run a program. The test case will cover the following functionality: • Compiling and loading a program via the IDE; • Correctly run the loaded program.

Outcome of the Project: Integration Tests

ID	Name	Description
A4R-ITC-01	Vital Unit Hardware Software Integration	The objective of this Test Case is to test the HW/SW interface of the component Vital Unit.
A4R-ITC-02	Microcontroller Hardware Software Integration	The objective of this Test Case is to test the HW/SW interface of the component Microcontroller.
A4R-ITC-03	Microcontroller Camera Integration	The objective of this Test Case is to test the interface between the Microcontroller and Camera.
A4R-ITC-04	Microcontroller Receiver Integration	The objective of this Test Case is to test the interface between the Microcontroller and the GNSS receiver.
A4R-ITC-05	Vital Unit Microcontroller Integration	The objective of this Test Case is to test the interface between Vital Unit and the microcontroller.
A4R-ITC-06	GNSS Receiver, Camera and Clock Synchronizer Integration	The objective of this Test Case is to test the interface between GNSS receiver, Camera and Clock synchronizer

Outcome of the Project: System Testing (1/2)

ID	Name	Description
A4R-TC-01	QR-Code Positioning	The objective of this Test Case is to demonstrate that AGIS4RAIL systems shall be able: • To detect QR-code • To decode the detected QR-code • To estimate QR code detection time • To archive in database the QR-code and their content
A4R-TC-02	GNSS Positioning	The objective of this Test Case is to demonstrate that AGIS4RAIL systems shall be able: • To receive GNSS position
A4R-TC-03	Voter	The objective of this Test Case is to demonstrate that AGIS4RAIL systems shall be able: • To provide the absolute train position by voting the QR-code and the GNSS position

Outcome of the Project: System Testing (2/2)

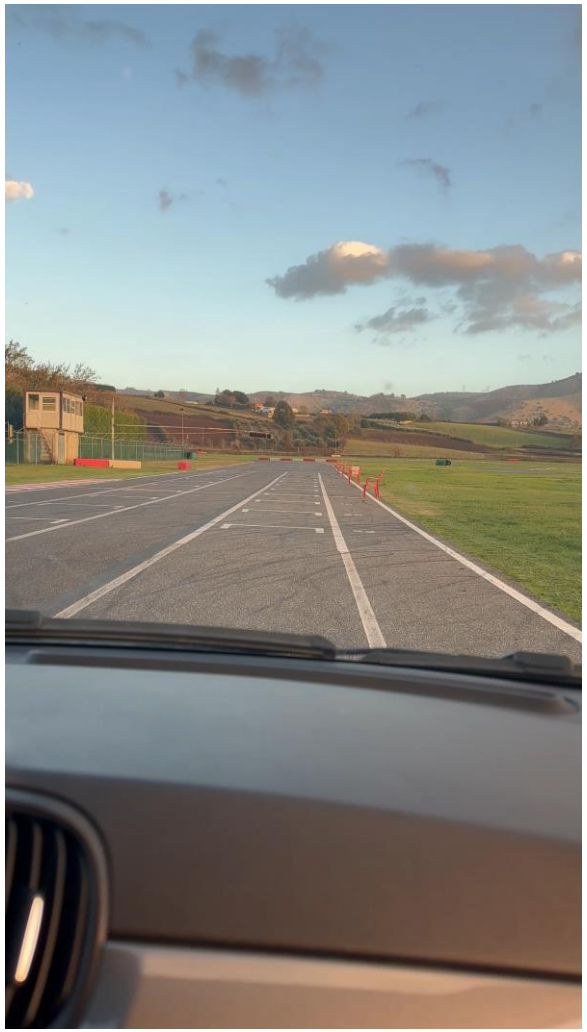
ID	Name	Description
A4R-TC-04	Telegram Handling	The objective of this Test Case is to demonstrate that AGIS4RAIL systems shall be able: • To write and send a telegram to EVC • To correctly handle the BTM telegrams in input
A4R-TC05	Performace	The objective of this Test Case is to demonstrate that AGIS4RAIL systems shall be able: • To have an availability of train position at least 95% • To have a QR-code detection rate higher than 10% • To have a QR-code decoding rate higher than 10% • To have an accuracy of the position made through the QR code lower than 5 meters • To have an accuracy of the position made through the GNSS lower than the Protection Level when the Protection Level is lower than the Alert Limit. • To have an accuracy of the position made through the voting lower than the Protection Level when the Protection Level is lower than the Alert Limit. • To have an unavailability due to environment condition lower than 50% for illumination and 95% for fog, rain and snow

Outcome of the project: In-Lab Test Results

The first test was executed inside Intecs' hardware laboratory.
The cameras were fixed on a monitor reproducing QR-Code images for brief intervals, based on the simulated train speed, while the GNSS Receiver were connected to a simulator.

The aim of the test was to check the correct functionality of the prototype before the on-field testing and to verify the system response in different conditions.

Outcome of the project: On-Field Test Results



The second test was executed on a go-kart track field on which 5 different fiducial points were installed 10 meters from each other.
The tests consisted of 30 laps around the field, with different conditions.

AGIS4RAIL correctly identified the position of the vehicle at every lap, often at the first fiducial point.

The maximum speed supported by the system is 35 Km/h, which is 5 Km/h above the limit of a train after a SoM event.
The maximum estimated error for the system is of 4,76 m, which is inline with the requirements of 5 m.

In conclusion, the on-field test campaign successfully showed the potential of AGIS4RAIL system.

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Product Opportunities: AGIS4RAIL Features

Main aspects and characteristics of AGIS4RAIL:

- Increase the performance of the positioning system both in terms of **availability** and in terms of **integrity**. Particularly, the use of imaging sensors acts like a mitigation towards all those local effects that can degrade the performance of a GNSS-based positioning systems like the multipath

- improve the **resiliency to jamming and spoofing attack**. In fact, even under jamming attack the system can counts on the imaging sensors. In case of spoofing, the imaging sensors can be exploited to validate the output of the GNSS PVT estimation. To avoid spoofing of the QR-code landmarks, they will contain data for the authentication of the landmark itself.

Product Opportunities: Future Opportunities

Looking forward, AGIS4RAIL foresees:

- Convince the potential users of the advantages of the proposal solution: establishing new contacts with the Italian railway infrastructure managers (RFI, Ferrovie Nord, etc.) and railway undertakings (Trenitalia, TreNord, etc.) to present the implemented solution performances.
- Identify an industry partnership for the product commercialization: intending to start a collaboration with a current ERTMS on board system supplier, to identify how the AGIS4RAIL solution can be integrated into their product. Remaining in Italy, but not only, Alstom and Hitachi are already cooperating with Intecs in industrial and research project.

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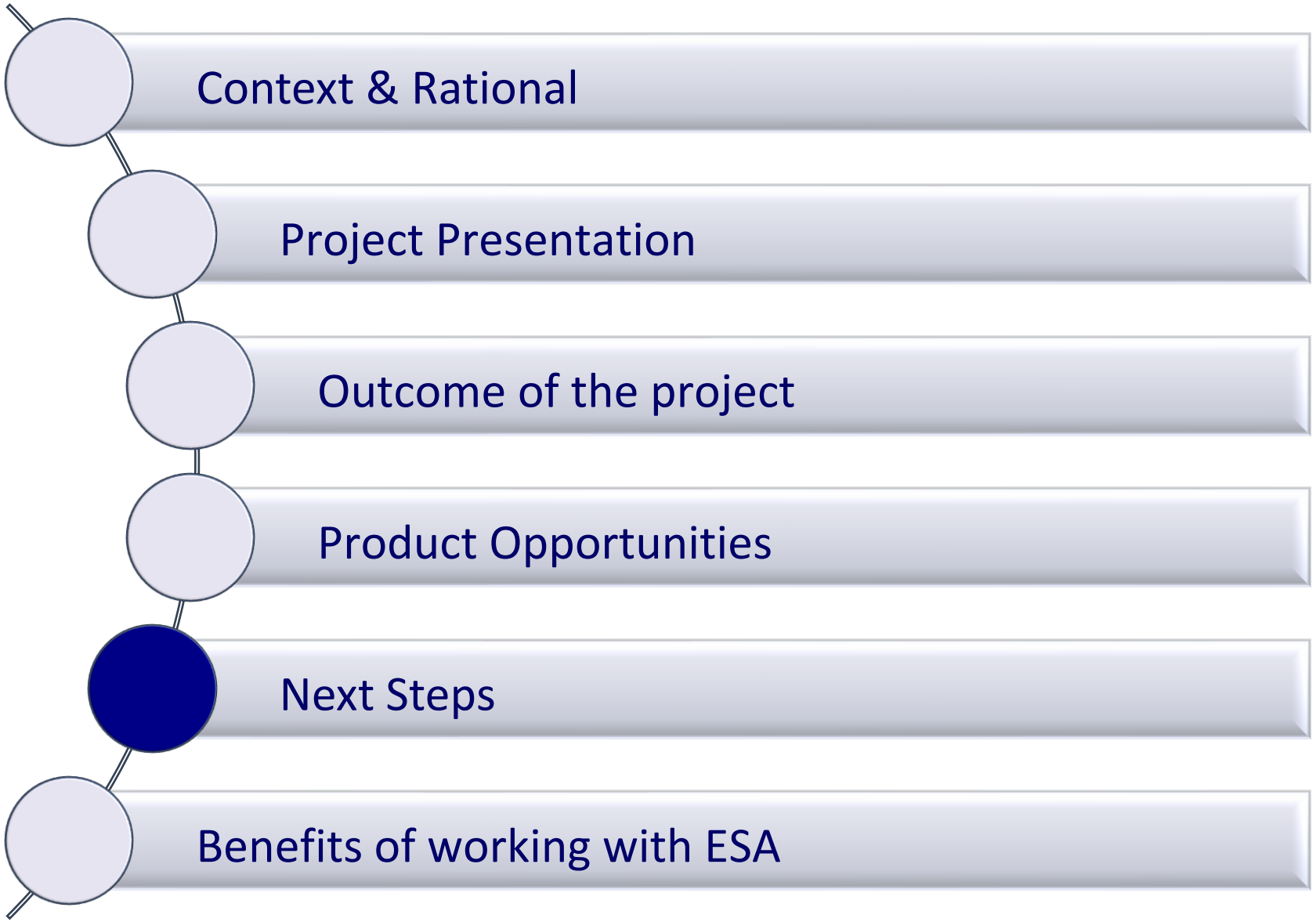
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Next Steps: Future goals (1/2)

- In the short-term the focus should be the analysis of new types of sensors to integrate in the system to further improve its performances and solve some minor problems related to environment conditions.

- The mid-term goal is an on-board real train testing campaign, that foresee the installation of the system on the train control system in passive mode. The prototype is already designed to be seamlessly included in an existing environment and the whole system can function as an information relay from the balise to the central computer when it is not in use. In passive mode AGIS4RAIL will elaborate real inputs but will not influence the train control.

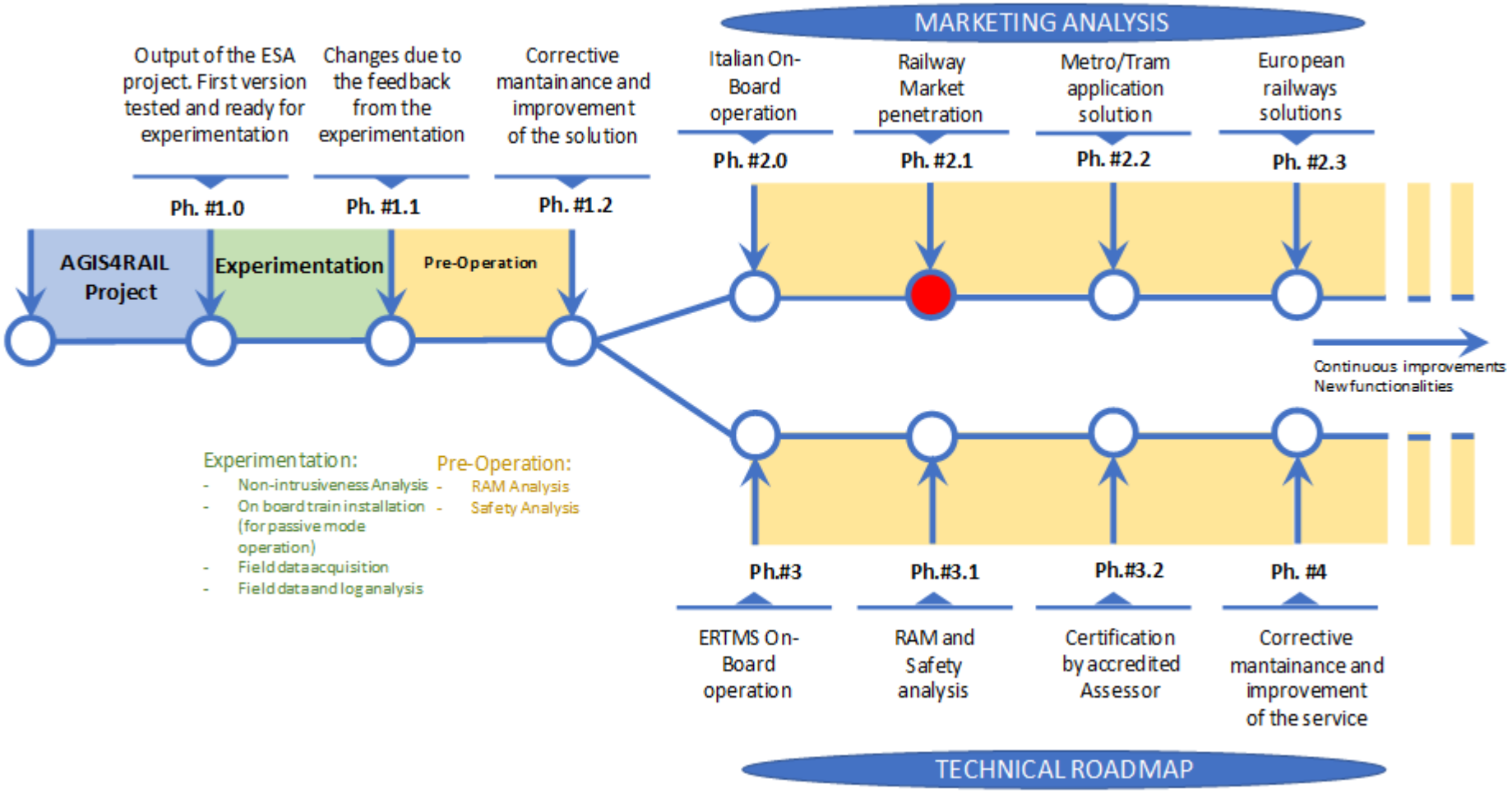
Next Steps: Future goals (2/2)

- To gain the approval for on-board testing, it is necessary for an external assessor to perform a Non-intrusiveness Analysis to demonstrate that the AGIS4RAIL system does not interfere with any other on-board instruments.

- Once the approval is granted, AGIS4RAIL can be installed on board and the tests can be executed, while the train proceed with its normal operation, wholly independent by the outputs of AGIS4RAIL system. This way the prototype will be acquire real operational data that can be used for improving the system.

- In the long-term the final goal is the development of a certified product which can be fully integrated in the train control system.

Next Steps: Roadmap



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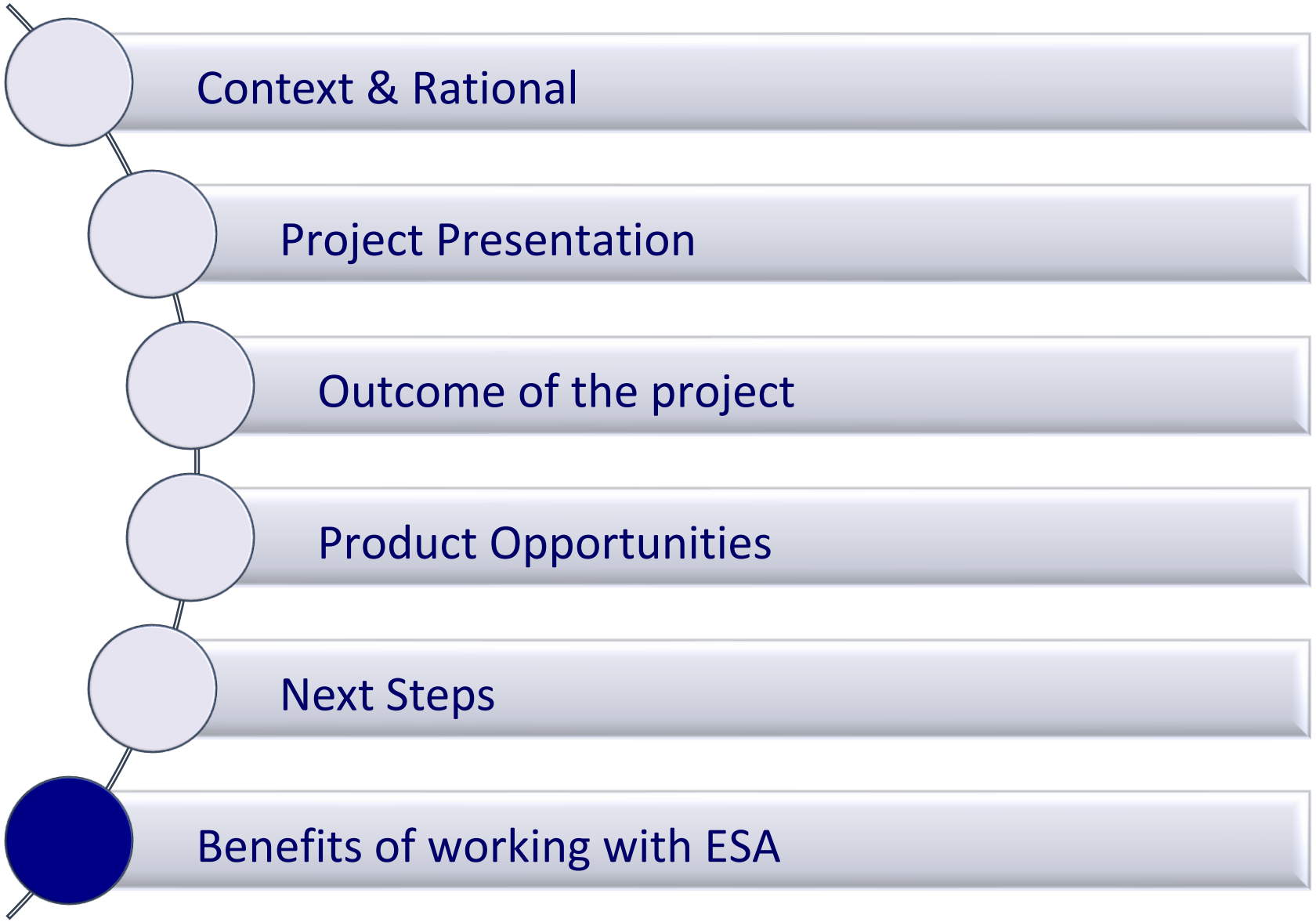
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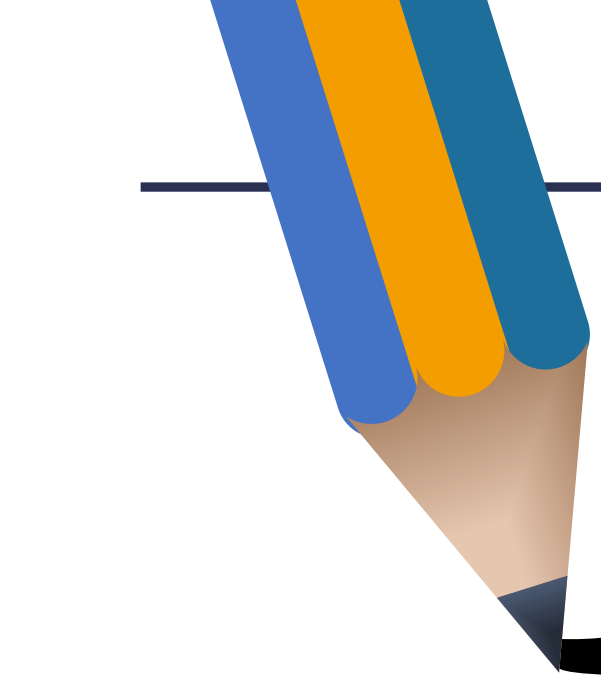
Benefits of working with ESA

- Intecs, thanks to the NAVISP program, had the opportunity to develop the concept of AGIS4RAIL as an additional positioning system increasing its performance both in terms of **availability** and in terms of **integrity** and to demonstrate its prototypal performances with in-Lab and On-Field testing

- The review process proposed by ESA helped the projects to reach the expected maturity in order to properly identify the user needs and the market applicability in the field of the Railway positioning system using the GNSS

- The fully cooperative interaction with ESA allowed the continuous evolution of AGIS4RAIL program to better fit the expected performances

- Working with ESA helped Intecs to identify potential improvements of the present AGIS4RAIL program in order to propose new features for desirable project evolution



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