Projet ERASMO : système de localisation intègre pour le véhicule autonome

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Journée outils logiciels et matériels pour la recherche sur les véhicules terrestres autonomes

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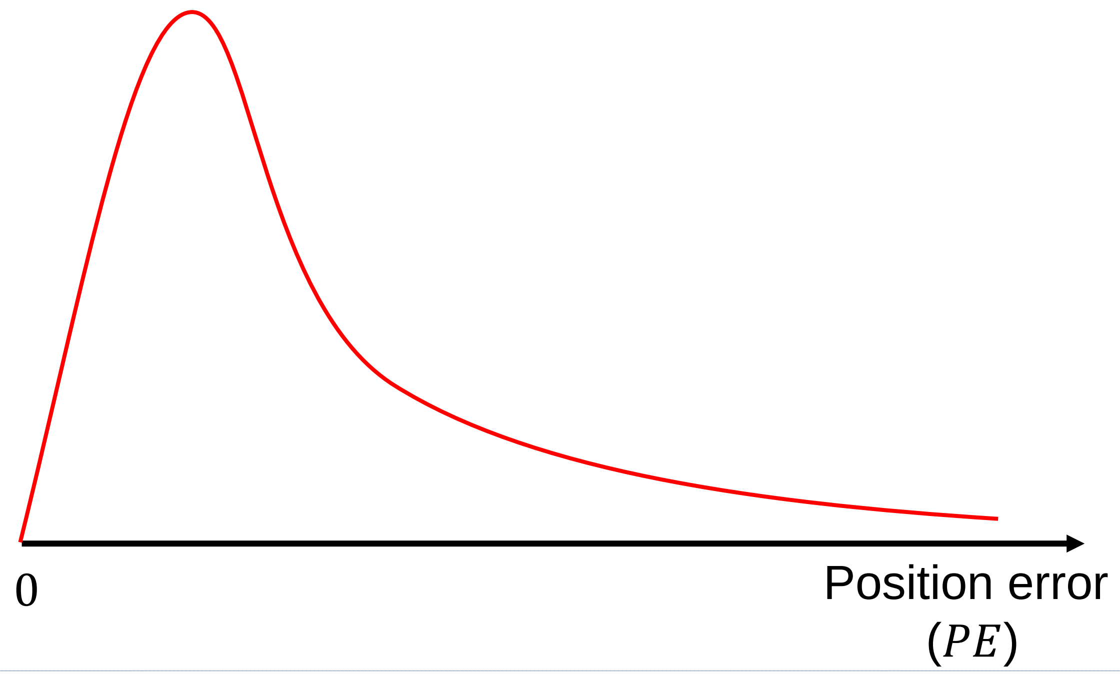
Consortium

Perception System
Vehicle Information
World Model
Monitoring System
ERASMO
HD-Maps
Supervisory Controller
Decision-Making & Path Planning
Control System

Localization integrity



Position error:

$$PE = \|\hat{X} - X\|$$

Accuracy:

$$MSE(\hat{X}) = \mathbb{E}\left[\|\hat{X} - X\|^2\right]$$

$$= \|\mathbb{E}[\hat{X}] - X\|^2 + \mathbb{E}[\|\hat{X} - \mathbb{E}[\hat{X}]\|]^2$$

$$= \|\mathrm{Bias}(\hat{X})\|^2 + \mathrm{trace}\left(\mathrm{Var}(\hat{X})\right)$$

Trueness
(« justesse »)

Precision
(« fidélité »)

Accuracy
(« exactitude »)

Localization integrity

Position error:

$$PE = \|\hat{X} - X\|$$

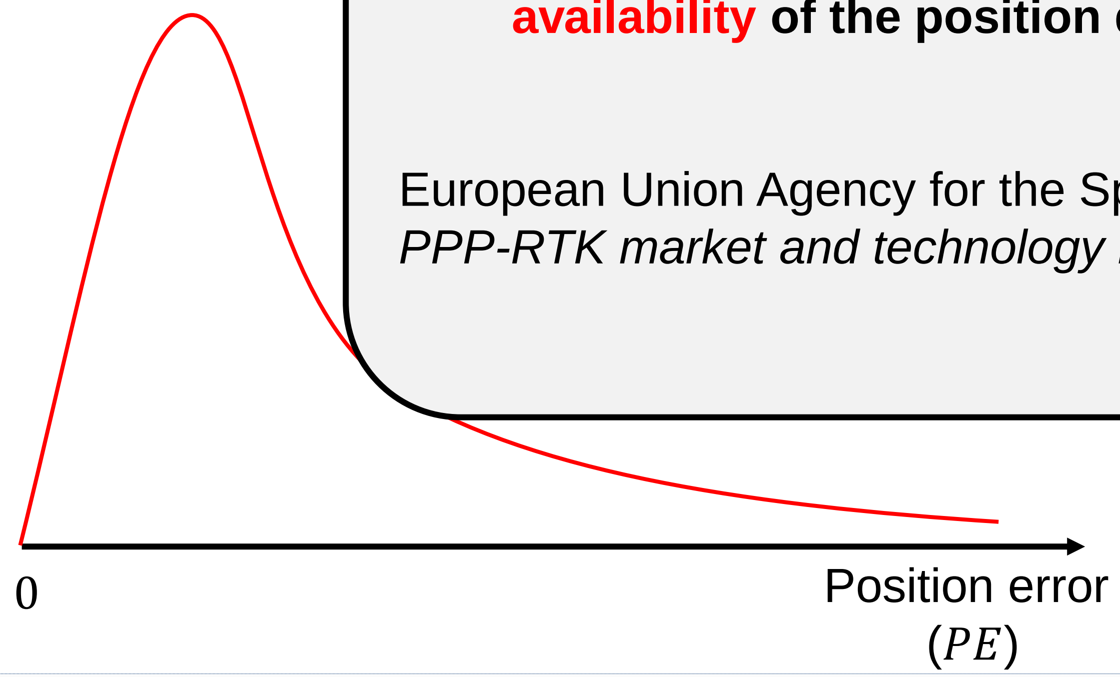
It was highlighted by multiple experts that **the importance of “accuracy” is often over-emphasised and that the integrity and availability of the position data must also be considered.**

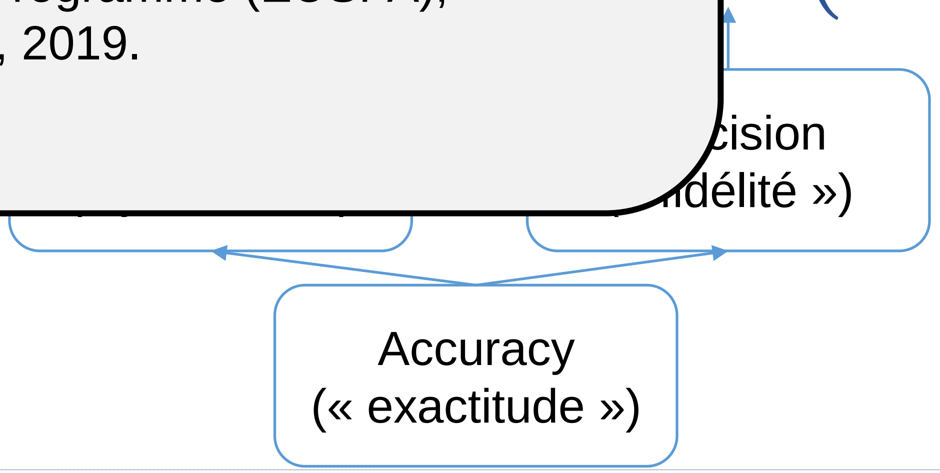
European Union Agency for the Space Programme (EUSPA), *PPP-RTK market and technology report*, 2019.

$\hat{X} - X\|^2]$

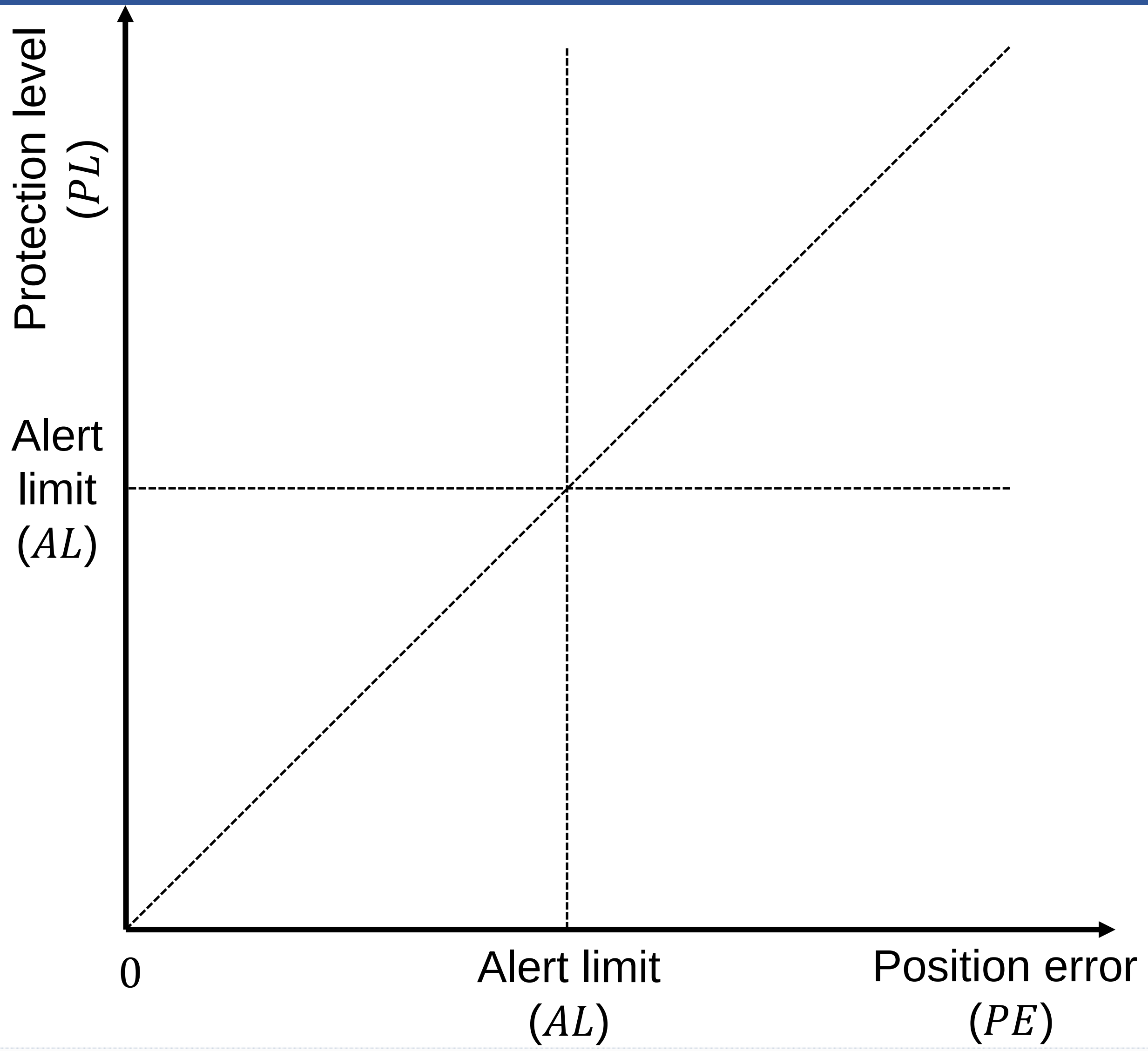
$\hat{X} - \mathbb{E}[\hat{X}]\|]^2$

$\mathrm{ce}\left(\mathrm{Var}(\hat{X})\right)$





Localization integrity



Position error:

$$PE = \|\hat{X} - X\|$$

Protection level:

$$\mathbb{P}\big(PE > PL(\alpha)\big) \leq \alpha$$

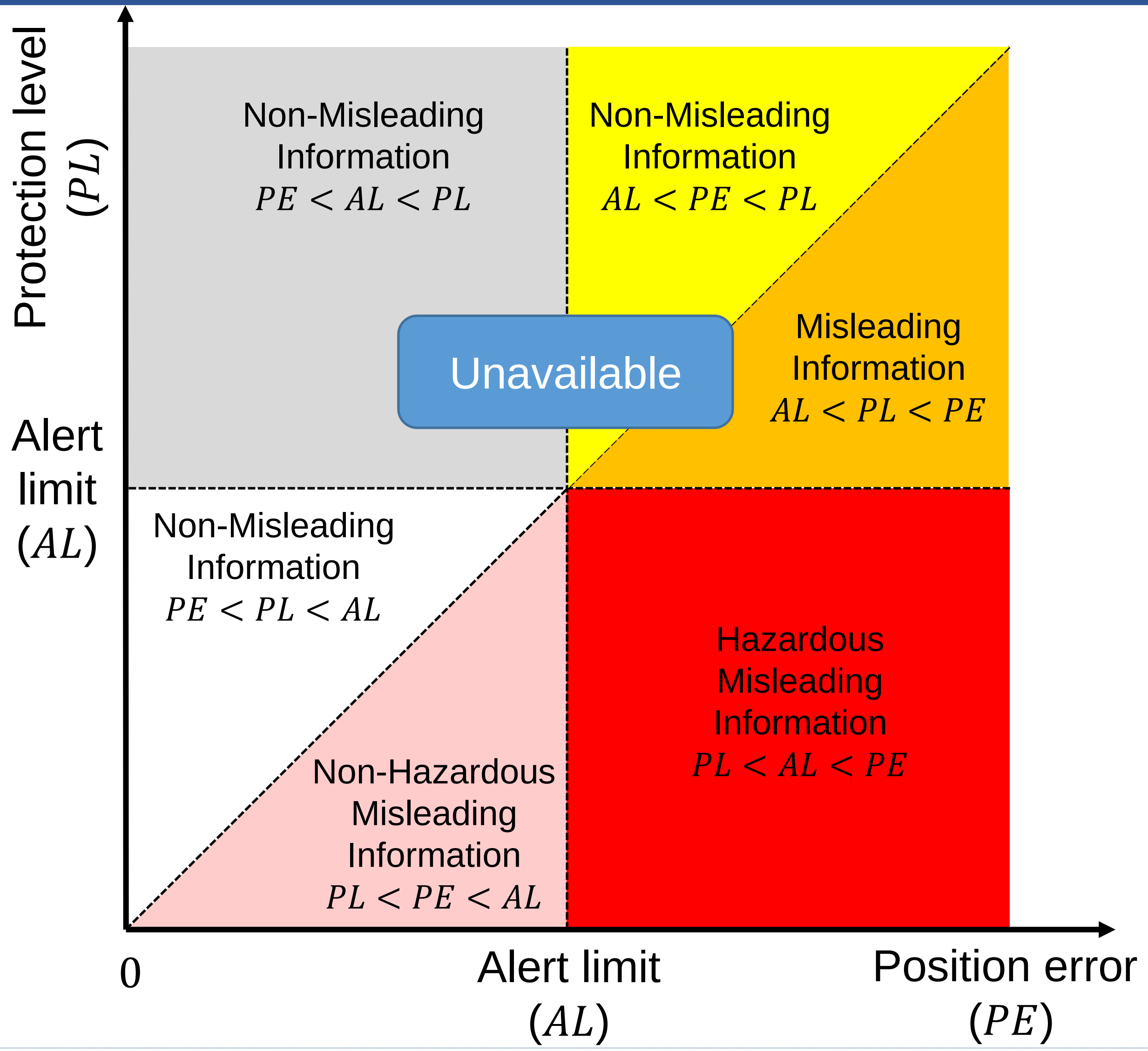
Target integrity risk: α

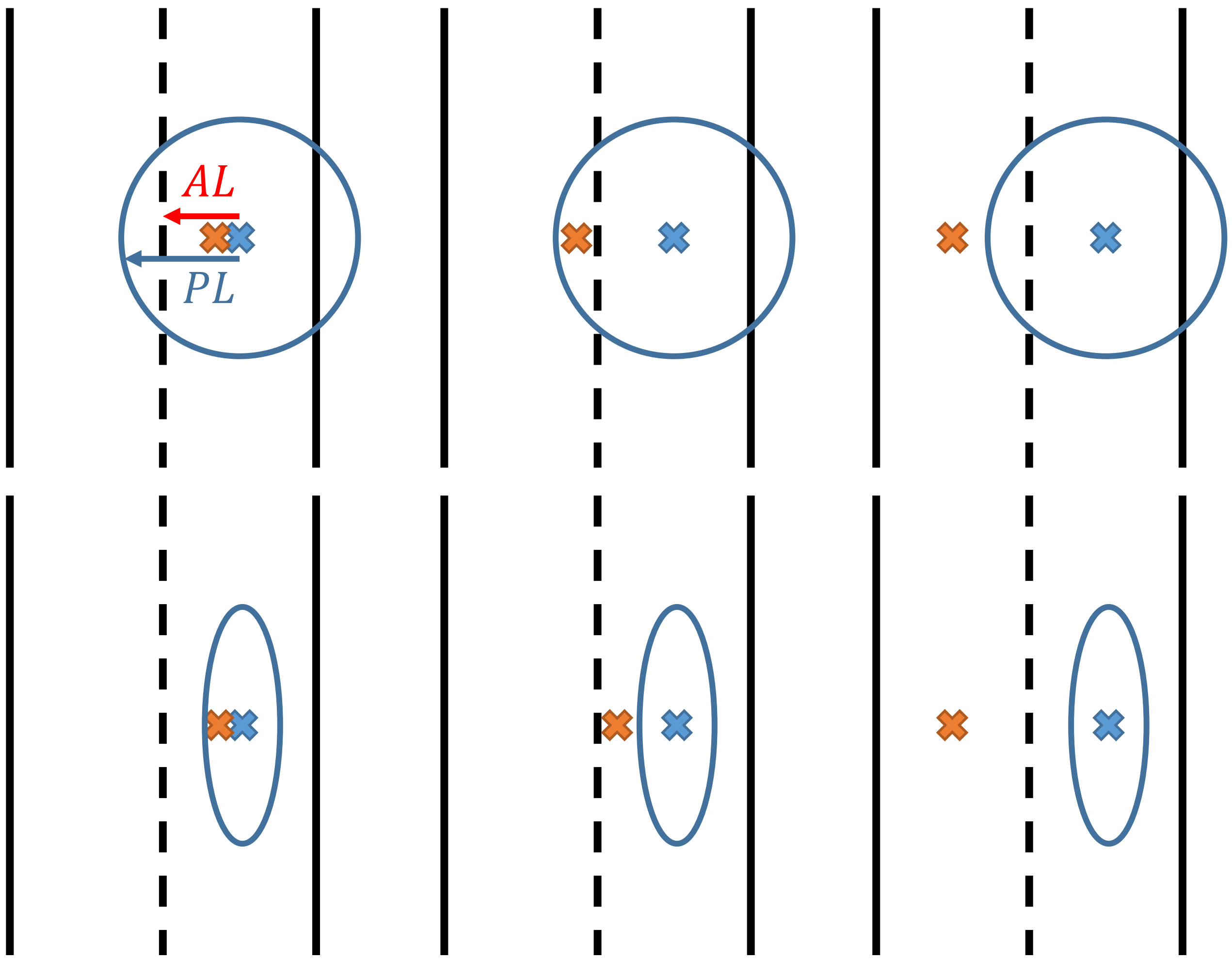
Alert limit: AL

System availability:

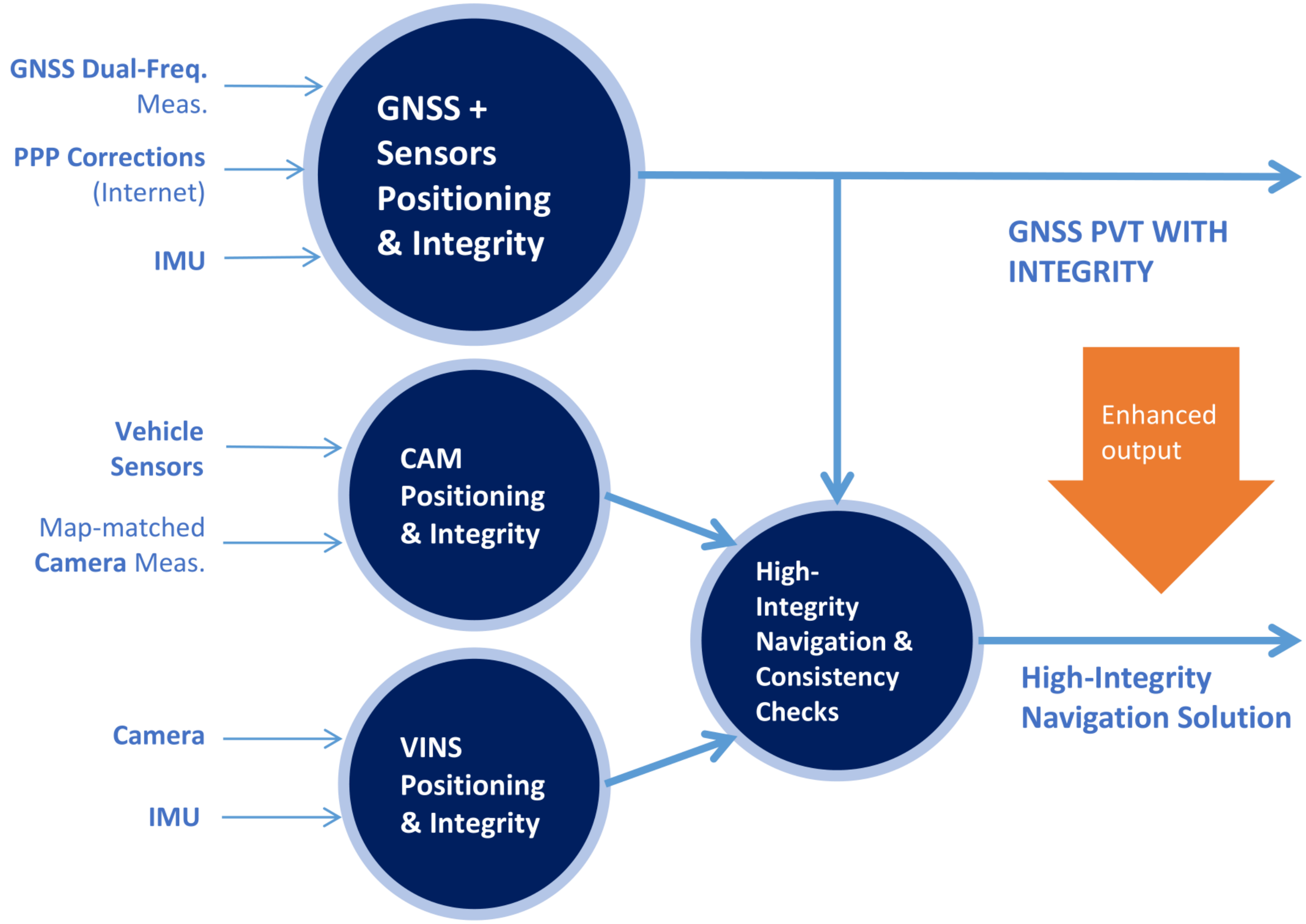
$$\mathbb{P}(PL < AL)$$

Localization integrity





Solution ERASMO



- Two GNSS PVT solutions computed in parallel
  - **SPP**: Standard Point Positioning
  - **PPP**: Precise Point Positioning

- Hybrid solution with integrity layer making the most of all the sensors that should be in Level 4 and 5 SAE vehicles
- Consistency checks performed between all the computed solutions

Solution GNSS

Overcoming the limitations of RTK and PPP

- From the *RTK* point of view

- To overcome its disadvantages (high bandwidth, high update rate and dense network) → instead of providing the measurements from the network of base stations (Observation State Representation – OSR) the evolution is **to provide precise orbits and clocks along with iono measurements** (State Space Representation – SSR)
- Thus reducing the bandwidth, the update rate and allowing to have less dense station networks.

- From the *PPP* point of view

- To overcome its disadvantages (convergence time), the evolution is **to provide**, in addition to the precise orbits and clocks, **regional ionosphere measurements**
- Thus reducing the convergence time to a few tens of seconds at the cost of needing a low dense station network to provide the iono measurements.

- The evolution of both methods converge into a set of techniques, a.k.a. *PPP-RTK*

- ***PPP-RTK*** provides SSR corrections (precise orbits and clocks along with ionosphere measurements) based on a low dense station network (~a few hundreds of km) **allowing the user navigation algorithm to converge and reach cm/dm accuracy in a few tens of seconds**

Performance

Scenario	GNSS	HD-map/Camera/LiDAR		Artisense
		Camera (road marking)	LiDAR	
Open-sky (rural, i.e. few visual features)	High	Middle	Low	Low
Peri-urban	Middle	High	Middle	Middle
Urban (with multipath and NLOS)	Low	High	High	High
Indoor parking	N/A	Low	Low	High

Scenario	GNSS	HD-map/Camera/LiDAR		Artisense
		Camera (road marking)	LiDAR	
Night	High	Low	High	Middle/Low
Foggy	High	Middle/Low	Middle/Low	Middle/Low
Rainy	High	Middle/Low	Middle/Low	Middle/Low

Scenario	GNSS	HD-map/Camera/LiDAR		Artisense
		Camera (road marking)	LiDAR	
Sparse	Independent	High	High	High
Nominal	Independent	Middle	High	Middle
Dense	Independent	Low	Middle	Low

Experiments in Compiègne, France

Driving environments

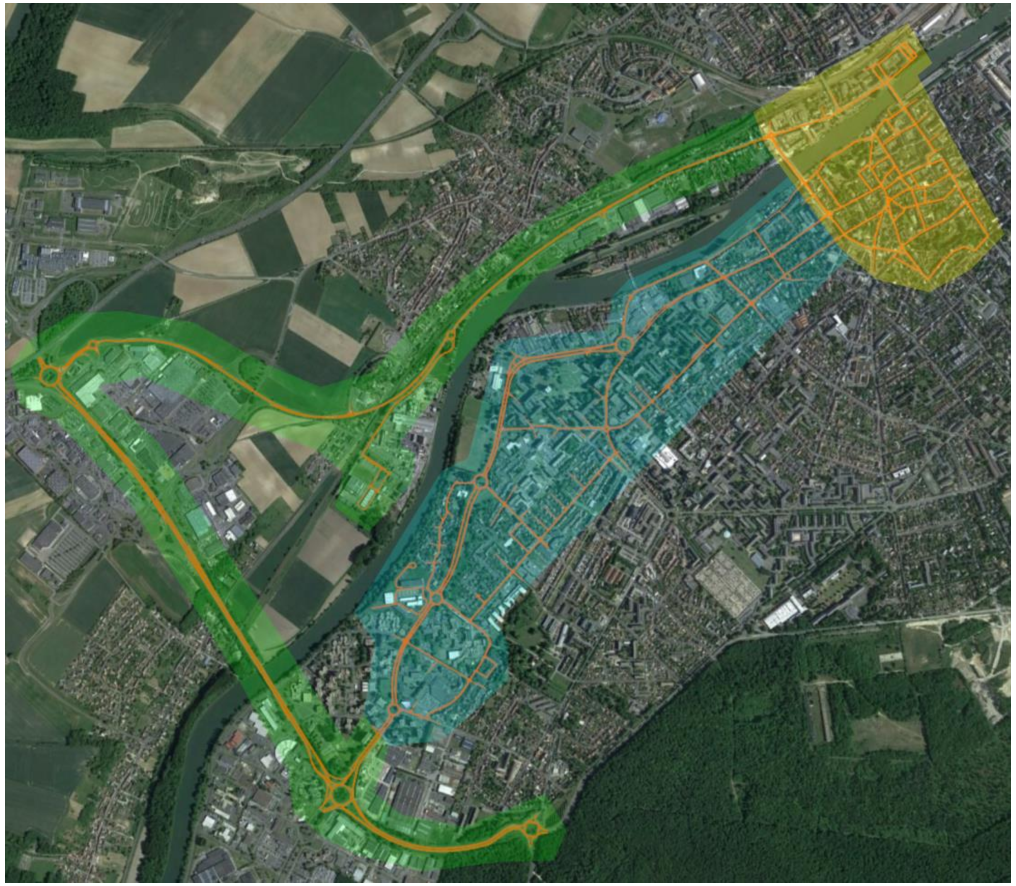
- Rural (green)
- Peri-urban (blue)
- Urban (yellow)

Weather and light conditions

- Sunny
- Rain
- Night

Traffic conditions

- Normal
- Dense



Driving environments

Traffic conditions

Dataset

Date [dd-mm-yyyy]	Time [h:min]	Weather	Traffic
10-05-2022	10:00-11:30	sunny	nominal
19-05-2022	17:00-18:30	sunny	dense
20-05-2022	14:30-15:30	little rainy	nominal
24-05-2022	09:00-10:00	sunny	nominal
28-06-2022	10:00-11:00	sunny	nominal
06-07-2022	10:00-11:00	sunny	nominal
15-07-2022	10:00-11:00	sunny	nominal
20-09-2022	09:15-11:00	cloudy	nominal
28-09-2022	14:50-15:40	sunny	nominal