

***magicPPP***

**High Precision and Safe  
GNSS Positioning  
System for Automotive  
Market**

NAVISP Industry Days, ESTEC, January 2020  
Round Table: "Solutions for Autonomous Road Vehicle"

# Science Fiction in the 80s

KNIGHT RIDER (1982-1986)



And now...

**gmv**

> 30 years of  
experience in  
**GNSS** & 15 years  
in **Automotive**



**EGNOS**

**magicPPP for Automotive**

**R&D**

Highly motivated and talented

# THE CHALLENGE

## Classical PPP

Open Environment

- Agriculture, Off-shore, Mining...

Human Supervised

Low risk for human lives



# THE CHALLENGE

## Classical PPP

Open Environment

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Low risk for human lives



## Automotive PPP

Harsh Environment

- Buildings, tree canopies, tunnels, underpasses...

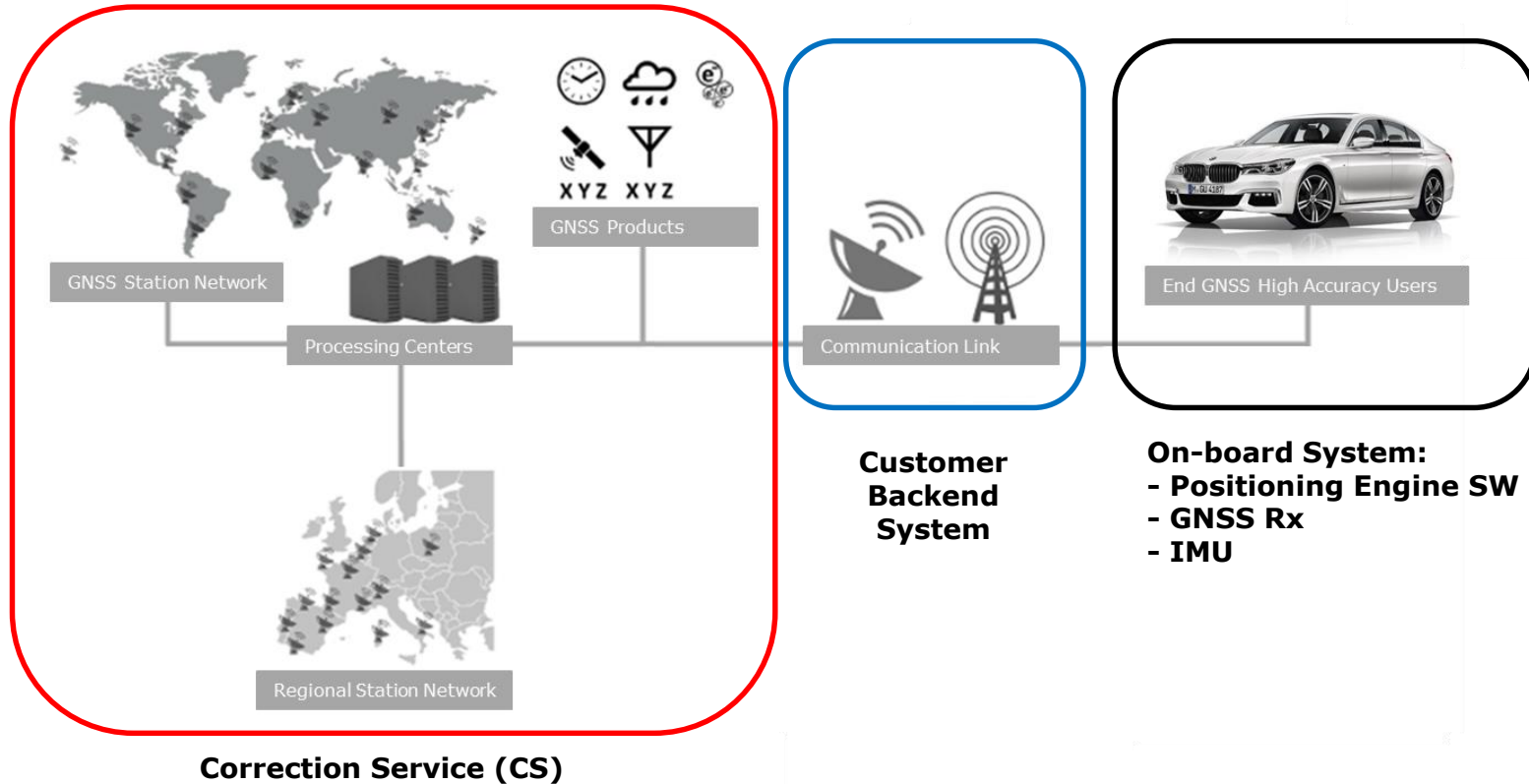
Fast Convergence in hot and cold start

High Availability

Safety Critical



# OVERALL SYSTEM ARCHITECTURE



# ALGORITHMIC ENHANCEMENTS



## Accuracy

- Integer Ambiguity Fixing at Orbit Determination
- Phase biases estimation
- Zero-Difference Ambiguity Fixing

# ALGORITHMIC ENHANCEMENTS



## Accuracy + Fast Convergence

- Integer Ambiguity Fixing at Orbit Determination
- Phase biases estimation
- Regional Ionosphere Estimation
- Zero-Difference Ambiguity Fixing
- Ionosphere correction

# ALGORITHMIC ENHANCEMENTS



## Accuracy + Fast Convergence + Dead Reckoning

- Integer Ambiguity Fixing at Orbit Determination
- Phase biases estimation
- Regional Ionosphere Estimation
- Zero-Difference Ambiguity Fixing
- Ionosphere correction
- Sensor fusion
- Gap-bridging algorithms

# ALGORITHMIC ENHANCEMENTS



## Accuracy + Fast Convergence + Dead Reckoning + Integrity

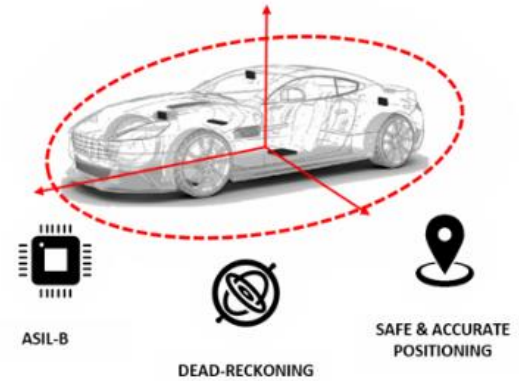
- Integer Ambiguity Fixing at Orbit Determination
- Phase biases estimation
- Regional Ionosphere Estimation
- Safety Processor
- Zero-Difference Ambiguity Fixing
- Ionosphere correction
- Sensor fusion
- Gap-bridging algorithms
- Threat Monitors
- KIPL Bounding

# POSITIONING SOLUTION FOR AUTOMOTIVE

- High accuracy positioning system customized to the particular requirements of the automotive market.
- Two levels of service:

Service Level	High Accuracy	Safety
QM	✓	X
ASIL-B	✓	✓

- Solution based on **Precise Point Positioning (PPP)** technology:
  - Preferred over RTK due to proven PPP advantages:
    - Stability of solution, comms bandwidth minimization, network density minimization.
  - Nevertheless, the solution is compatible with RTK positioning engines as it can emulate virtual RTK stations.
- System designed to fulfil **key requirements** received from various customers.



# KEY CAPTURED CUSTOMER REQUIREMENTS

#	Customer Requirements	<i>magicPPP</i>
1	High accuracy	✓
2	Fast Convergence	✓
3	Full integration with IMU for dead-reckoning during GNSS outages	✓
4	ASIL-B Safety	✓
5	Protection to jamming and spoofing attacks	✓
6	Flexibility to integrate with customer back-end services	✓
7	Bandwidth minimization	✓
8	Robustness vs connection outages with correction service	✓
9	(Cyber-)security protection of system assets and communication links	✓
10	Service Areas: Initial service over Europe and North America, others regions under study	✓

# KEY SYSTEM PERFORMANCE REQUIREMENTS

KPI	Value
Horizontal Accuracy	< 10 cm RMS
Integrity Risk (TIR)	Up to $10^{-7}$ per hour
Convergence Time	< 30 sec
Service Availability	> 99.9 %
Corrections Update Rate	1 sec – 1 min



FULL SAFETY CASE AND ARTIFACTS PRODUCED  
IN ACCORDANCE WITH ISO 26262

# EXAMPLE OF TESTING CASE

## TRAJECTORY

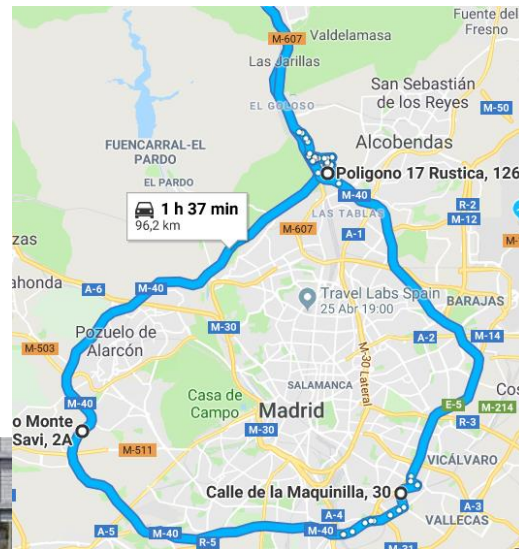
### Peripheral highway in Madrid (M40)

High multipath

Multiple overpasses

Max speed 100km/h

Medium-High level traffic during whole day



# PERFORMANCE TESTING SET UP

## Vehicle Equipment



Amotech AGA556022



uBlox ZED-F9P



Xsens Mti-10

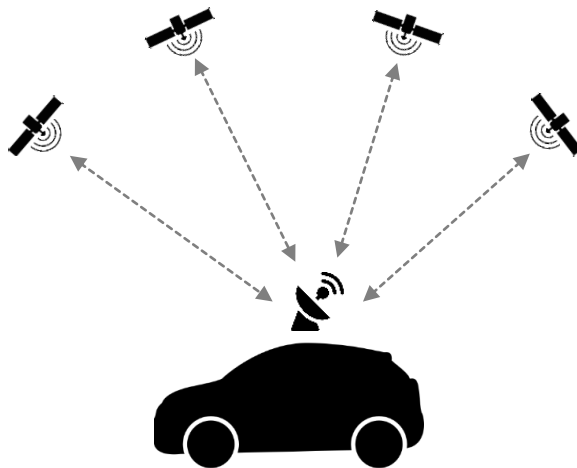
## Constellations



GPS



Galileo



## Ground Truth



Novatel GNSS 850

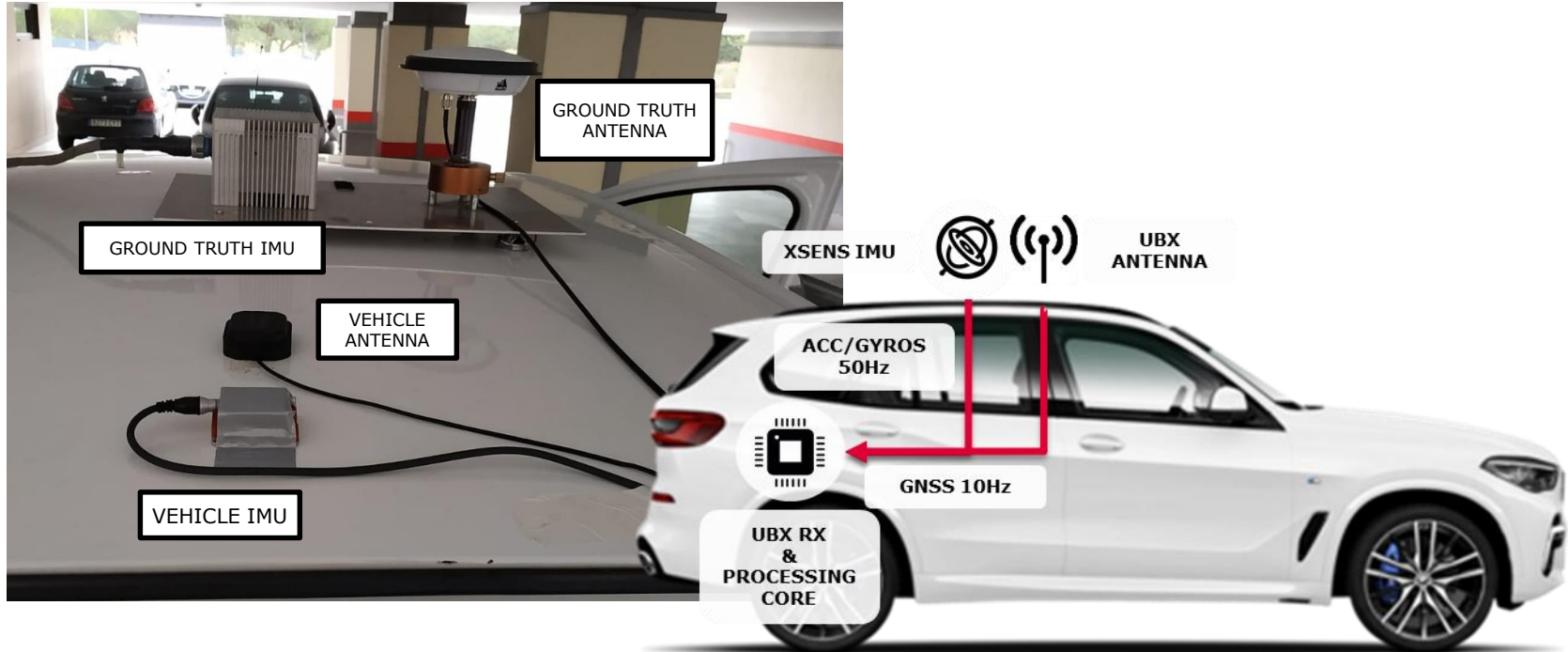


Novatel OEMV



Imar FSAS

# PERFORMANCE TESTING SET UP

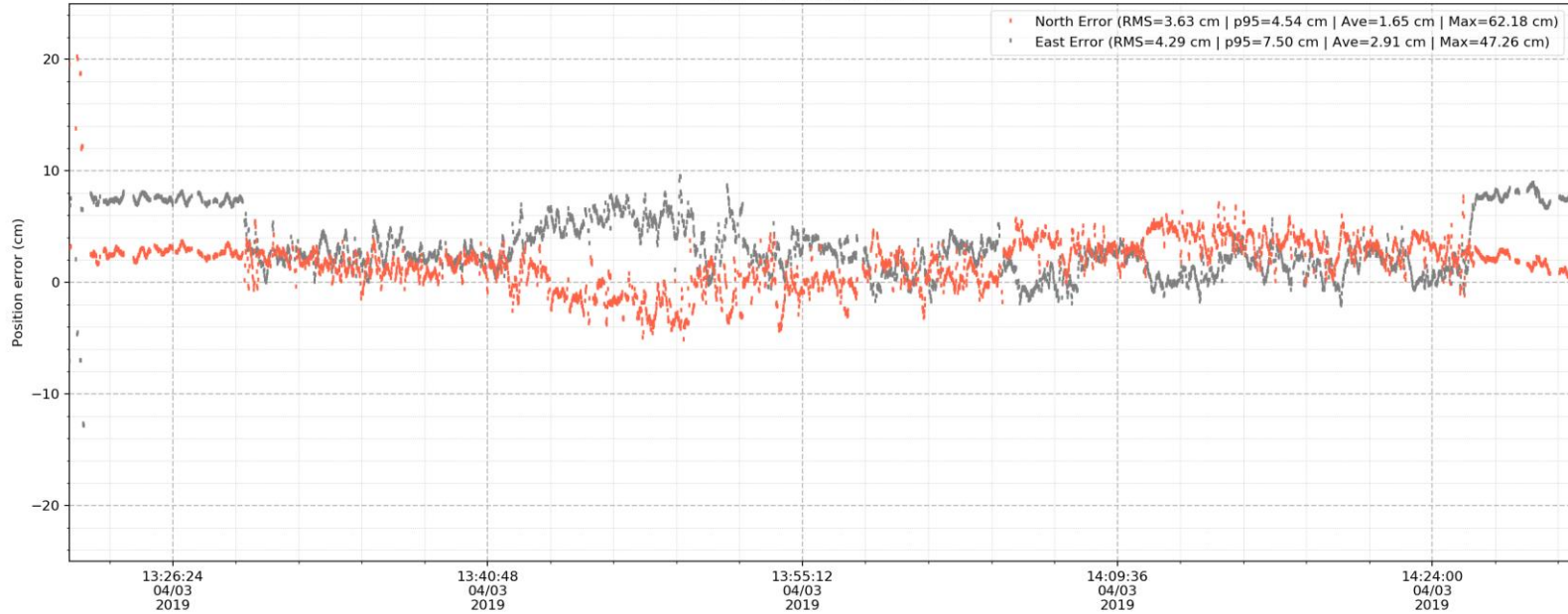


# TYPICAL ACCURACY - OPEN SKY

**magic**  
GNSS

PPP Monitor Stats  
PPP Position Error

**gmv**  
INDUSTRIAL SOLUTIONS

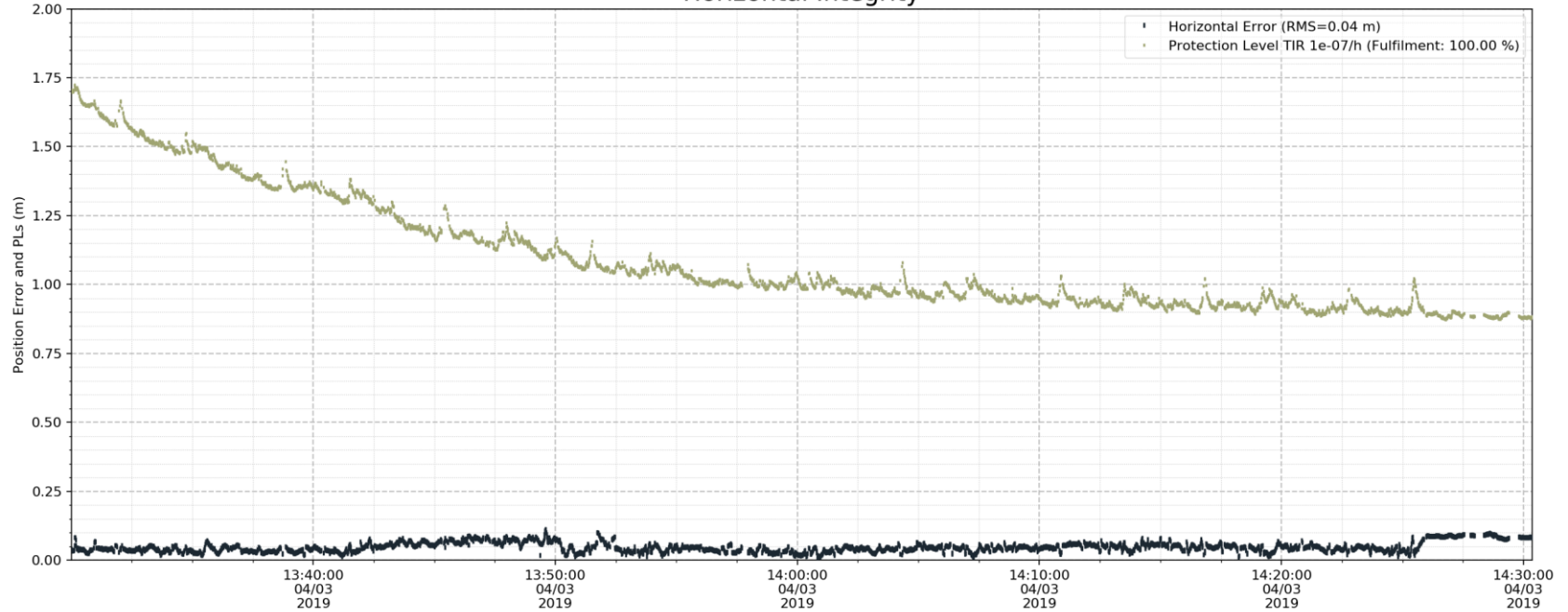


# TYPICAL PL SIZE - OPEN SKY

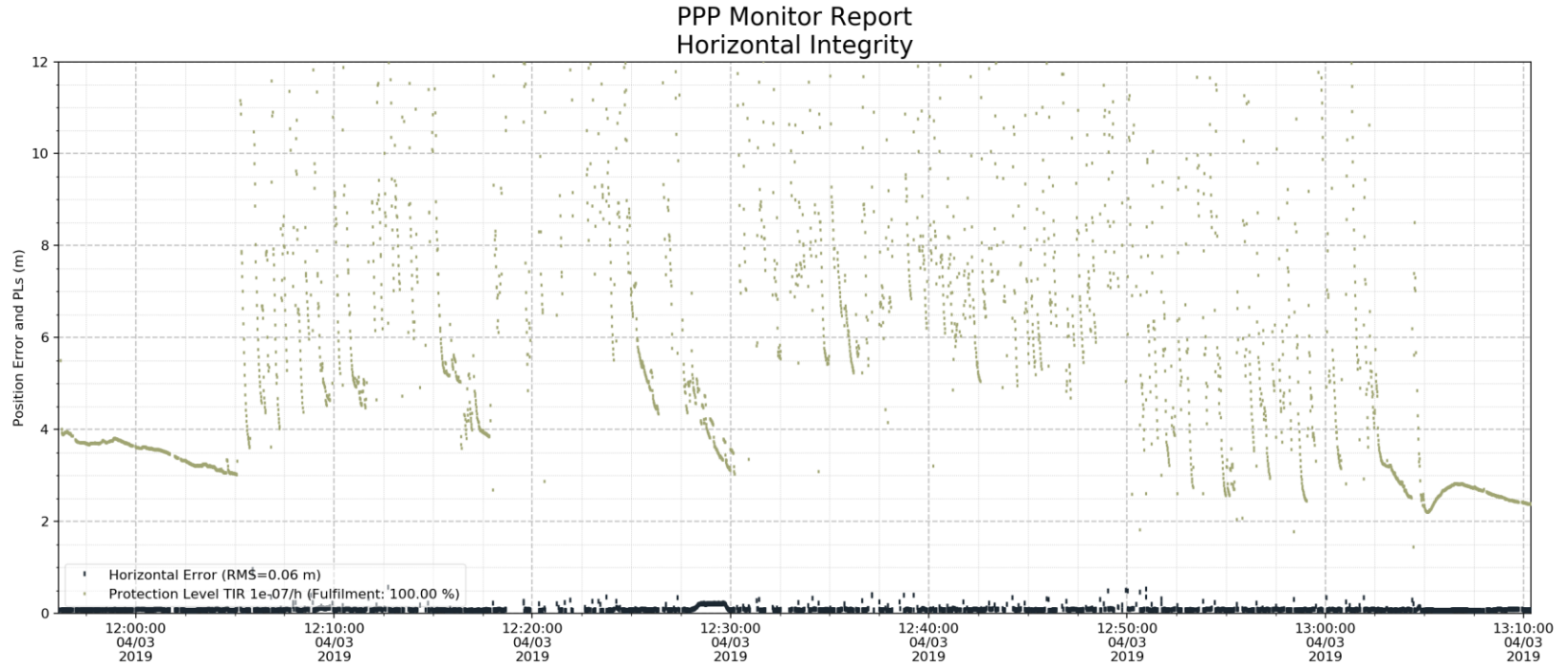
**magic**  
GNSS

PPP Monitor Report  
Horizontal Integrity

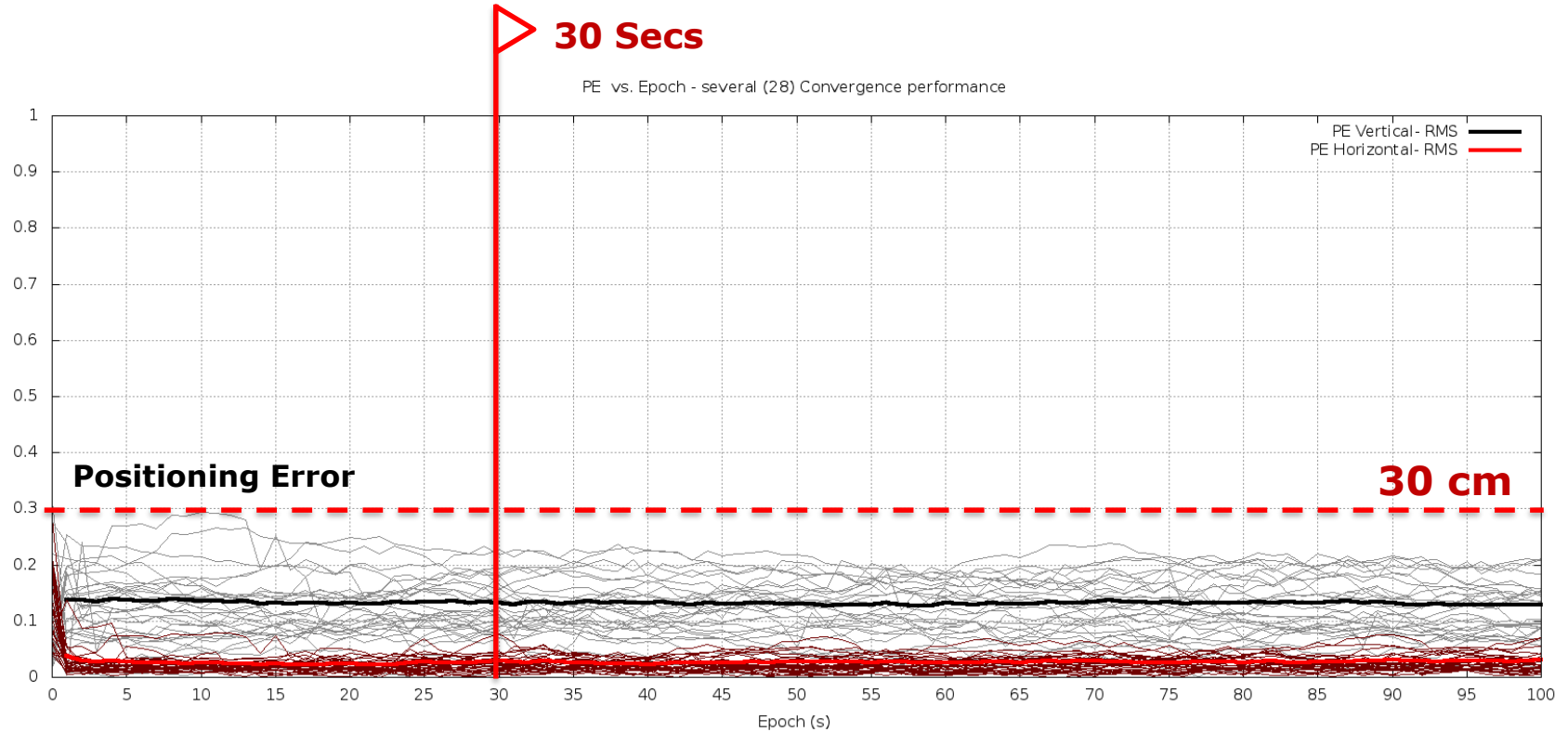
**gmv**  
INNOVATIVE SOLUTIONS



# TYPICAL PERFORMANCE – HIGH-WAY



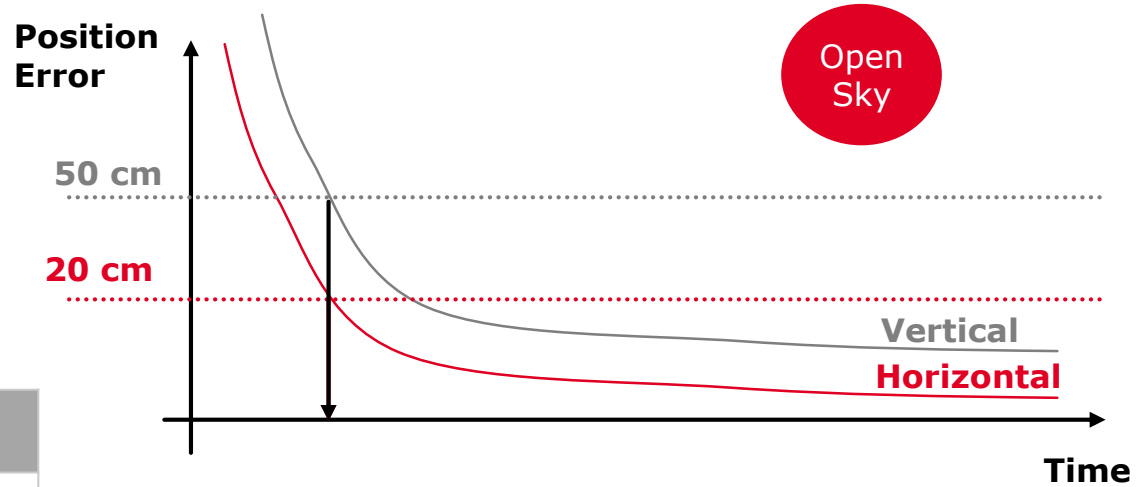
# COLD (INITIAL) CONVERGENCE



# COLD (INITIAL) CONVERGENCE

**3,88 seconds!**

Convergence tests	Time (seconds)
<b>RMS</b>	3.88
<b>P95</b>	10.10
<b>Average</b>	1.69
<b>Max</b>	12.3

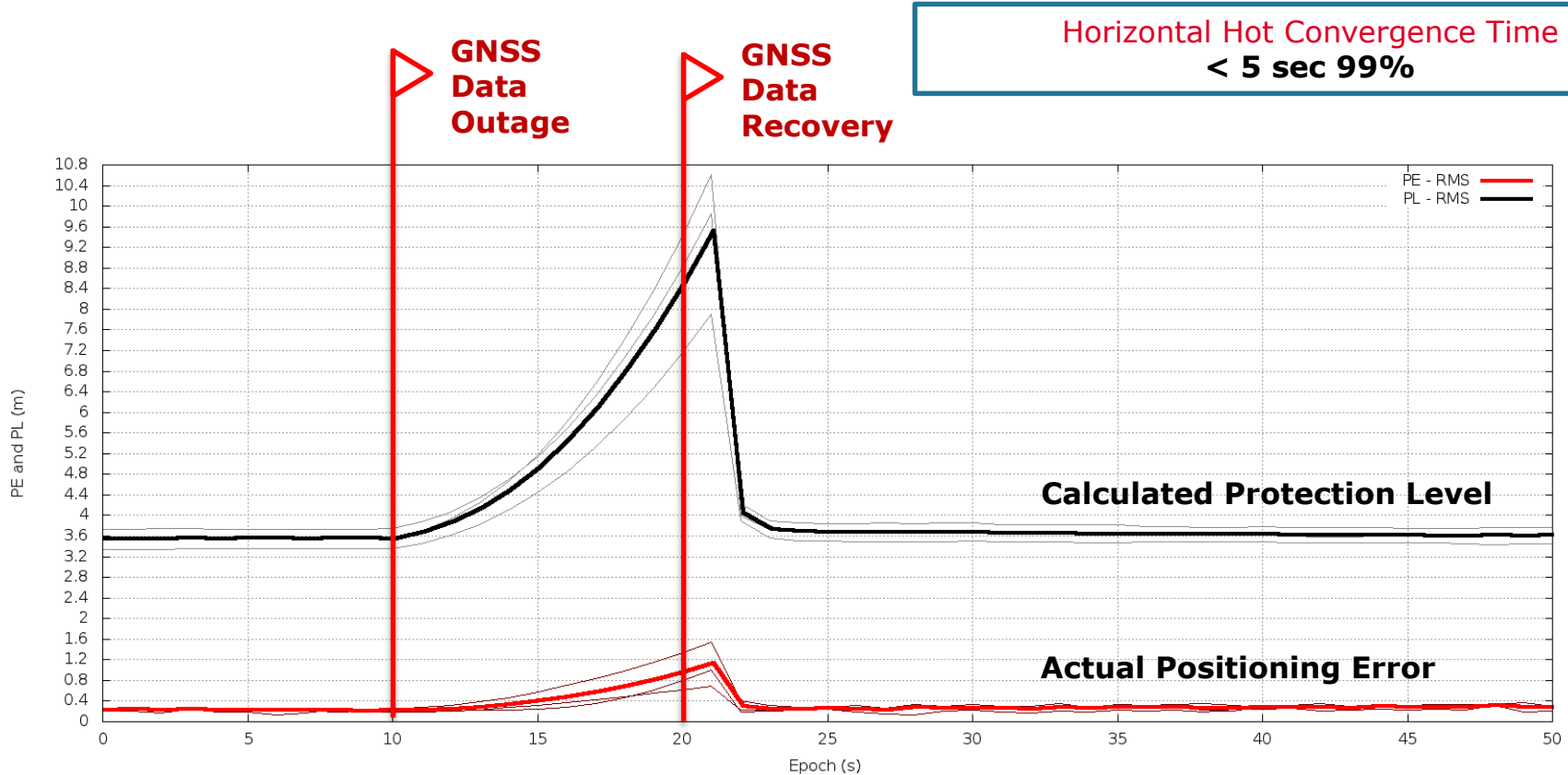


# HOT CONVERGENCE

Performance Recovery Time after short signal outages  
Bridges, Tunnels, Tree Canopies...



# DEAD RECKONING WITH IMU DATA



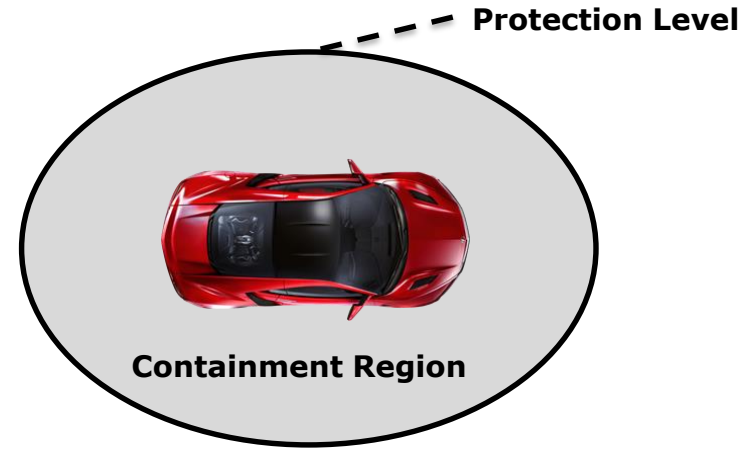
# Thank you

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# INTEGRITY PROCESSING

- Integrity assurance based on the calculation of real time **Protection Levels (PLs)**:
  - PLs bound the positioning errors
  - Define the region where the car is contained with high probability
  - Probability of error bounding failure < TIR requirement



- Integrity concept:
  - In absence of failures (fault free condition) the integrity algorithms ensure that the Protection Levels bound the actual positioning error
  - Built-in integrity monitors in CS and PE check the presence of all potential failure conditions
  - Residual errors taken into account in the Protection Levels calculation

