

ESA NAVISP EL1-115 ADAS Technology and PNT

acitoflux

Final Presentation Handout



ESA TECHNICAL OFFICER

Russ Whiton

AUTHORS OF ACITOFUX

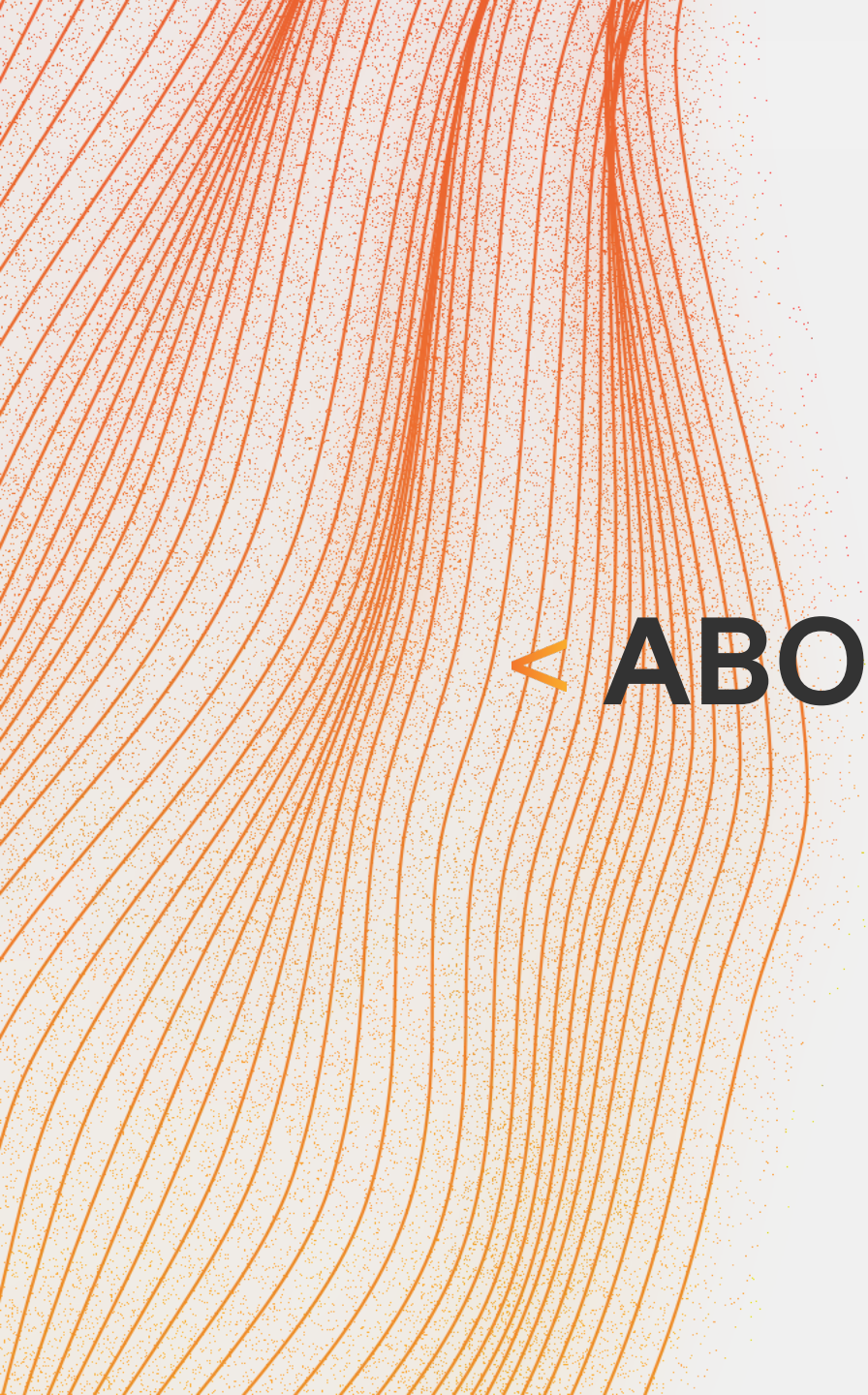
Lennart Säger, Mika Mänz, Marc Halft

DATE

July 03rd 2026

PRIME

acitoflux GmbH



◀ ABOUT ACITOFLEX

ABOUT ACITOFUX | VENTURE CREW

Hej, nice meeting you!



MIKA
Founder | CEO



LENNART
Co-Founder | COO



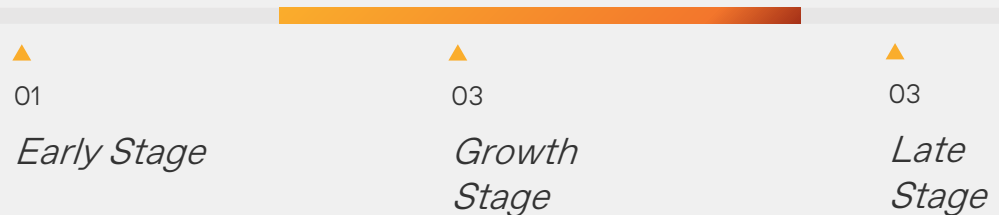
MARC
Investment Analyst & Venture Builder

ABOUT ACITOFUX

acitoflux transforms technology & creativity into real-world ventures that improve people's everyday life.

Innovation Capital for scale-ups, investors and corporate partners to grow & speed up.

OUR HOME TURF



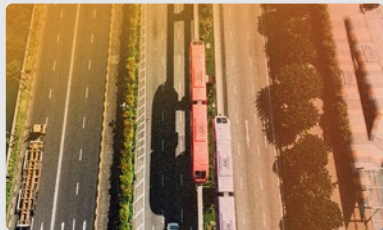


ABOUT ACITOFUX

OUR ECOSYSTEMS & NEW SPACE VENTURES



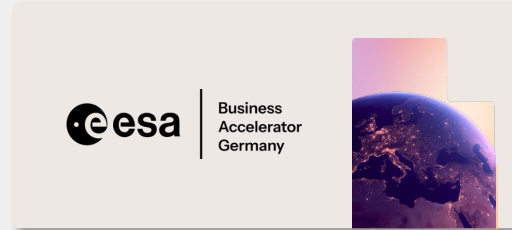
New Space



Future Mobility



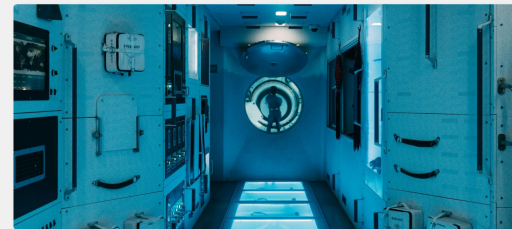
Digital Health



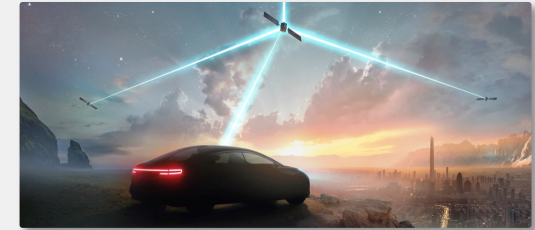
Innovation Capital



Earth Observation



In-Space Services



Sat Communication



Sat Navigation



Space Healthcare

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acitoflux GmbH

www.acitoflux.com

Studio Stuttgart

Königstraße 35
70173 Stuttgart

Studio Paris

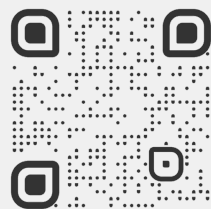
5 Parv. Alan Turing
75013 Paris

Studio Copenhagen

Danneskiold-Samsøes
Allé 41
1434 Copenhagen

Social Media –

 [linkedin.com/company/acitoflux](https://www.linkedin.com/company/acitoflux)



Studio Hamburg

Stadtdeich 2-4
20097 Hamburg

Studio Barcelona

C/ de St. Antoni
Maria Claret, 167,
08025 Barcelona,

Studio Tokyo

3F Nihonbashi IT Building
(X-NIHONBASHI BASE),
Nihonbashi Muromachi 3-
3-9, Chuo-ku, Tokyo



Contact

Lennart Säger
Co-Founder | COO

lennart.saeger@acitoflux.com



Contact

Mika Mänz
Founder | CEO

mika.maenz@acitoflux.com



Contact

Marc Halft
Investment Analyst & Venture Builder

Marc.halft@acitoflux.com



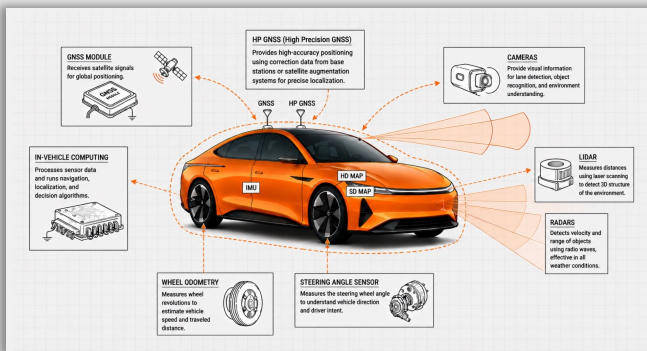
ESA NAVISP EL1-115

ADAS Technology and PNT

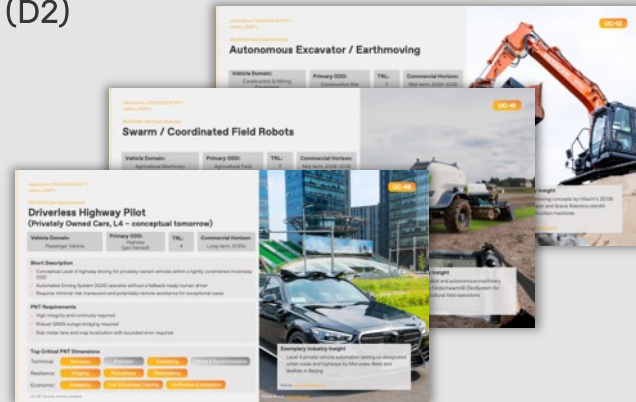
CONTEXT & METHODOLOGY OF THE PROJECT

Structed process led us to recommended NAVIS 1-3 Elements

Task 1: State of the art Technology (D1)



Task 2: Emerging AD/ADAS Applications (D2)



Task 3: Gap Analysis (D3):

- Based on 10 relevant PNT dimensions

Cluster 1 – Technical Performance

01 Accuracy How close the estimated state is to the true state.	02 Precision How stable and consistent the estimate is over repeated observations.	03 Availability (Continuity/Coverage) PNT usability through the whole OOD incl. urban canyons, tunnels, canyons, and poor weather.	04 Timing & Synchronization Internal synchronization – between sensors within the vehicle; External synchronization – synchronization with global time sources (e.g. GNSS).
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Cluster 2 – Signal Quality, Trust & Resilience

05 Integrity Protection levels, confidence in estimate, fault detection, and safety case support, performance under normal conditions includes confidence levels.	06 Robustness Performance under disturbed or hostile conditions, includes resistance to jamming, spoofing, and interference.	07 Redundancy Ability to maintain safe operation or degrade gracefully through architectural fallbacks, incl. sensor fusion, alternate references and graceful degrad. strategies.
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Cluster 3 – Economic Deployment & Viability

08 Scalability Deployment at industrial scale across real vehicle fleets, use cases, and OODs beyond demo or pilot.	09 Cost and Business Viability Cost vs. Capability trade-offs – technically good PNT can fail if cost structure is wrong.	10 Verification and Validation Ability to demonstrate that the system works correctly, safely, and with sufficient evidence. Includes certification readiness, and regulatory compliance.
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- PNT Gap Framework, scoring per AD/ADAS application / Use Case

Cluster	Dimension	Definition	Scoring System	Scoring System	Scoring System	Scoring System	Scoring System	Scoring System
Cluster 1 – Technical Performance	01 Accuracy	How close the estimated state is to the true state.	0-5 (0: Not accurate enough, 5: Accurate enough)	0-5 (0: Not accurate enough, 5: Accurate enough)	0-5 (0: Not accurate enough, 5: Accurate enough)	0-5 (0: Not accurate enough, 5: Accurate enough)	0-5 (0: Not accurate enough, 5: Accurate enough)	0-5 (0: Not accurate enough, 5: Accurate enough)
Cluster 1 – Technical Performance	02 Precision	How stable and consistent the estimate is over repeated observations.	0-5 (0: Not stable, 5: Stable)	0-5 (0: Not stable, 5: Stable)	0-5 (0: Not stable, 5: Stable)	0-5 (0: Not stable, 5: Stable)	0-5 (0: Not stable, 5: Stable)	0-5 (0: Not stable, 5: Stable)
Cluster 1 – Technical Performance	03 Availability (Continuity/Coverage)	How usable the PNT system is through the whole OOD incl. urban canyons, tunnels, canyons, and poor weather.	0-5 (0: Not usable, 5: Usable)	0-5 (0: Not usable, 5: Usable)	0-5 (0: Not usable, 5: Usable)	0-5 (0: Not usable, 5: Usable)	0-5 (0: Not usable, 5: Usable)	0-5 (0: Not usable, 5: Usable)
Cluster 1 – Technical Performance	04 Timing & Synchronization	Internal synchronization between sensors within the vehicle; External synchronization with global time sources (e.g. GNSS).	0-5 (0: Not synchronized, 5: Synchronized)	0-5 (0: Not synchronized, 5: Synchronized)	0-5 (0: Not synchronized, 5: Synchronized)	0-5 (0: Not synchronized, 5: Synchronized)	0-5 (0: Not synchronized, 5: Synchronized)	0-5 (0: Not synchronized, 5: Synchronized)
Cluster 2 – Signal Quality, Trust & Resilience	05 Integrity	Protection levels, confidence in estimate, fault detection, and safety case support, performance under normal conditions includes confidence levels.	0-5 (0: Not protected, 5: Protected)	0-5 (0: Not protected, 5: Protected)	0-5 (0: Not protected, 5: Protected)	0-5 (0: Not protected, 5: Protected)	0-5 (0: Not protected, 5: Protected)	0-5 (0: Not protected, 5: Protected)
Cluster 2 – Signal Quality, Trust & Resilience	06 Robustness	Performance under disturbed or hostile conditions, includes resistance to jamming, spoofing, and interference.	0-5 (0: Not robust, 5: Robust)	0-5 (0: Not robust, 5: Robust)	0-5 (0: Not robust, 5: Robust)	0-5 (0: Not robust, 5: Robust)	0-5 (0: Not robust, 5: Robust)	0-5 (0: Not robust, 5: Robust)
Cluster 2 – Signal Quality, Trust & Resilience	07 Redundancy	Ability to maintain safe operation or degrade gracefully through architectural fallbacks, incl. sensor fusion, alternate references, and graceful degradation strategies.	0-5 (0: Not redundant, 5: Redundant)	0-5 (0: Not redundant, 5: Redundant)	0-5 (0: Not redundant, 5: Redundant)	0-5 (0: Not redundant, 5: Redundant)	0-5 (0: Not redundant, 5: Redundant)	0-5 (0: Not redundant, 5: Redundant)
Cluster 3 – Economic Deployment & Viability	08 Scalability	Deployment at industrial scale across real vehicle fleets, use cases, and OODs beyond demo or pilot.	0-5 (0: Not scalable, 5: Scalable)	0-5 (0: Not scalable, 5: Scalable)	0-5 (0: Not scalable, 5: Scalable)	0-5 (0: Not scalable, 5: Scalable)	0-5 (0: Not scalable, 5: Scalable)	0-5 (0: Not scalable, 5: Scalable)
Cluster 3 – Economic Deployment & Viability	09 Cost and Business Viability	Cost vs. Capability trade-offs – technically good PNT can fail if cost structure is wrong.	0-5 (0: Not viable, 5: Viable)	0-5 (0: Not viable, 5: Viable)	0-5 (0: Not viable, 5: Viable)	0-5 (0: Not viable, 5: Viable)	0-5 (0: Not viable, 5: Viable)	0-5 (0: Not viable, 5: Viable)
Cluster 3 – Economic Deployment & Viability	10 Verification and Validation	Ability to demonstrate that the system works correctly, safely, and with sufficient evidence. Includes certification readiness, and regulatory compliance.	0-5 (0: Not verified, 5: Verified)	0-5 (0: Not verified, 5: Verified)	0-5 (0: Not verified, 5: Verified)	0-5 (0: Not verified, 5: Verified)	0-5 (0: Not verified, 5: Verified)	0-5 (0: Not verified, 5: Verified)

Identified Technology Use Case Gaps, baseline for NAVISP Elements discussion

Task 4: Derivation of NAVISP Elements (D4)

- Via technology-use case-gap analysis
- Statements/Informations of interview partners, what is needed in the industry
- Overall PNT tech trend analysis, in context of AD/ADAS

Element 1: Innovation in PNT

- Develop novel PNT-related systems and technologies along the entire value chain
- ITTs released on esa-star
- Fully funded

Element 2: PNT Industrial Competitiveness

- Improve European industry's capabilities in the global market for PNT technologies and services (products and services)
- Direct negotiation
- Co-funded(*)

Element 3: Support ESA Member States initiatives

- Support European National Programmes along the whole value chain
- Direct negotiation
- Fully funded

Long List: 53 Element Projects

Short List: 15 Element Projects (Recommendation)



CHAPTER 1

STATE OF THE ART

“INTRODUCTION”

1. INTRODUCTION – STATE OF THE ART

Automated Driving and Assisted Driving Systems shaping a new era of tech

The increasing automation and digitalisation of road transport is reshaping the European mobility and automotive landscape. Advanced Driver Assistance Systems (ADAS) and Automated Driving (AD) functions are progressing rapidly, driven by technological innovation, regulatory frameworks, and societal demands for safety, sustainability, and efficiency.

A central challenge concerns safety assurance. Functional Safety (ISO 26262) addresses risks caused by system malfunctions, while the Safety of the Intended Functionality (SOTIF, ISO/PAS 21448) covers hazards arising from performance limitations, for instance in AI-based perception and decision-making systems. Both approaches prescribe lifecycle processes for identifying and mitigating risks, and their integration is increasingly recognised as a prerequisite for building a comprehensive safety case for automated vehicles.

On the regulatory level, the European Union has taken major steps to strengthen road safety. The General Safety Regulation (EU) 2019/2144 introduced mandatory requirements for a broad set

of advanced safety features such as advanced emergency braking, intelligent speed assistance, lane-keeping systems, driver drowsiness warnings, and event data recorders.

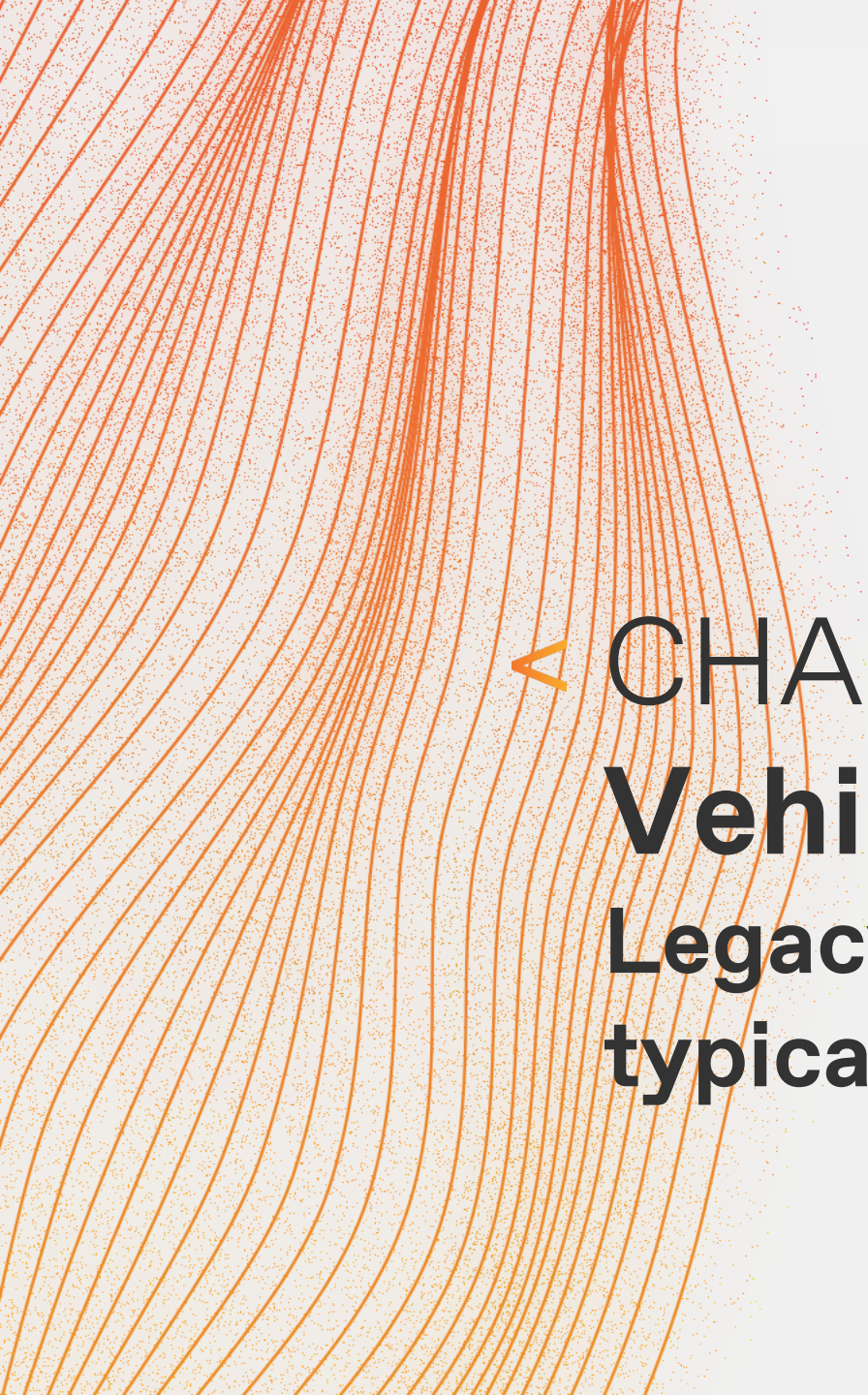
Complementary to this, Directive 2010/40/EU established the framework for the coordinated deployment of Intelligent Transport Systems (ITS), highlighting the role of interoperable and satellite-based solutions for positioning and timing.

More recently, Regulation (EU) 2022/1426 defined uniform procedures and technical specifications for the type-approval of automated driving systems, covering use cases such as hub-to-hub freight operations and automated valet parking. At the same time, the role of space-based technologies for road transport continues to expand. The European Union Agency for the Space Programme (EUSPA) reports a growing reliance on precise Positioning, Navigation, and Timing (PNT) enabled by Galileo and EGNOS, as well as Earth Observation (EO) for infrastructure monitoring. Applications include connected and automated driving, road user charging, eCall, fleet management, and predictive maintenance.

However, Global Navigation Satellite Systems (GNSS) face limitations in urban canyons and under adverse conditions. To address these challenges, hybrid approaches combining GNSS with complementary sensors (LiDAR, radar, cameras, inertial sensors) and emerging technologies such as 5G-based or Low Earth Orbit (LEO) satellite localisation are being actively explored.

In this context, ESA's Navigation Innovation and Support Programme (NAVISP) acts as a strategic enabler by fostering innovation in PNT technologies, enhancing industrial competitiveness, and supporting European sovereignty in this domain.

WP1 establishes the methodological and regulatory foundation for the project. It integrates user needs, safety-critical requirements, and regulatory conditions with the state of technological development. The objective is to provide a coherent baseline for subsequent work packages, aligning technological progress with European values of safety, resilience, and sustainability.



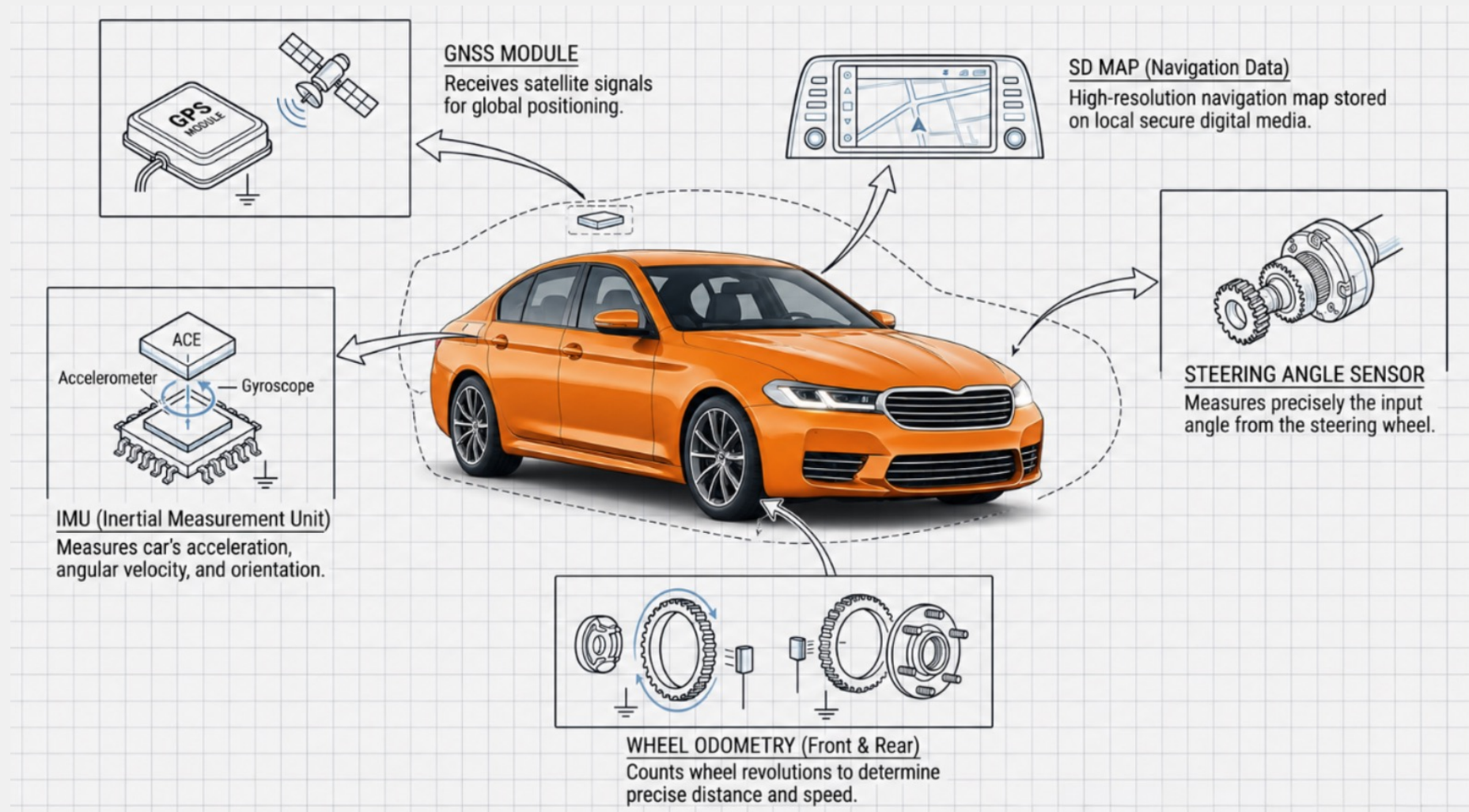
◀ CHAPTER 1.2

Vehicle Tech Stack

**Legacy and current tech stack of
typical AD/ADAS vehicles**

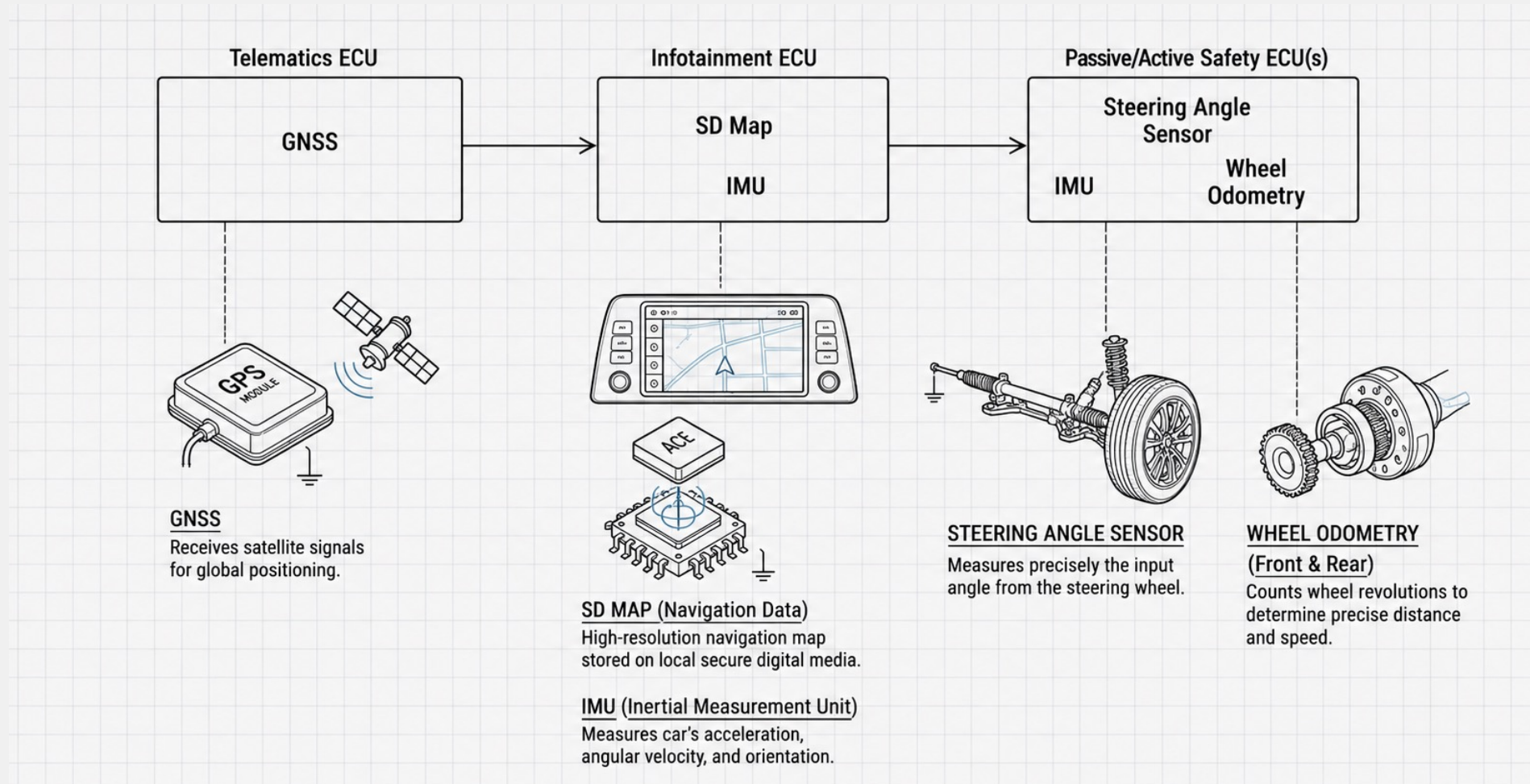
2. INTRODUCTION – VEHICLE TECH STACK

Legacy Navigation Architecture



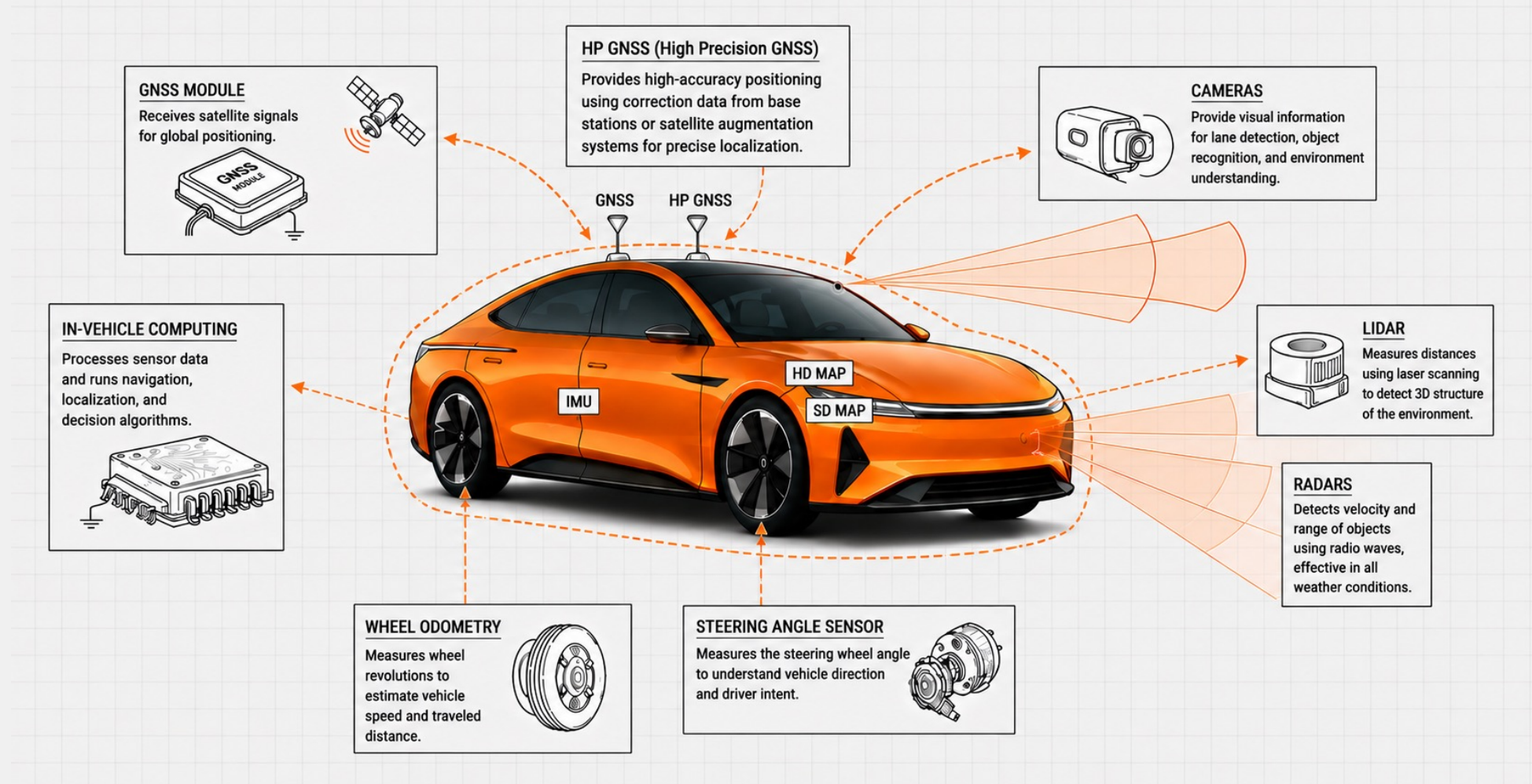
2. INTRODUCTION – VEHICLE TECH STACK

Legacy Navigation Architecture



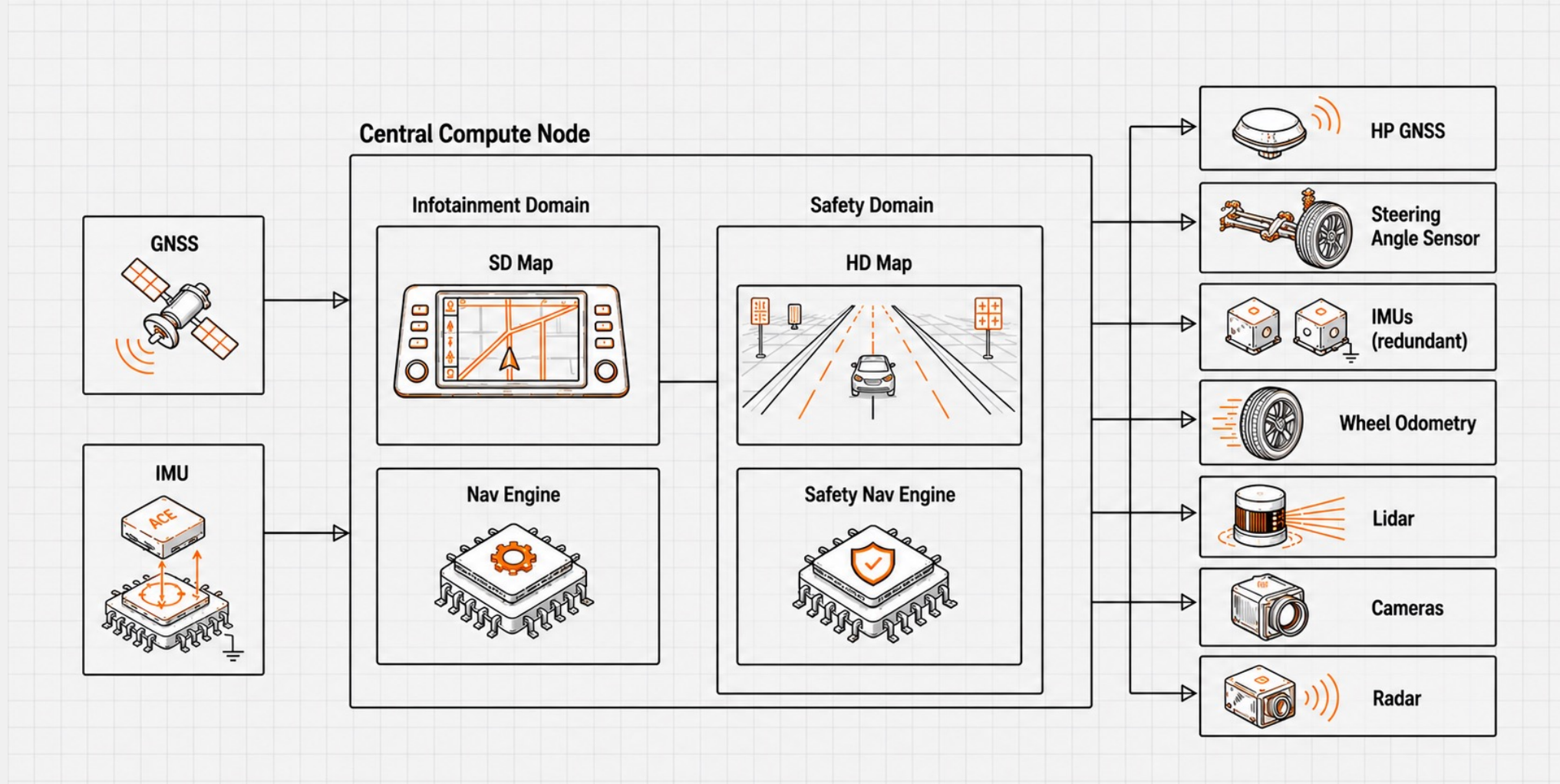
2. INTRODUCTION - VEHICLE TECH STACK

High Automation Navigation Architecture



2. INTRODUCTION - VEHICLE TECH STACK

High Automation Navigation Architecture



◀ CHAPTER 1.4
STATE OF THE ART
“PNT MODALITIES IN USE –
GNSS”

4. PNT MODALITIES IN USE – GNSS

Today four major GNSS constellations are being used for AD/ADAS systems, oftentimes supporting multi-constellation and dual-frequency receivers

PNT Technology Stack – Industry Standard Today

To support advanced driver assistance and autonomous functions, modern vehicles integrate a diverse set of positioning and perception technologies.

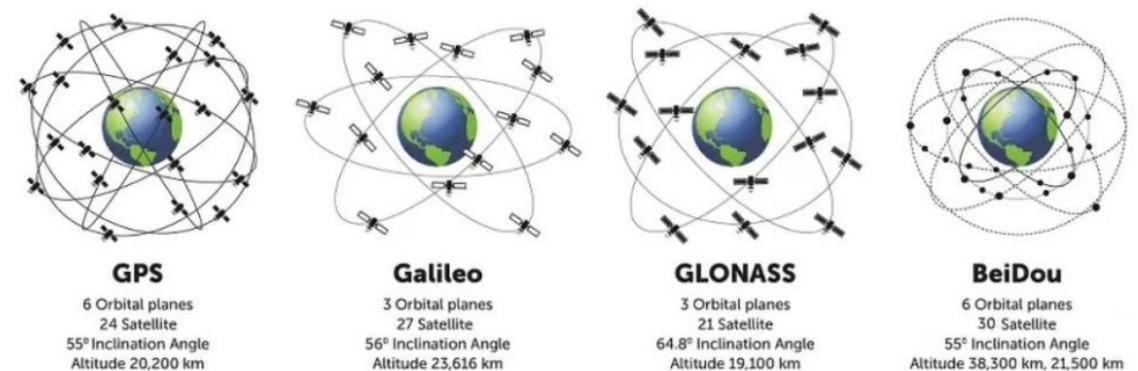
Below is an outline of the key terms and technologies referenced in the current state-of-the-art PNT technology stack based on internal expert interviews and literature review:

Global Navigation Satellite Systems (GNSS)

GNSS refers to satellite-based navigation systems providing global positioning and timing services. Most AD/ADAS systems support **multi-constellation** and **dual-frequency** receivers to improve robustness and availability.

- **GPS** – Global Positioning System (USA)
- **Galileo** – European GNSS
- **GLONASS** – Global Navigation Satellite System (Russia)
- **BeiDou II & III** – Chinese Navigation Satellite System
- +
- **QZSS** (Japan / Asia-Oceania)
- **NavIC** (India)

Major GNSS Constellations



Source: Introduction to GNSS Geodesy, Springer, 2022

Definition of relevant PNT dimensions

3 clusters of PNT Dimensions have been identified to discuss use cases (D2)

Cluster 1 – Technical Performance

01

Accuracy

How close the estimated state is to the true state.

02

Precision

How stable and consistent the estimate is over repeated observations.

03

Availability (Continuity/Coverage)

PNT usability through the whole ODD incl. urban canyons, tunnels, canopy, and poor weather.

04

Timing & Synchronization

Internal synchronization – between sensors within the vehicle; External synchronization synchronization with global time sources (e.g. GNSS)

Cluster 2 – Signal Quality, Trust & Resilience

05

Integrity

Protection levels, confidence in estimate, fault detection, and safety case support, performance under normal conditions includes confidence levels.

06

Robustness

Performance under disturbed or hostile conditions, includes resistance to jamming, spoofing, and interference.

07

Redundancy

Ability to maintain safe operation or degrade gracefully through architectural fallback. Incl. sensor fusion, alternate references and graceful degrad. strategies.

Cluster 3 – Economic Deployment & Viability

08

Scalability

Deployment at industrial scale across real vehicle fleets, use cases, and ODDs beyond demo or pilot.

09

Cost and Business Viability

Cost vs. capability tradeoffs – technically good PNT can fail if cost structure is wrong.

10

Verification and Validation

Ability to demonstrate that the system works correctly, safely, and with sufficient evidence. Includes certification readiness, and regulatory compliance.

◀ CHAPTER 1.5
STATE OF THE ART
**“EUROPEAN ECOSYSTEM,
SECTOR ANALYSIS”**

5. TIERED EUROPEAN ECOSYSTEM ANALYSIS

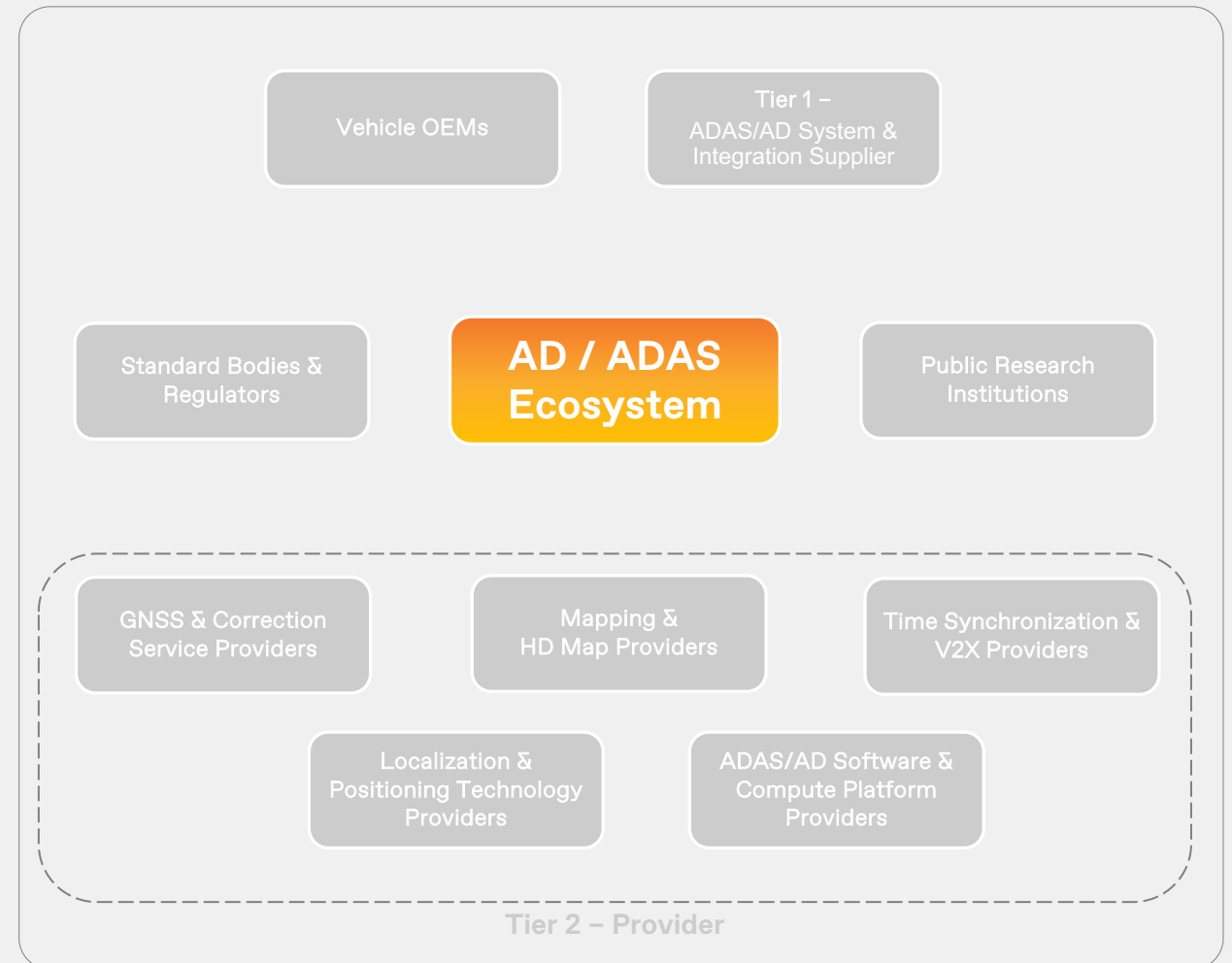
Tiered European Ecosystem Analysis

Mapping of Relevant Actors (Europe/Canada)

This chapter provides a structured overview of the current ADAS/AD and PNT ecosystem relevant to land mobility across Europe and Canada. It covers passenger vehicles, commercial and heavy vehicles, construction and mining equipment, agricultural machinery, logistics and material-handling vehicles, as well as off-road automation domains increasingly reliant on precision positioning, localization, timing and autonomy.

The analysis covers actors across the value chain, classified through the defined Player Role taxonomy: Vehicle OEMs, Tier 1 ADAS/AD System & Integration Suppliers, Tier 2 providers across GNSS and correction services, localization and positioning, mapping and HD maps, time synchronization and V2X, and ADAS/AD software and compute platforms, as well as Public Research Institutions and Standardization Bodies & Regulators.

Actors are further categorized by sector-specific relevance, technology focus, TRL relevance, regional presence, and representative products, projects or initiatives. Furthermore, selected global non-EU/Canada companies of very high relevance in Land Mobility, PNT and ADAS/AD are included as benchmark cases for comparative technology analysis.

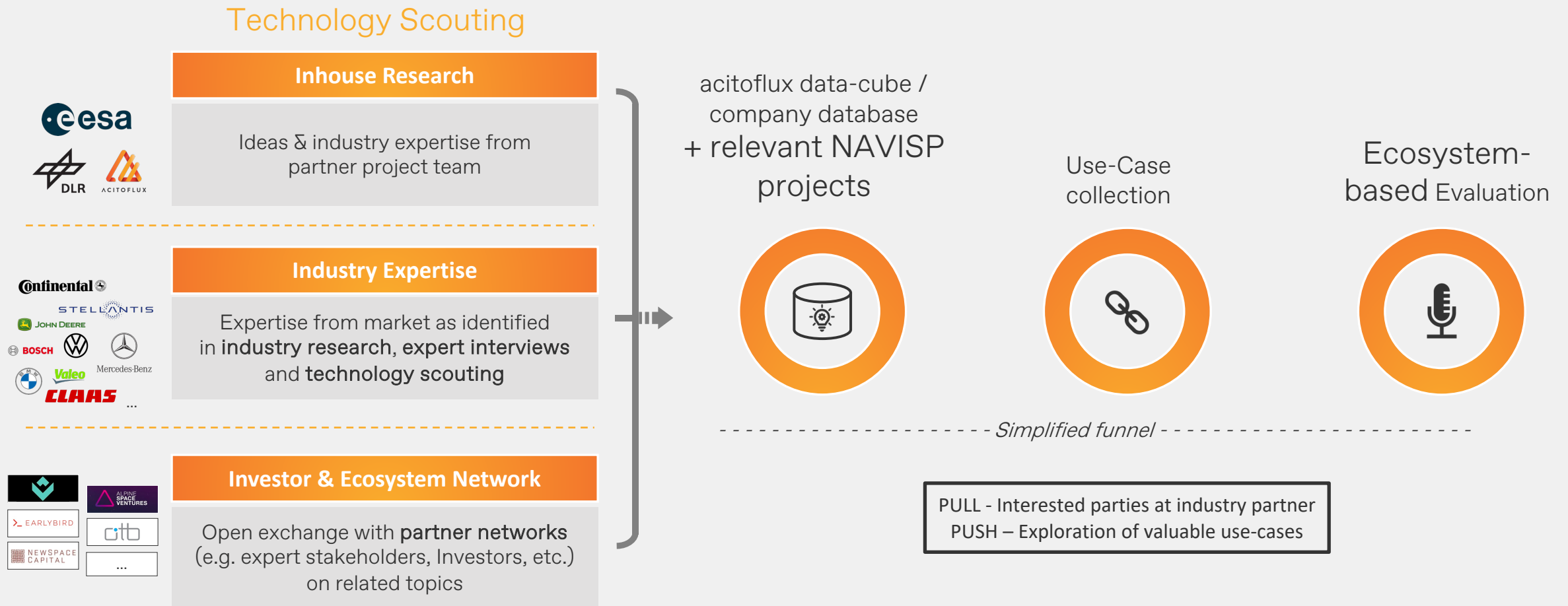


CHAPTER 1.6

SCREENING APPROACH OF STATE OF THE ART TECHNOLOGIES

6. SCREENING APPROACH OF STATE OF THE ART TECHNOLOGIES & ASSOCIATED COMPANIES

Multi-dimensional technology scouting & assessment to evaluate gaps and opportunities

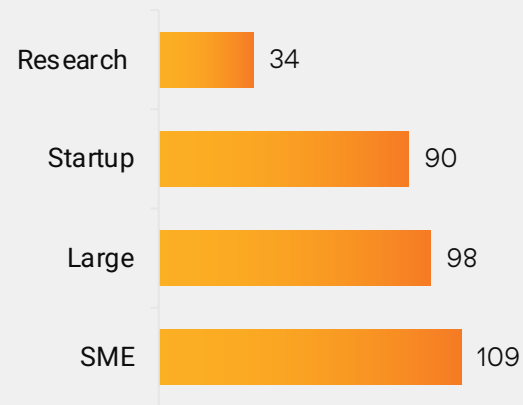


7. PNT STATE OF THE ART | DATABASE INSIGHTS

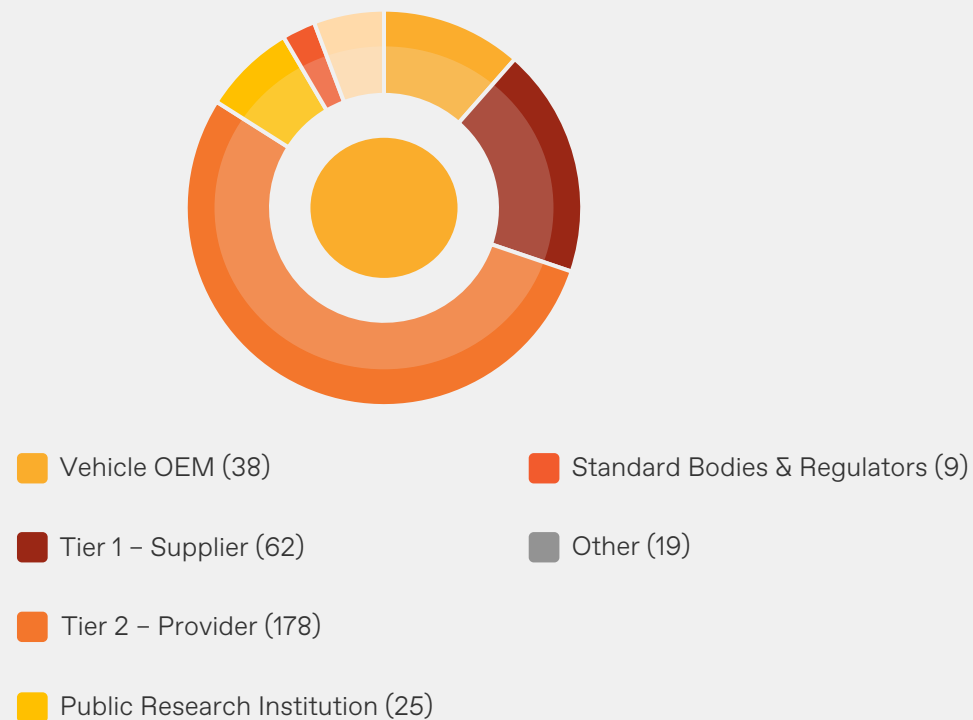
Data overview of long listed companies

n = 331 screened and long-listed companies

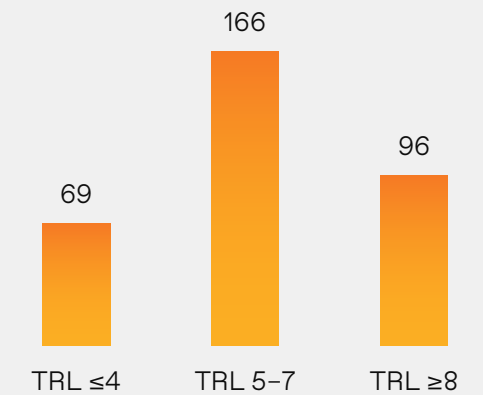
Company Size



Player Role

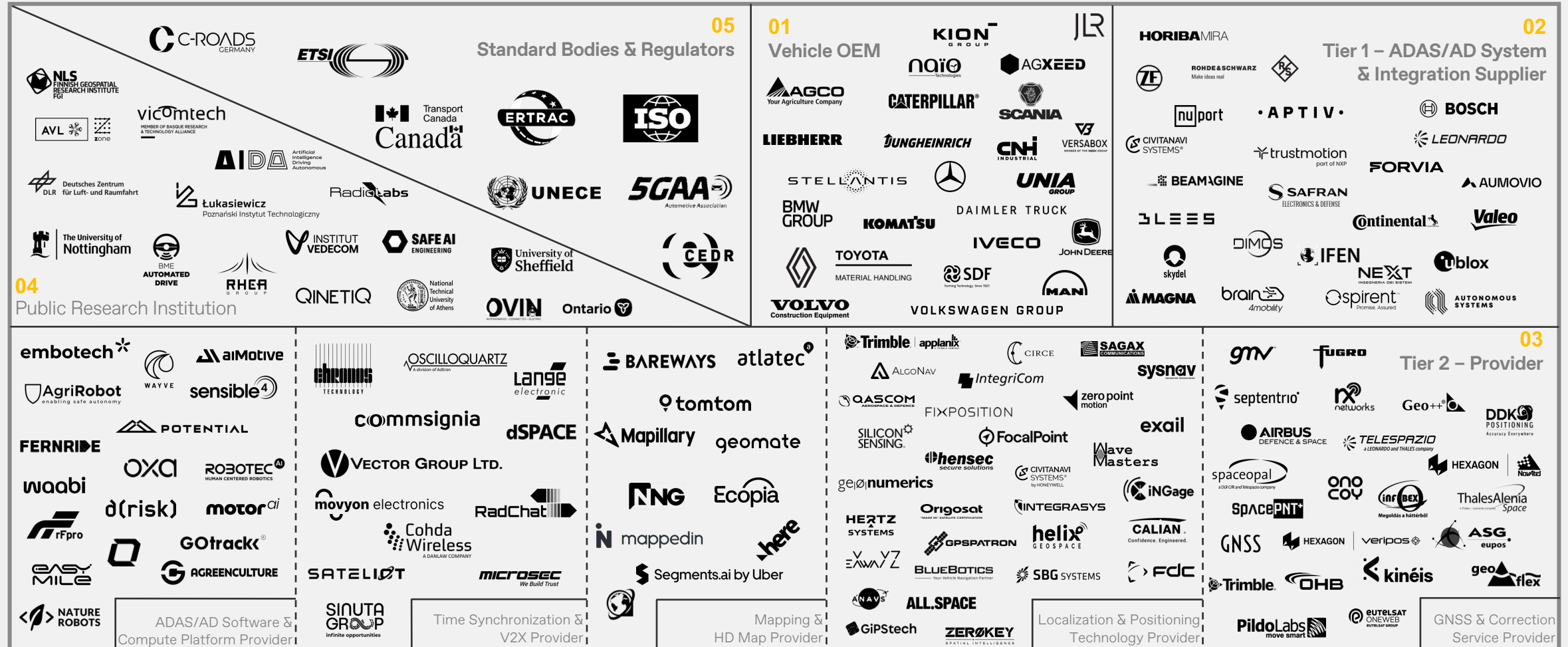


TRL Relevance



7. PNT STATE OF THE ART | DATABASE INSIGHTS

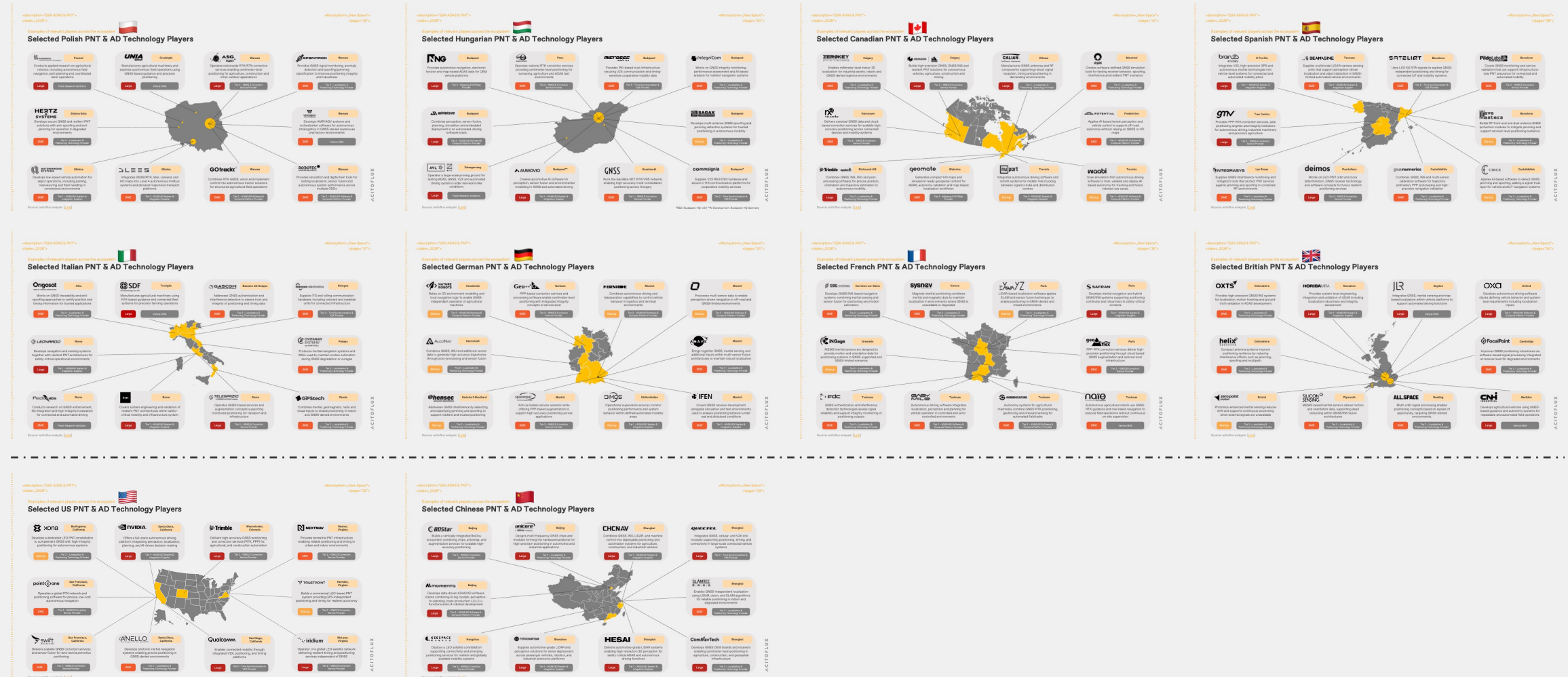
Exemplary overview of different player roles



◀ CHAPTER 1.7 GLOBAL ECOSYSTEM INSIGHTS – incl. outside-in [EXCERPT]

Examples of relevant players across the ecosystem

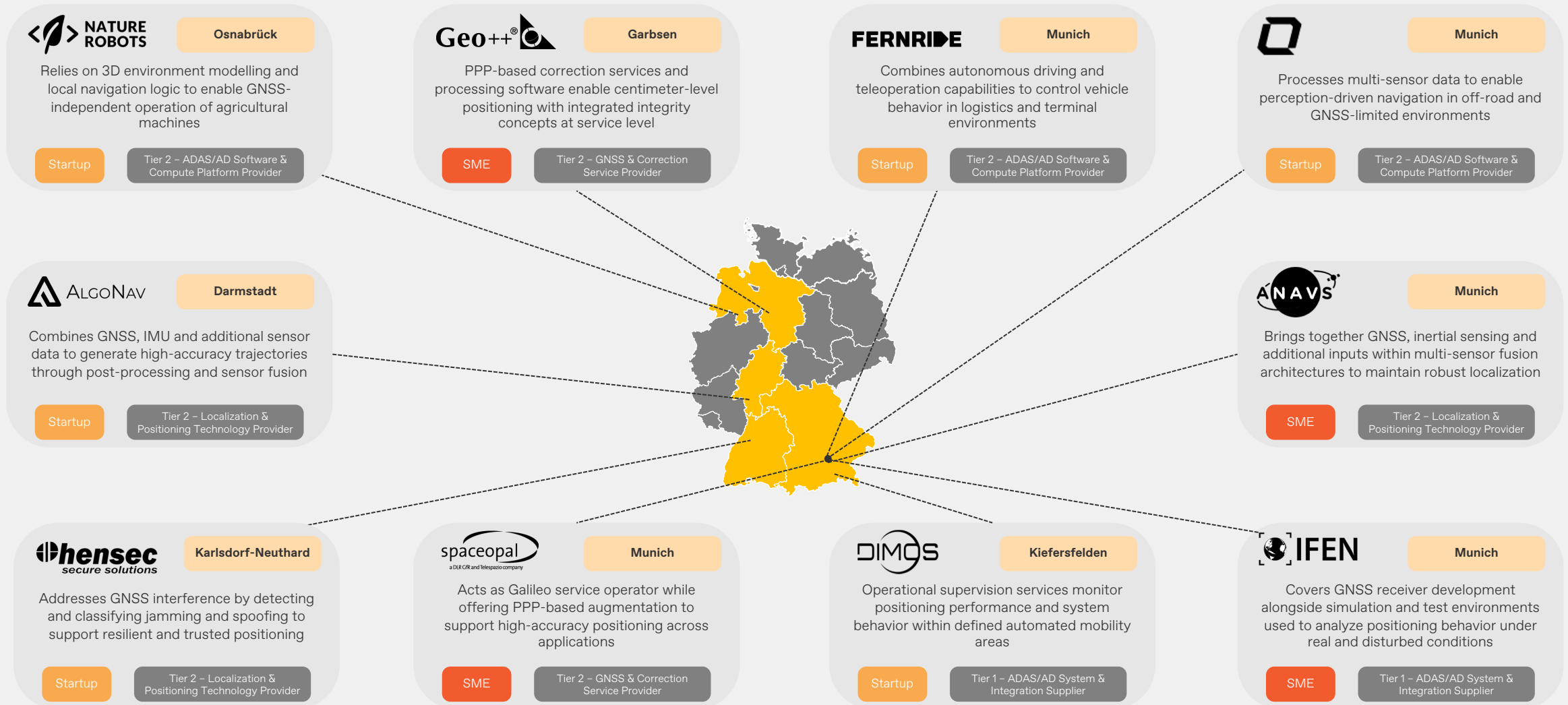
Overview Selected PNT & AD Technology Players per Country



Examples of relevant players across the ecosystem



Selected German PNT & AD Technology Players



CHAPTER 1.8
STATE OF THE ART
**“LEADING PROJECTS
OF THE ECOSYSTEM” [EXCERPT]**

<#ecosystem=„New Space“>

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Overview Selcted Leading Projects per Player Role

shape how ADAS/AD functions are tested.

8. PNT STATE OF THE ART | ECOSYSTEM PROJECTS AND IMPLICATIONS

SELECTED LEADING PROJECTS - Vehicle OEMs

Mercedes-Benz – SAE Level 4 Testing



- > Approved for public-road SAE Level 4 testing on designated urban roads and highways using upgraded S-Class test vehicles.
- > Multi-sensor architecture with LiDAR, radar, cameras and redundant systems validated in real-world traffic conditions.

Source: Welt, Aug 08th 24 [\[Link\]](#)

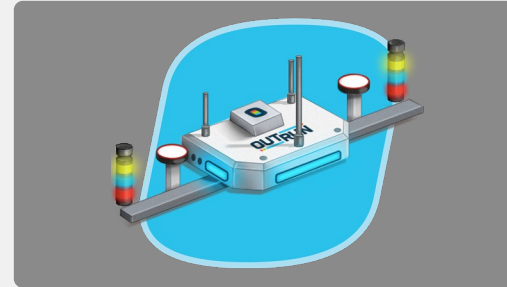
MAN Truck & Bus – ATLAS-L4 Autonomous Hub-to-Hub



- > Level 4 motorway automation programme for freight transport between logistics hubs on predefined routes.
- > Integrates perception systems, GNSS-supported localization and technical supervision within real-world highway operations.

Source: MAN, May 08th 25 [\[Link\]](#)

AGCO / PTx Trimble – OutRun™



- > Retrofit autonomy platform enabling driverless grain cart and tillage operations with existing agricultural tractors.
- > PTx Trimble location technology, guidance and remote mission control support scalable autonomous field workflows.

Source: AGCO, Jun 12th 25 [\[Link\]](#)

Caterpillar – Autonomous Cat® 777 Quarry Truck



- > Fully autonomous Cat® 777 off-highway truck demonstrated for quarry operations at Luck Stone's Bull Run plant.
- > MineStar™ Command extends proven autonomous haulage from mining into quarry environments with site-level fleet control.

Source: Caterpillar, Jan 07th 26 [\[Link\]](#)

Technology State of the Art

- > Vehicle OEMs are moving from isolated ADAS features toward ODD-defined automated driving and autonomous off-highway operations.
- > Localization is becoming a system-level function combining GNSS, inertial sensing, perception, maps, route supervision and safety monitoring.
- > Agriculture, hub-to-hub freight and quarry/mining operations show faster autonomy maturity because their ODDs are bounded, repeatable and operationally valuable.

Source: acitoflux analysis [\[Link\]](#)

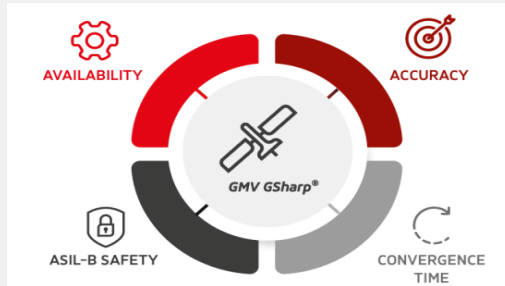
Direction & Implications

- > Vehicle platforms require positioning outputs that include confidence, integrity and fallback-related information alongside nominal position estimates.
- > Automated driving functions are currently deployed within defined operational domains with controlled environmental and operational conditions.
- > System architectures incorporate multiple positioning inputs and interfaces to support integration into safety-relevant vehicle functions.

8. PNT STATE OF THE ART | ECOSYSTEM PROJECTS AND IMPLICATIONS

SELECTED LEADING PROJECTS – GNSS & Correction Service Provider

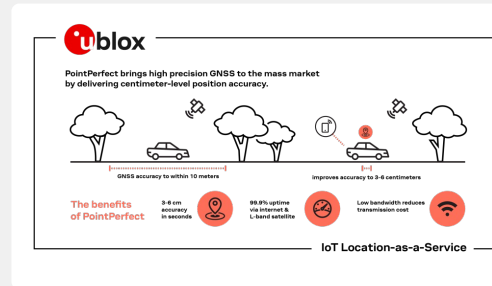
GMV – GSharp® PPP-RTK



- > Automotive-oriented PPP-RTK corrections with a safe positioning engine for higher automation use cases.
- > Integrity monitoring, protection levels and ISO 26262 / SOTIF alignment support safety-grade localization confidence.

Source: GMV, Oct 10th 24 [\[Link\]](#)

u-blox – PointSafe / PointPerfect



- > Continental-scale PPP-RTK correction service delivering centimeter-level positioning with fast convergence.
- > Mixed-receiver support and standardized formats enable scalable deployment for autonomous machines and mobility fleets.

Source: u-blox, Aug 31st 21 [\[Link\]](#)

Trimble – RTX / RTX-NMA



- > Real-time GNSS corrections enabling centimetre-level positioning across land mobility, agriculture and construction.
- > RTX-NMA adds navigation-message authentication to improve spoofing resilience and trusted positioning confidence.

Source: Geospatial World, Aug 18th 25 [\[Link\]](#)

Xona / Septentrio – Pulsar & LeoRx



- > Early LEO-PNT validation chain combining Xona Pulsar signals with Septentrio's LeoRx reference receiver.
- > X1/X5 signal tracking and interference monitoring assess LEO-PNT as a resilience layer for autonomous mobility.

Source: everything RF, Apr 24th 26 [\[Link\]](#)

Technology State of the Art

- > GNSS correction services are progressing from local RTK and best-effort PPP toward scalable PPP-RTK with defined quality, convergence and service-health characteristics.
- > Safety-relevant positioning increasingly combines corrections with integrity monitoring, authentication, protection levels and receiver-side interference mitigation.
- > LEO-PNT is emerging as a complementary layer to improve signal strength, geometry and resilience where classical GNSS is degraded.

Source: acitoflux analysis [\[Link\]](#)

Direction & Implications

- > Correction services provide positioning data together with additional information related to quality and consistency of the solution.
- > Positioning services are applied across different operational domains with varying environmental and signal conditions.
- > Service architectures consider the combination of multiple satellite systems and complementary approaches for positioning and timing.

◀ CHAPTER 2
**EMERGING AD/ADAS
APPLICATIONS**
“ENVIRONMENTAL ANALYSIS”

1. AD/ADAS ENVIRONMENT ANALYSIS

What's changing in AD/ADAS Market? – Tech, regulation, and consumer drivers

TECHNOLOGY



- Lane-level localization is moving from “nice to have” to “enabler” for **L2++/L3 use cases** (highway assist, traffic jam assist, ALKS, geo-fenced functions, speed compliance)
- **Software-defined AD/ADAS**: rapid iteration via Over-the-Air updates + data feedback loops from OEMs
- **AI as a key technology driver** for enhanced supervised **L2++** „AD-like“ use cases with growing convenience for users
- **Assured (accurate + trustworthy) positioning** becomes a safety feature (especially for ADAS)

REGULATION



- Increased EU General Safety Regulation (GSR) is basically forcing ADAS to become baseline equipment
- Practical impact: Since July 2024 (Stage B) onward, many “**modern ADAS**” elements become compulsory for new types / registrations depending on the measure and vehicle class, and more requirements tighten again around January 2026 / July 2026 stages.
 - Type approval by UNECE and EU for pathways for higher automation are maturing enabling **L3/L4 expansion in constrained ODDs**; motorway pilots, automated parking, hub2hub freight pilots
 - **EU AI Act**: Applies progressively – AD/ADAS is increasingly regulated as a High Risk AI (**software + data product**), not only as mechatronics; PNT is pulled into cybersecurity governance

ENVIRONMENT
OF EMERGING
AD/ADAS APPLICATIONS

CONSUMER BEHAVIOR / COMMERCIAL



- EU-mandated features like ISA (Intelligent Speed Assistance) are explicitly overrideable, but if the system is noisy (wrong limits, poor positioning/ map matching, harsh interventions), users will fight it
- **Safety ratings and transparency are becoming purchase shortcuts** and they increasingly evaluate AD/ADAS “behavior,” not marketing claims, e.g. Euro NCAP is implementing a major protocol overhaul for 2026 and runs an [Assisted Driving Grading](#)
- First insurance companies adapt to “**autonomous car insurance**” for **half the price**, e.g. if driver was using Tesla FSD (Full Self-Driving) mode; Monetary aspect will quickly change users behavior

◀ CHAPTER 2
**EMERGING AD/ADAS
APPLICATIONS**
“ODD TRENDS AND IMPLICATIONS ”

6. ODD TRENDS AND IMPLICATIONS

ODD Trends and Implications

Trends	Description	Implication
Expansion of ODDs (from narrow to broader domains)	ADS functions are being designed to operate under more complex and diverse conditions. Moving from restricted “highway-only” or “daytime-only” operation toward more general domains that include urban areas, bad weather, or nighttime.	Improvements in sensing, perception, and localization.
Standardization and taxonomy of ODD attributes	Global efforts (SAE, ISO, ASAM) are defining standardized frameworks for describing ODD attributes, such as environment, geography, infrastructure, traffic, and time-of-day. ODDs will be formally specified, verified, and compared.	Allows regulators and manufacturers to align ODD definitions and testing requirements.
Dynamic and adaptive ODDs	Because the real world is dynamic, there is growing focus on how systems can detect and adapt to changes in operating conditions (e.g., sudden rain, construction zones, or low visibility).	Leads to concepts like “micro-ODDs,” dynamic ODD recognition, and automatic fallback procedures when conditions fall outside the defined domain.
ODD-based validation and safety assurance	Validation, verification, and safety case processes are increasingly centered around ODD boundaries.	Need for comprehensive test scenarios and simulation frameworks that represent ODD conditions

 AD/ADAS is moving from “works in a few fixed situations” to “works across broader, messier real-world conditions,” which means every use case must be explicitly ODD-defined, continuously ODD-monitored, adaptive when conditions shift, and proven safe with ODD-centered validation.

CHAPTER 1.9
STATE OF THE ART
TREND DERIVATION

9. TREND DERIVATION AND CONCLUSIO

Overall State of the Art Trends in PNT regarding AD/ADAS being synthesized

MAJOR TRENDS (TECH & ECOSYSTEM)

Trend A: From “accuracy” to “trust” (integrity + availability + resilience)

- “Position + confidence” becomes a first-class interface to AD stacks
- ODD gating depends on localization confidence (enter/exit conditions)

Trend C: Corrections scale-up: RTK is mature; PPP / PPP-RTK is the growth vector

- RTK: operationally proven (but infrastructure-heavy)
- PPP-RTK / scalable correction services: where the competition is moving (coverage, convergence, safety qualification)

Trend E: “Local infrastructure positioning” vs “pure satellite resilience”

- Asset heavy: V2X / Road side units (RSU) / Cooperative Intelligent Transport Systems (C-ITS) / 5G-related positioning
- Still pre-productization compared to GNSS/INS + correction services

Trend B: Tight GNSS/Internal Sensors (INS) coupling is becoming baseline for autonomy-relevant localization

- GNSS-only is insufficient (urban canyon, tunnels, interference)
- Multi-constellation / multi-frequency GNSS is the baseline foundation
- Tightly coupled GNSS-IMU with motion constraints now a standard building block

Trend D: Off-road autonomy is the fastest “PNT-to-product” pathway

- Better to calculate – earlier deployment : Controlled ODD, lower speeds, strong business case
- Potential spillover to on-road autonomy

Trend F: Alternative sensors complementing GNSS

- Vision/camera-based positioning (e.g., Provizio-style perception-aided localization)
- High-grade inertial & wheel-odometry stacks (e.g., ZeroPoint Motion) for GNSS-denied dead-reckoning
- LiDAR / visual SLAM and HD-map matching as redundant localization channels

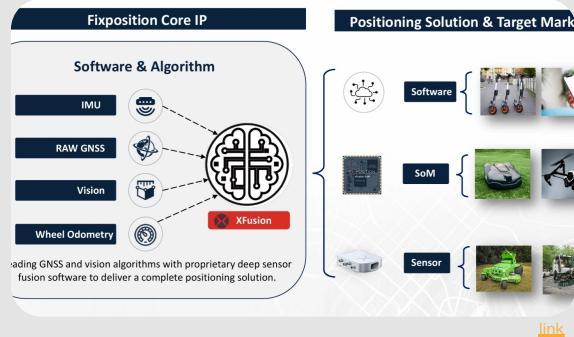
9. TREND DERIVATION AND CONCLUSION

When considering emerging PNT technologies [TLR 5-7] in AD/ADAS – Sensor Fusion (IMU measurements, GNSS, Camara, etc.), High-accuracy corrections, Resiliency, AI-powered GNSS and 5G Network convergence are key topics

EMERGING TECHNOLOGY TRENDS

Sensor Fusion, depending on precise time alignment

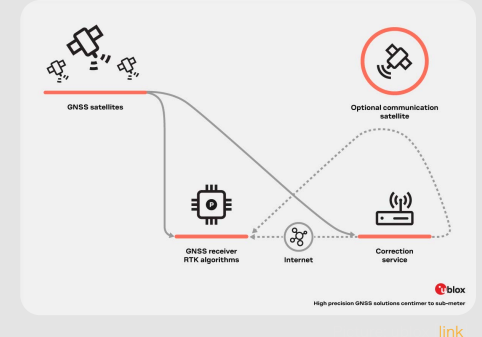
Camera/radar/lidar/IMU/GNSS measurements are fused across Electronic control units (ECUs), precise time alignment is crucial.



[link](#)

Scalable automotive-grade integration & AD-relevant PPP-RTK correction services

Guaranteed performance (SLA) + safety qualification + fast convergence under dynamics is still evolving



[link](#)

AI-powered GNSS receivers to enable AD

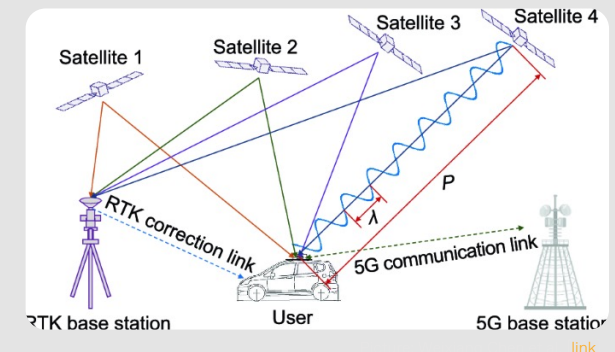
AI-powered GNSS might be an emerging differentiator mainly for urban robustness and trust metrics (integrity-like outputs)



[link](#)

Convergence of GNSS with 5G Networks

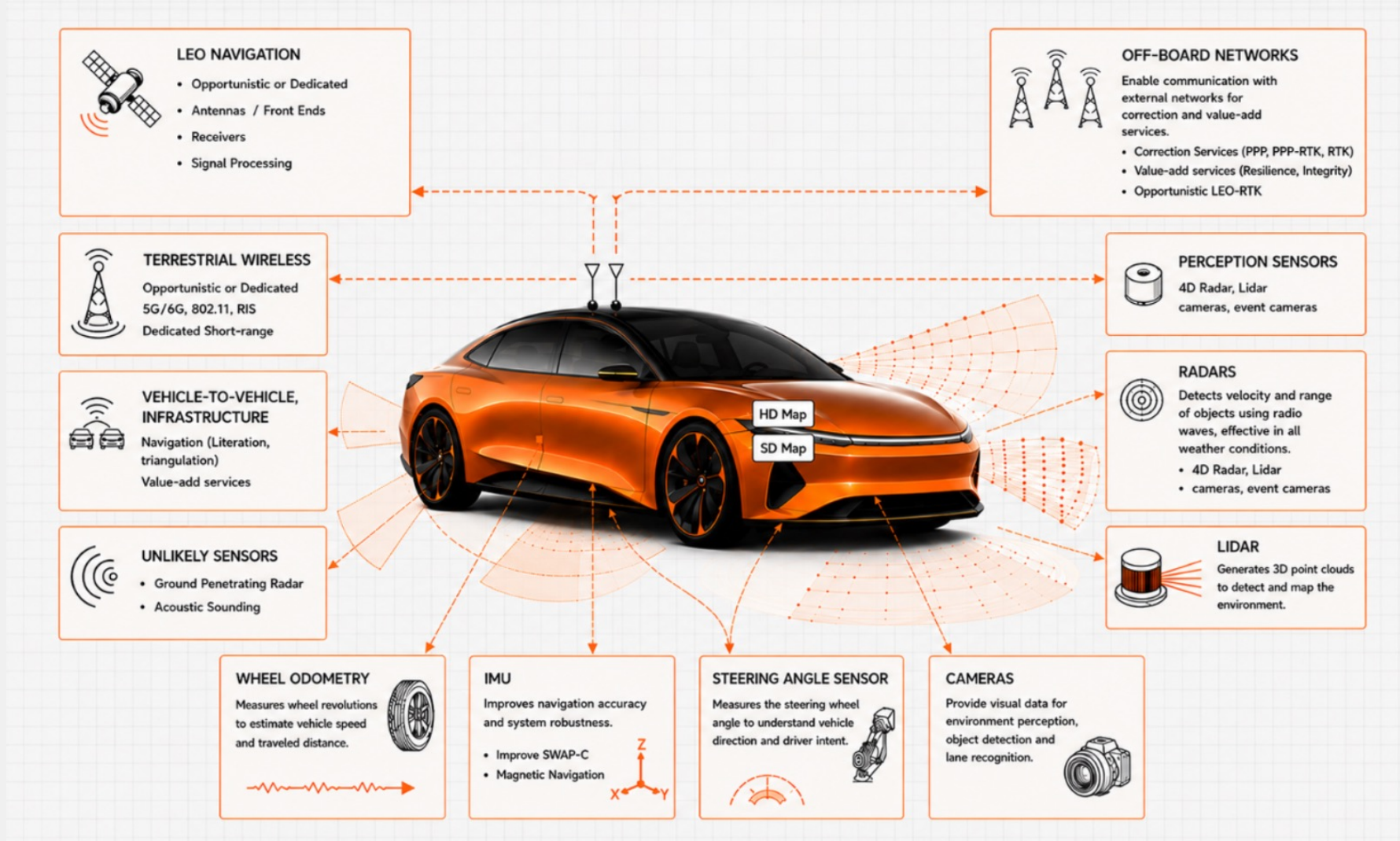
5G will enhance GNSS by delivering faster, more reliable, low-latency location services + timing source → 3GPP Rel. 18 discusses resilient clock synchronization



[link](#)

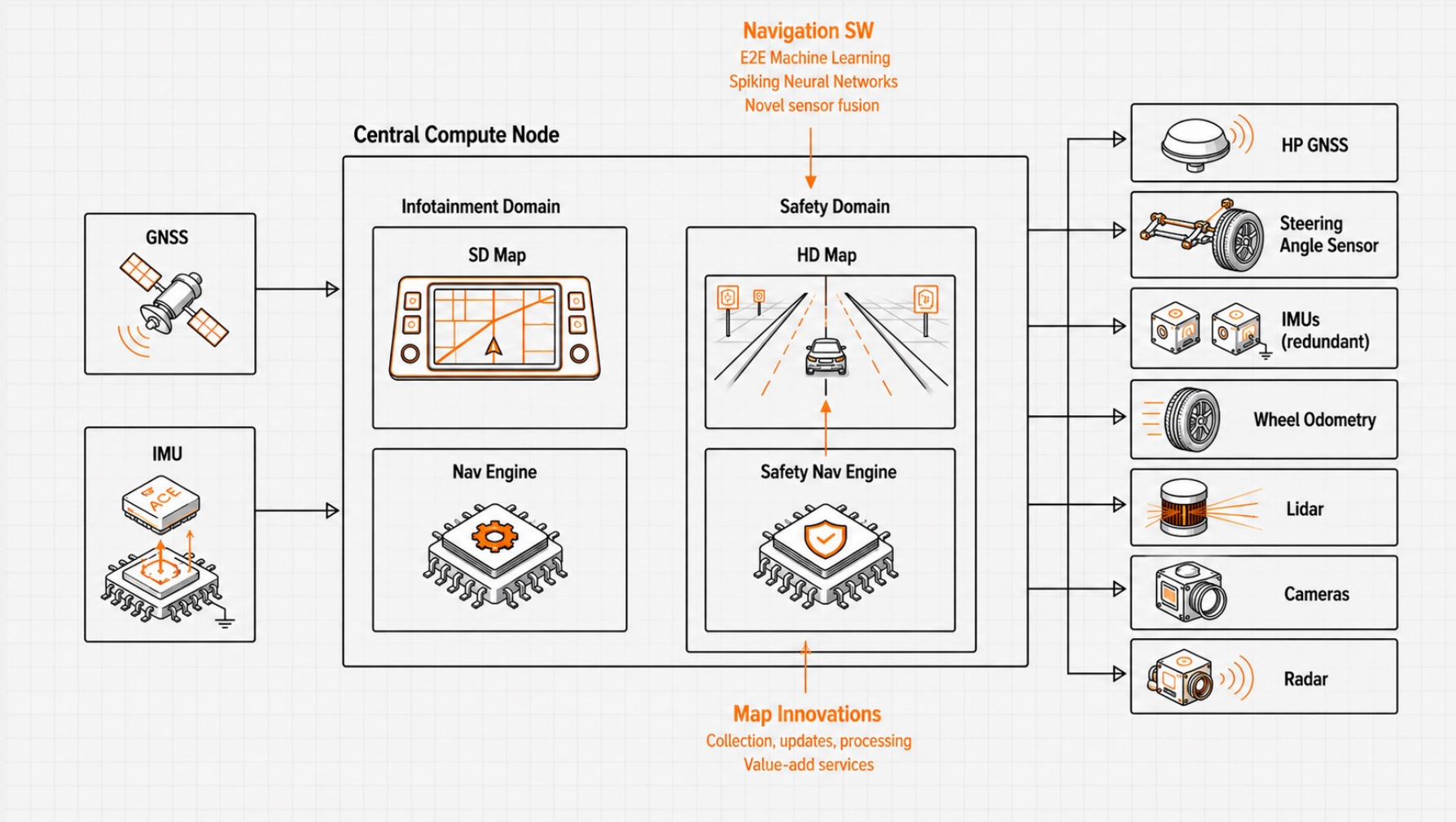
9. TREND DERIVATION AND CONCLUSION

First Opportunities for NAVISP: High Automation Navigation Architecture



9. TREND DERIVATION AND CONCLUSION

First Opportunities for NAVISP: High Automation Navigation Architecture

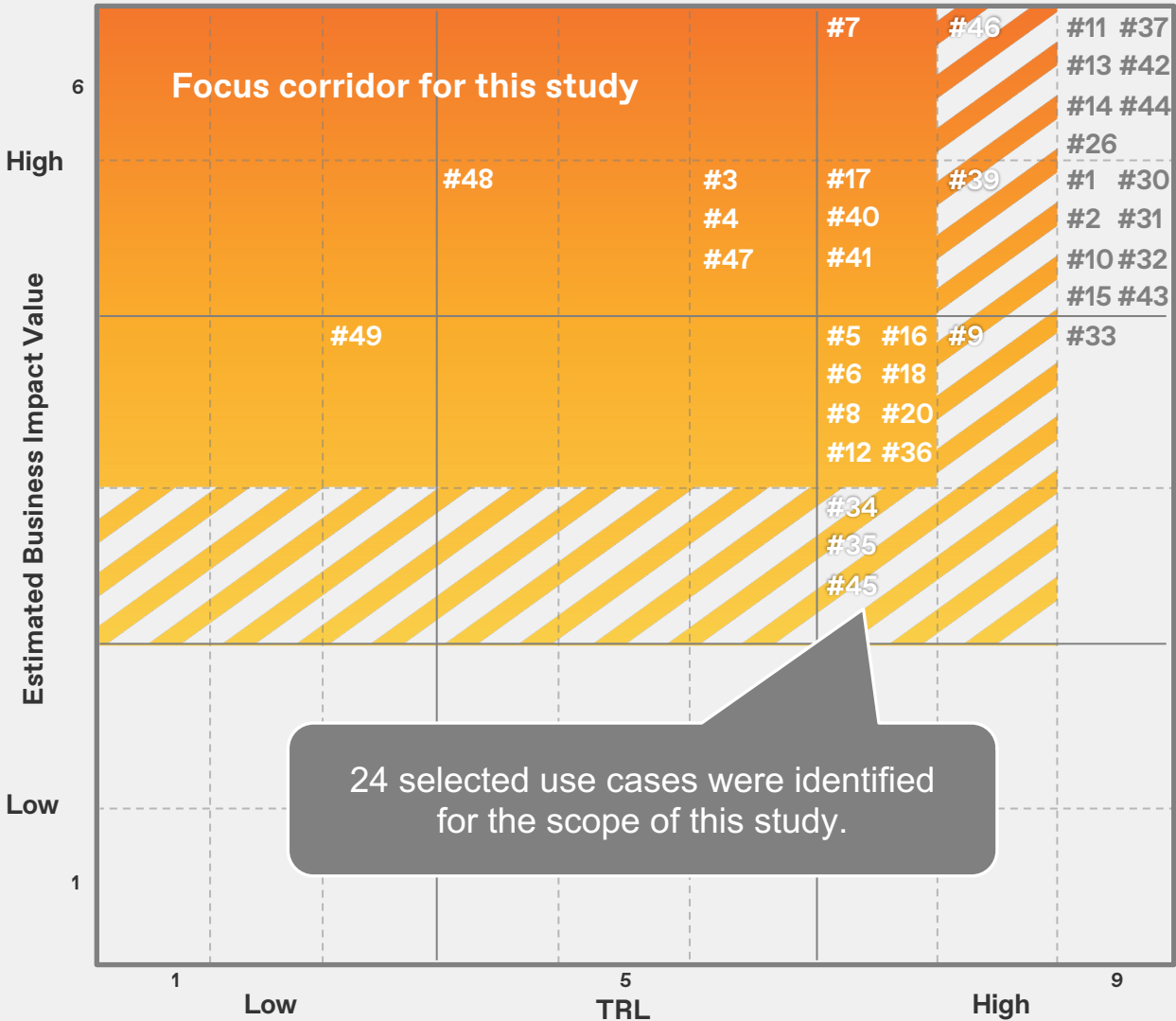


◀ CHAPTER 2
**EMERGING AD/ADAS
APPLICATIONS**
**“USE CASES & COMMERCIAL
DEPLOYMENT TIMELINES”**

8. AD/ADAS APPLICATIONS – RELEVANCY & TRL ASSESSMENT

40 PNT relevant Use Cases have been evaluated regarding Impact and their TRL

UC-01 Adaptive Cruise Control (ACC)	UC-26 Intelligent Speed Assistance (ISA) / Speed Limit Info
UC-02 Lane Keeping Assist / Lane Centering	UC-30 Corrective Steering / Lane Keeping System (steering regulation anchor)
UC-03 Automated Lane Keeping System (ALKS)	UC-31 Turn Assist / VRU Turn Warning (bus/truck)
UC-04 Traffic Jam Chauffeur	UC-32 Predictive Cruise Control / Eco-ACC (topography-aware)
UC-05 Automated Valet Parking (AVP / AVPS)	UC-33 Remote / Assisted Parking (incl. remote park assist)
UC-06 Truck Platooning (CACC / cooperative platooning)	UC-34 Cooperative Hazard Warning (V2X via DENM)
UC-07 Hub-to-Hub Autonomous Trucking	UC-35 Cooperative Awareness (V2X via CAM)
UC-08 Autonomous Shuttle Bus (fixed route)	UC-36 Remote Operation / Tele-driving for Exceptions
UC-09 Autonomous Delivery Robot (last-mile)	UC-37 Fleet Orchestration (AMR/AGV traffic management)
UC-10 Autonomous Tractor (field ops)	UC-39 Geofencing & Exclusion Zone Enforcement
UC-11 Precision Spraying & Fertilizing (site-specific)	UC-40 GNSS-Denied Resilient Navigation (site ops)
UC-12 Autonomous Excavator / Earthmoving	UC-41 Swarm / Coordinated Field Robots
UC-13 Autonomous Haul Truck (AHS)	UC-42 Fleet Optimization & Dispatch (connected autonomy ops)
UC-14 Autonomous Mobile Robot (AMR) / AGV	UC-43 Energy-Aware Routing / Range Optimization
UC-15 Autonomous Yard Vehicle (containers)	UC-44 Predictive Maintenance for Autonomous Fleets
UC-16 Autonomous Baggage Tug / Tow Tractor	UC-45 Unoccupied Low-Speed Automated Driving (AVP-like zones)
UC-17 Autonomous Yard Shunting Vehicle (rail-adjacent)	UC-46 Driverless Robo-Taxi / Ride-Hailing (L4)
UC-18 Smart Intersection Assistance (V2X hazard warnings)	UC-47 Autonomous Ride-Pooling Van (L4) – Service Vehicle
UC-19 Autonomous Firefighting / Hazard Response Vehicle	UC-48 Driverless Highway Pilot for Privately Owned Cars (L4 – conceptual tomorrow)
UC-20 Autonomous Ground Vehicle (UGV)	UC-49 Universal Full Driving Automation (L5 passenger car – conceptual)



◀ **CHAPTER 2**
EMERGING AD/ADAS
APPLICATIONS
24 SHORT-LISTED USE CASES
PROFILES
(TRL<9, PNT relevant), Excerpt

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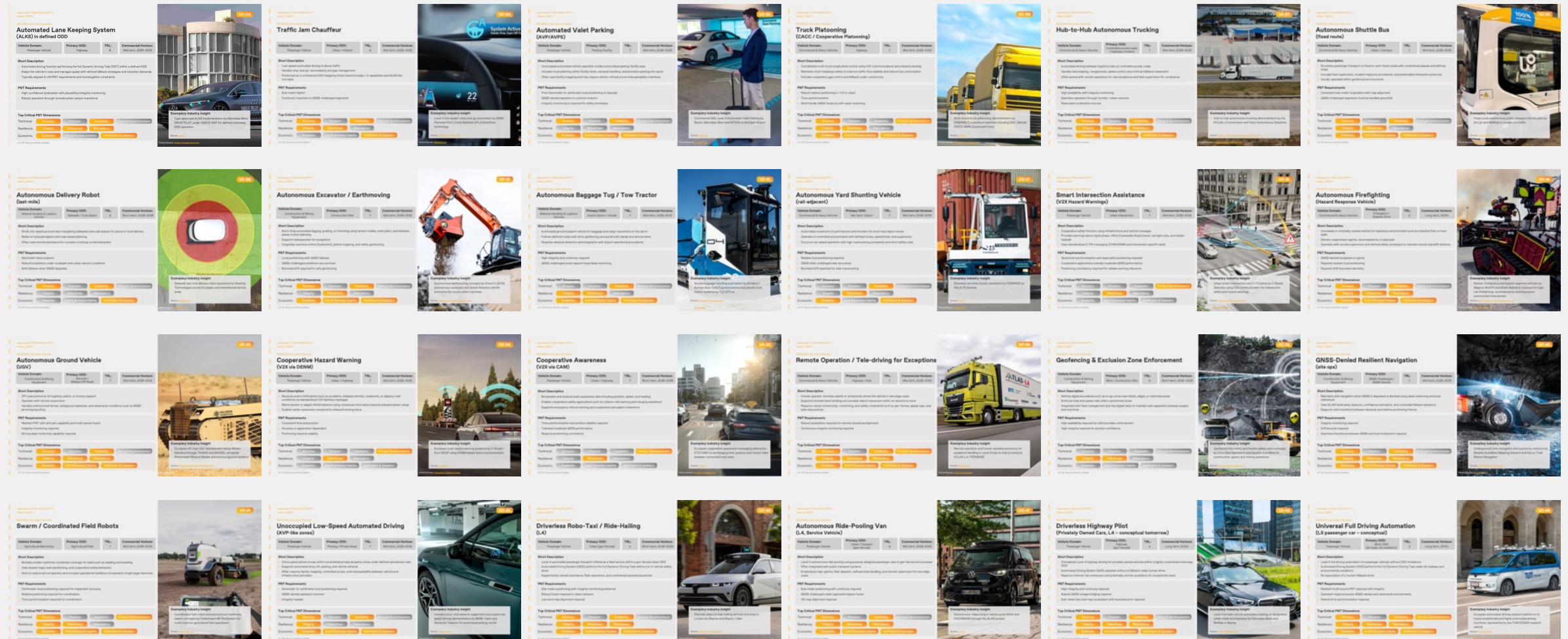
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AD/ADAS Use Case Overview

USE CASE OVERVIEW, SHORT LIST



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AD/ADAS Use Case Overview

Automated Valet Parking (AVP/AVPS)

Vehicle Domain: Passenger Vehicle	Primary ODD: Parking Facility	TRL: 7	Commercial Horizon: Mid-term, 2029–2032
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Short Description

- > Unoccupied automated vehicle operation inside a prescribed parking-facility area
- > Includes route planning within facility lanes, obstacle handling, and precision parking into spots
- > Often uses facility mapping and may require vehicle–infrastructure interoperability interfaces

PNT Requirements

- > From Decimeter-to-centimeter local positioning is required
- > GNSS-denied operation is common indoors
- > Integrity monitoring is required for safety envelopes

Top Critical PNT Dimensions

Technical:	Accuracy	Precision	Availability	Timing & Synchronization
Resilience:	Integrity	Robustness	Redundancy	
Economic:	Scalability	Cost & Business Viability	Verification & Validation	



Exemplary Industry Insight

- > Commercial SAE Level-4 Automated Valet Parking by Bosch, Mercedes-Benz and APCOA at Stuttgart Airport

Source: apcoa.com

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AD/ADAS Use Case Overview

Smart Intersection Assistance (V2X Hazard Warnings)

Vehicle Domain:

Passenger Vehicle

Primary ODD:

Urban Intersection

TRL:

7

Commercial Horizon:

Mid-term, 2029–2032

Short Description

- > Cooperative safety function using infrastructure and vehicle messages
- > Provides warnings about signal phase, VRUs (Vulnerable Road Users), red-light risks, and hidden hazards
- > Uses standardized C-ITS messaging (CAM/DENM and intersection-specific data)

PNT Requirements

- > Good time synchronization and reasonable positioning required
- > Cooperative applications tolerate moderate GNSS performance
- > Positioning consistency required for reliable warning relevance

Top Critical PNT Dimensions

Technical:

Accuracy

Precision

Availability

Timing & Synchronization

Resilience:

Integrity

Robustness

Redundancy

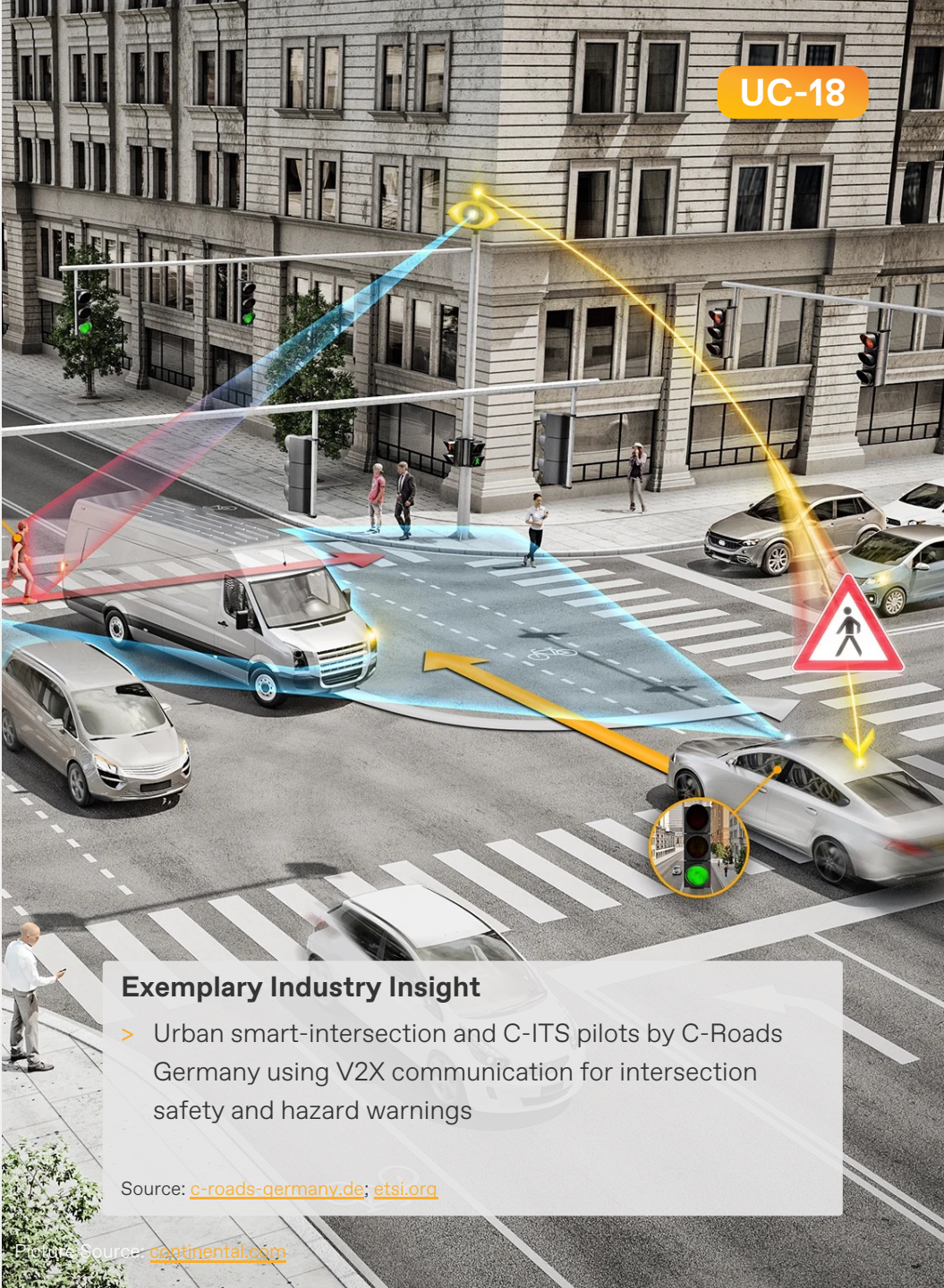
Economic:

Scalability

Cost & Business Viability

Verification & Validation

UC-18



Exemplary Industry Insight

- > Urban smart-intersection and C-ITS pilots by C-Roads Germany using V2X communication for intersection safety and hazard warnings

Source: c-roads-germany.de; etsi.org

Autonomous Firefighting (Hazard Response Vehicle)

Vehicle Domain:
Commercial & Heavy Vehicles

Primary ODD:
Emergency / Disaster Zone

TRL:
5

Commercial Horizon:
Long-term, 2033+

Short Description

- > Uncrewed or minimally crewed vehicle for hazardous environments such as industrial fires or toxic spills
- > Delivers suppression agents, reconnaissance, or payloads
- > Operates with remote supervision and defined safety envelopes to maintain human standoff distance

PNT Requirements

- > GNSS-denied navigation is typical
- > Requires resilient local positioning
- > Requires drift-bounded odometry

Top Critical PNT Dimensions

Technical:

Accuracy

Precision

Availability

Timing & Synchronization

Resilience:

Integrity

Robustness

Redundancy

Economic:

Scalability

Cost & Business Viability

Verification & Validation



Exemplary Industry Insight

- > Robotic firefighting and hazard-response vehicles by Magirus Wolf R1 and Shark Robotics Colossus for high-risk firefighting, reconnaissance and hazardous-environment intervention

Source: shark-robotics.com; magirusgroup.com

GNSS-Denied Resilient Navigation (site ops)

Vehicle Domain:
Construction & Mining
Equipment

Primary ODD:
GNSS-Challenged /
GNSS-Denied

TRL:
7

Commercial Horizon:
Mid-term, 2029–2032

Short Description

- > Maintains safe navigation when GNSS is degraded or blocked using dead-reckoning and local references
- > Uses SLAM landmarks, beacons, confidence estimation, and controlled fallback behaviors
- > Supports safe transitions between absolute and relative positioning frames

PNT Requirements

- > Integrity monitoring required
- > Drift bounds required
- > Seamless transitions between GNSS and local localization required

Top Critical PNT Dimensions

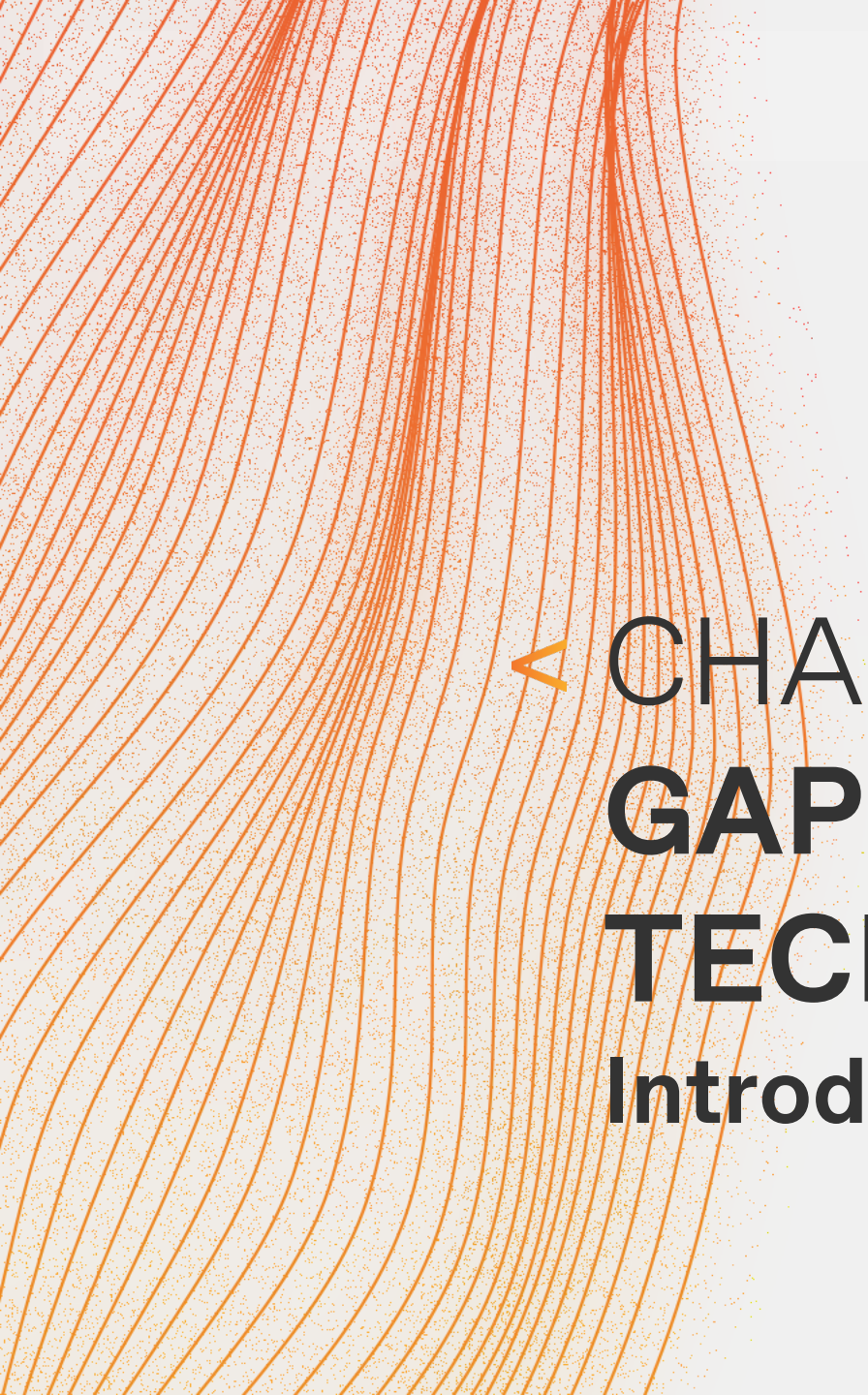
Technical:	Accuracy	Precision	Availability	Timing & Synchronization
Resilience:	Integrity	Robustness	Redundancy	
Economic:	Scalability	Cost & Business Viability	Verification & Validation	



Exemplary Industry Insight

- > Underground mine-navigation and autonomy solutions by Sandvik AutoMine Mapping Solution and Epiroc Total Station Navigation

Source: mining.sandvik.com; epiroc.com



CHAPTER 3

GAP ANALYSIS IN PNT

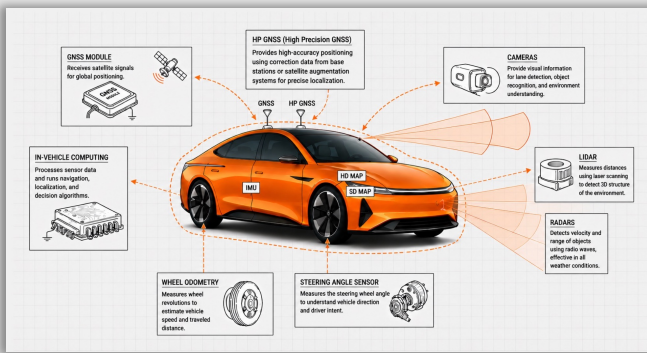
TECHNOLOGIES

Introduction

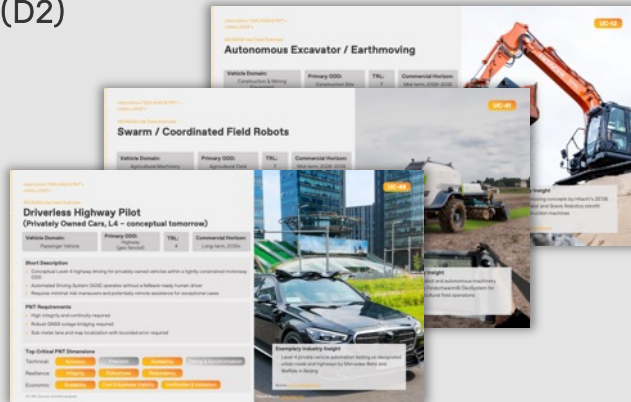
2. PNT dimensions gap analysis of AD/ADAS | Methodology

Based on previous results, the following gap analysis will be baseline for NAVISP Elements

Task 1: State of the art Technology (D1)



Task 2: Emerging AD/ADAS Applications (D2)



Task 3: Gap Analysis (D3):

- Based on 10 relevant PNT dimensions

Cluster 1 - Technical Performance

01 Accuracy How close the estimated state is to the true state.	02 Precision How stable and consistent the estimate is over repeated observations.	03 Availability (Continuity/Coverage) PNT usability through the whole OOD incl. urban canyons, tunnels, canopy, and poor weather.	04 Timing & Synchronization Internal synchronization - between sensors within the vehicle; External synchronization - synchronization with global time sources (e.g. GNSS).
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Cluster 2 - Signal Quality, Trust & Resilience

05 Integrity Protection levels, confidence in estimate, fault detection, and safety case support, performance under normal conditions includes confidence levels.	06 Robustness Performance under disturbed or hostile conditions, includes resistance to jamming, spoofing, and interference.	07 Redundancy Ability to maintain safe operation or degrade gracefully through architectural fallbacks, incl. sensor fusion, alternate references and graceful degrad. strategies.
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Cluster 3 - Economic Deployment & Viability

08 Scalability Deployment at industrial scale across real vehicle fleets, use cases, and OODs beyond demo or pilot.	09 Cost and Business Viability Cost vs. Capability trade-offs - technically good PNT can fail if cost structure is wrong.	10 Verification and Validation Ability to demonstrate that the system works correctly, safely, and with sufficient evidence. Includes certification readiness, and regulatory compliance.
---	---	---

- PNT Gap Framework, scoring per AD/ADAS application / Use Case

Cluster	Dimension	Definition	Scoring System	1	2	3	4	5
Cluster 1 - Technical Performance	01 Accuracy	How close the estimated state is to the true state.	Is the estimate accurate enough when the user is required?	Software across intended OOD heavily sufficient, limited margin errors.	Only sufficient in selected OODs with strong margins.	Only sufficient in selected OODs with strong margins.	Only sufficient in selected OODs with strong margins.	Only sufficient in selected OODs with strong margins.
Cluster 1 - Technical Performance	02 Precision	How stable and consistent the estimate is over repeated observations.	Is the estimate stable enough over time for control or decision making?	Minor stability limits remain.	Minor stability limits remain.	Minor stability limits remain.	Minor stability limits remain.	Minor stability limits remain.
Cluster 1 - Technical Performance	03 Availability (Continuity/Coverage)	How usable through the whole OOD, including urban canyons, tunnels, canopy, and poor weather.	Can the user use the system through the whole OOD without using backup PNT?	Operational across intended OOD.	Operational across intended OOD.	Operational across intended OOD.	Operational across intended OOD.	Operational across intended OOD.
Cluster 1 - Technical Performance	04 Timing & Synchronization	Internal synchronization between sensors, external (GNSS). Does the user case get the timing performance it needs?	Timing fully supports the use case.	Minor timing limitations remain.	Minor timing limitations remain.	Minor timing limitations remain.	Minor timing limitations remain.	Minor timing limitations remain.
Cluster 2 - Signal Quality, Trust & Resilience	05 Integrity	Protection levels, confidence in estimate, fault detection, and safety case support, performance under normal conditions.	Can the user rely on the estimate, trusted PNT, and safety case support?	Confidence and fault detection highly sufficient, but some margin errors.	Confidence and fault detection highly sufficient, but some margin errors.	Confidence and fault detection highly sufficient, but some margin errors.	Confidence and fault detection highly sufficient, but some margin errors.	Confidence and fault detection highly sufficient, but some margin errors.
Cluster 2 - Signal Quality, Trust & Resilience	06 Robustness	Performance under disturbed or hostile conditions, including jamming, spoofing, and interference.	Can the system degrade gracefully when user conditions are disturbed or hostile?	Confidence and fault detection highly sufficient, but some margin errors.	Confidence and fault detection highly sufficient, but some margin errors.	Confidence and fault detection highly sufficient, but some margin errors.	Confidence and fault detection highly sufficient, but some margin errors.	Confidence and fault detection highly sufficient, but some margin errors.
Cluster 2 - Signal Quality, Trust & Resilience	07 Redundancy	Ability to maintain safe operation or degrade gracefully through architectural fallbacks, incl. sensor fusion, alternate references, and graceful degradation strategies.	Can the system degrade gracefully when user conditions are disturbed or hostile?	Confidence and fault detection highly sufficient, but some margin errors.	Confidence and fault detection highly sufficient, but some margin errors.	Confidence and fault detection highly sufficient, but some margin errors.	Confidence and fault detection highly sufficient, but some margin errors.	Confidence and fault detection highly sufficient, but some margin errors.
Cluster 3 - Economic Deployment & Viability	08 Scalability	Deployment at industrial scale across real vehicle fleets, use cases, and OODs beyond demo or pilot.	Can the PNT scale to beyond beyond pilot, into real fleets or use cases?	Scalable at operational scale/complexity with evidence of real-world constraints.	Scalable at operational scale/complexity with evidence of real-world constraints.	Scalable at operational scale/complexity with evidence of real-world constraints.	Scalable at operational scale/complexity with evidence of real-world constraints.	Scalable at operational scale/complexity with evidence of real-world constraints.
Cluster 3 - Economic Deployment & Viability	09 Cost and Business Viability	Cost vs. Capability trade-offs - technically good PNT can fail if cost structure is wrong.	Is the use case economically viable with the targeted PNT cost?	Business case works for the target use case.	Business case works for the target use case.	Business case works for the target use case.	Business case works for the target use case.	Business case works for the target use case.
Cluster 3 - Economic Deployment & Viability	10 Verification and Validation	Ability to demonstrate that the system works correctly, safely, and with sufficient evidence. Includes certification readiness, and regulatory compliance.	Can the PNT be verified, validated, and justified for the intended OOD?	Verifiable and validatable.	Verifiable and validatable.	Verifiable and validatable.	Verifiable and validatable.	Verifiable and validatable.

Identified Technology Use Case Gaps, baseline for NAVISP Elements discussion

Task 4: Derivation of NAVISP Elements (D4)

- Via technology-use case-gap analysis
- Statements/Informations of interview partners, what is needed in the industry
- Overall PNT tech trend analysis, in context of AD/ADAS

Element 1: Innovation in PNT

- Develop novel PNT-related systems and technologies along the entire value chain
- ITTs released on esa-star
- Fully funded

Element 2: PNT Industrial Competitiveness

- Improve European industry's capabilities in the global market for PNT technologies and services (products and services)
- Direct negotiation
- Co-funded(*)

Element 3: Support ESA Member States initiatives

- Support European National Programmes along the whole value chain
- Direct negotiation
- Fully funded

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4.3 PNT dimensions gap analysis of AD/ADAS use cases – Results / Findings

Based on updated PNT Dimensions, 49 use cases had been re-evaluated, and filtered to non-TRL9 (24 use cases) – Results

Cluster 1 Technical Performance

Cluster 2 Signal Quality, Trust & Resilience

Cluster 3 Economic Deployment & Viability

ID	Use Case	Vehicle Domain	Description	ODD (optional)	Estimated Tm (1-6)	01.1 Accuracy gap	01.2 Accuracy score	02.1 Precision gap	02.2 Precision score	03.1 Availability gap	03.2 Availability score	04.1 Timing & Sync	04.2 Timing & Synchronization score	05.1 Integrity gap	05.2 Integrity score	06.1 Robustness gap	06.2 Robustness score	07.1 Redundancy gap	07.2 Redundancy score	08.1 Scalability gap	08.2 Scalability score	09.1 Cost & Btu viability gap	09.2 Cost & Btu viability score	10.1 Verification & validation gap	10.2 Verification & validation score	Avg Scoring per Use Case	Use Case	
1-49	Automated Lane Keeping System (ALKS) in defined ODD	Passenger vehicle	Automated lane keeping system for defined ODD, using sensor fusion and machine learning for lane detection and steering control.	Highway, urban roads, weather conditions, sensor range, system reliability, user interface, etc.	1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.8	Automated Lane Keeping System (ALKS) in defined ODD	
50-74	Traffic jam Chauffeur	Passenger vehicle	Automated lane keeping system for traffic jam situations, using sensor fusion and machine learning for lane detection and steering control.	Urban roads, weather conditions, sensor range, system reliability, user interface, etc.	2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	1.5	Traffic jam Chauffeur	
75-99	Automated Valet Parking (AVP) / AVPS	Passenger vehicle	Automated lane keeping system for automated valet parking, using sensor fusion and machine learning for lane detection and steering control.	Urban roads, weather conditions, sensor range, system reliability, user interface, etc.	3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	1.5	Automated Valet Parking (AVP) / AVPS	
100-124	Truck Platooning (ICAC) / cooperative platooning	Commercial & Heavy Vehicle	Automated lane keeping system for truck platooning, using sensor fusion and machine learning for lane detection and steering control.	Highway, urban roads, weather conditions, sensor range, system reliability, user interface, etc.	4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	1.7	Truck Platooning (ICAC) / cooperative platooning	
125-149	Hub-to-Hub Autonomous Trucking	Commercial & Heavy Vehicle	Automated lane keeping system for hub-to-hub autonomous trucking, using sensor fusion and machine learning for lane detection and steering control.	Highway, urban roads, weather conditions, sensor range, system reliability, user interface, etc.	5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1.9	Hub-to-Hub Autonomous Trucking	
150-174	Autonomous Shuttle Bus (fixed route)	Commercial & Heavy Vehicle	Automated lane keeping system for autonomous shuttle bus, using sensor fusion and machine learning for lane detection and steering control.	Urban roads, weather conditions, sensor range, system reliability, user interface, etc.	6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	1.8	Autonomous Shuttle Bus (fixed route)	
175-199	Autonomous Delivery Robot (last-mile)	Commercial & Heavy Vehicle	Automated lane keeping system for autonomous delivery robot, using sensor fusion and machine learning for lane detection and steering control.	Urban roads, weather conditions, sensor range, system reliability, user interface, etc.	7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	1.3	Autonomous Delivery Robot (last-mile)	
200-224	Autonomous Excavator / Earthmoving	Construction & Mining Vehicle	Automated lane keeping system for autonomous excavator, using sensor fusion and machine learning for lane detection and steering control.	Construction sites, weather conditions, sensor range, system reliability, user interface, etc.	8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	1.6	Autonomous Excavator / Earthmoving	
225-249	Autonomous Baggage Tug / Tow Tractor	Commercial & Heavy Vehicle	Automated lane keeping system for autonomous baggage tug, using sensor fusion and machine learning for lane detection and steering control.	Airport, weather conditions, sensor range, system reliability, user interface, etc.	9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	1.6	Autonomous Baggage Tug / Tow Tractor	
250-274	Autonomous Yard Shunting Vehicle (rail-adjacent)	Commercial & Heavy Vehicle	Automated lane keeping system for autonomous yard shunting vehicle, using sensor fusion and machine learning for lane detection and steering control.	Rail yard, weather conditions, sensor range, system reliability, user interface, etc.	10	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.3	Autonomous Yard Shunting Vehicle (rail-adjacent)	
275-299	Smart Intersection Assistance (V2X hazard warnings)	Commercial & Heavy Vehicle	Automated lane keeping system for smart intersection assistance, using sensor fusion and machine learning for lane detection and steering control.	Urban roads, weather conditions, sensor range, system reliability, user interface, etc.	11	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.2	Smart Intersection Assistance (V2X hazard warnings)	
300-324	Autonomous Firefighting / Hazard Response Vehicle	Commercial & Heavy Vehicle	Automated lane keeping system for autonomous firefighting/hazard response vehicle, using sensor fusion and machine learning for lane detection and steering control.	Urban roads, weather conditions, sensor range, system reliability, user interface, etc.	12	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	2.1	Autonomous Firefighting / Hazard Response Vehicle	
325-349	Autonomous Ground Vehicle (UGV)	Commercial & Heavy Vehicle	Automated lane keeping system for autonomous ground vehicle, using sensor fusion and machine learning for lane detection and steering control.	Urban roads, weather conditions, sensor range, system reliability, user interface, etc.	13	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	2	Autonomous Ground Vehicle (UGV)	
350-374	Cooperative Hazard Warning (V2X via DENM)	Commercial & Heavy Vehicle	Automated lane keeping system for cooperative hazard warning, using sensor fusion and machine learning for lane detection and steering control.	Urban roads, weather conditions, sensor range, system reliability, user interface, etc.	14	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.2	Cooperative Hazard Warning (V2X via DENM)	
375-399	Cooperative Awareness (V2X via CAM)	Commercial & Heavy Vehicle	Automated lane keeping system for cooperative awareness, using sensor fusion and machine learning for lane detection and steering control.	Urban roads, weather conditions, sensor range, system reliability, user interface, etc.	15	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.2	Cooperative Awareness (V2X via CAM)	
400-424	Remote Operation / Tele-driving for Excavation & Exclusion Zone Enforcement	Commercial & Heavy Vehicle	Automated lane keeping system for remote operation/tele-driving, using sensor fusion and machine learning for lane detection and steering control.	Urban roads, weather conditions, sensor range, system reliability, user interface, etc.	16	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	2.1	Remote Operation / Tele-driving for Excavation & Exclusion Zone Enforcement	
425-449	GNSS-Denied Resilient Navigation (like ops)	Commercial & Heavy Vehicle	Automated lane keeping system for GNSS-denied resilient navigation, using sensor fusion and machine learning for lane detection and steering control.	Urban roads, weather conditions, sensor range, system reliability, user interface, etc.	17	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.1	GNSS-Denied Resilient Navigation (like ops)	
450-474	Swarm / Coordinated Fleet Robots	Commercial & Heavy Vehicle	Automated lane keeping system for swarm/coordinated fleet robots, using sensor fusion and machine learning for lane detection and steering control.	Urban roads, weather conditions, sensor range, system reliability, user interface, etc.	18	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.9	Swarm / Coordinated Fleet Robots	
475-499	Unoccupied Low-Speed Automated Driving (AVP-like zones)	Commercial & Heavy Vehicle	Automated lane keeping system for unoccupied low-speed automated driving, using sensor fusion and machine learning for lane detection and steering control.	Urban roads, weather conditions, sensor range, system reliability, user interface, etc.	19	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.7	Unoccupied Low-Speed Automated Driving (AVP-like zones)	
500-524	Driverless Robo-Taxi / Ride-Hailing (L4)	Commercial & Heavy Vehicle	Automated lane keeping system for driverless robo-taxi/ride-hailing, using sensor fusion and machine learning for lane detection and steering control.	Urban roads, weather conditions, sensor range, system reliability, user interface, etc.	20	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.9	Driverless Robo-Taxi / Ride-Hailing (L4)	
525-549	Autonomous Ride-Pooling Van (L4) - Service Vehicle	Commercial & Heavy Vehicle	Automated lane keeping system for autonomous ride-pooling van, using sensor fusion and machine learning for lane detection and steering control.	Urban roads, weather conditions, sensor range, system reliability, user interface, etc.	21	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	1.9	Autonomous Ride-Pooling Van (L4) - Service Vehicle	
550-574	Driverless Highway Pilot for Privately Owned Cars (L4 - conceptual tomorrow)	Commercial & Heavy Vehicle	Automated lane keeping system for driverless highway pilot, using sensor fusion and machine learning for lane detection and steering control.	Urban roads, weather conditions, sensor range, system reliability, user interface, etc.	22	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	1.9	Driverless Highway Pilot for Privately Owned Cars (L4 - conceptual tomorrow)
575-599	Universal Full Driving Automation (L5 passenger car - conceptual)	Commercial & Heavy Vehicle	Automated lane keeping system for universal full driving automation, using sensor fusion and machine learning for lane detection and steering control.	Urban roads, weather conditions, sensor range, system reliability, user interface, etc.	23	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.9	Universal Full Driving Automation (L5 passenger car - conceptual)
						1.71		1.79		1.88		0.92		1.74		1.96		1.46		1.88		1.71		2.00				
						1.57						1.72						1.86										

Scoring Legend:

- <0,5: no/negligible PNT dimensional gaps
- <1,5: Minor limitations, still workable
- <2,5: Strong constraints/limits (e.g. ODDs)
- >2,5: Use Case blocked, gap(s) to high

Source: acitoflux analysis

4.4 PNT dimensions gap analysis of AD/ADAS use cases – Interpretations and Key Takeaways of Results

Technical performance is not the main bottleneck shown by Gap-Analysis; NAVISP should focus on trusted, validated and scalable PNT deployment

Key Takeaway 1 – The main AD/ADAS PNT gaps are availability, robustness, and verification — not accuracy alone

- Almost all PNT dimensions are relevant for emerging non-TRL9 AD/ADAS use cases.
- Accuracy and precision remain important, but they are not sufficient. AD/ADAS systems need PNT that is continuously usable, trustworthy, and demonstrably safe across the intended ODD.
- Typical stressors include urban canyons, tunnels, canopy, depots, mines, construction sites, poor weather, and RF-hostile environments.



- NAVISP should shift the focus from “better positioning accuracy” to “trusted, resilient, and certifiable PNT performance across real ODDs.”

Key Takeaway 2 – Timing and redundancy score lower today, but remain critical architectural enablers

- Timing & synchronization and redundancy show lower average gap scores than other PNT dimensions. This suggests they are not the dominant near-term blockers across the current use-case set → However, they should not be deprioritised completely.
- Timing is essential for sensor fusion, event ordering, V2X, cooperative manoeuvres, and future infrastructure-supported automation.
- Redundancy is essential for graceful degradation when GNSS, maps, sensors, corrections, or communication links fail.



- NAVISP should treat timing and redundancy as cross-cutting requirements in all hybrid PNT architectures, especially for future V2X, cooperative driving, and L4 use cases.

Key Takeaway 3 – The largest gap is economic deployment and viability — PNT must scale beyond pilots

- The strongest cluster-level gap is Economic Deployment & Viability, with an average score of 1.86. Technical Performance is lower, with an average score of 1.57.
- This means the main challenge is not only whether high-performance PNT exists. The harder question is whether it can be deployed across real fleets, vehicle classes, regions, and ODDs at acceptable cost and with sufficient approval evidence.
- Main barriers: receiver/correction-service cost, map dependency, integ. complexity, certification effort, fragmented ecosystems, and unclear business models.



- NAVISP can create the strongest impact by moving promising PNT concepts from technical feasibility to industrial deployment via Element 1-3 projects

CHAPTER 4.1

EUROPEAN STRENGTHS & GAPS – SUMMARY

4.1 EUROPEAN STRENGTHS & GAPS – SUMMARY

Europe's PNT strengths must now be converted into targeted NAVISP projects addressing AD/ADAS deployment gaps

Europe has the foundations for trusted AD/ADAS localisation:

Galileo/EGNOS, strong OEM and Tier-1 capabilities, specialised GNSS/correction/localisation/map/V2X/software providers, research institutions, standardisation bodies and regulators. D1 shows that AD/ADAS PNT is shifting from “accurate position” to position + confidence: integrity, availability, robustness, timing, fallback behaviour and validation evidence.

European strengths to build on

Europe can differentiate through open, modular and certifiable localisation architectures: multi-constellation / multi-frequency GNSS, RTK and PPP-RTK correction services, sensor fusion, authenticated signals, LEO-PNT, 5G/V2X timing and safety-case-driven validation. These are directly aligned with the NAVISP opportunity space identified in D1.

Key gaps

Emerging L2++/L3/L4 use cases require lane-level, continuously available and trustworthy localisation across wider ODDs. Current PNT limitations remain strongest in availability, robustness, scalability, cost/business viability and verification & validation, especially in urban canyons, tunnels, adverse weather and interference scenarios.

NAVISP Relevancy & Outlook Task 4

The opportunity is to translate Europe's strengths into short-, mid- and long-term NAVISP projects: authenticated and resilient GNSS, scalable correction services, LEO-PNT, 5G/V2X timing, sensor-fusion architectures, validation methods and industrial deployment concepts.

D4-2 therefore matches European ecosystem capabilities with the highest-impact AD/ADAS PNT gaps and derives Element 1–3 project candidates, in line with the Statement of Work requirement to synthesize Tasks 1–3 and recommend NAVISP activities.



◀ CHAPTER 4.2
**PROPOSED NAVISP
PROJECTS –
Overview + Example Element Projects**

4.2 PROPOSED NAVISP PROJECTS

Overview of the Top 1-3 NAVISP Elements recommendations, out of 53 (long-list)

E-01 Innovation

Artificial-intelligence prediction of Global Navigation Satellite Systems degradation and protection levels

Low Earth Orbit augmentation for urban lane-level vehicle positioning

Hybrid terrestrial and satellite positioning for tunnels, parking structures and urban canyons

Cooperative PNT Timing and Uncertainty Framework for Collective Perception

Fleet-sourced GNSS Risk Intelligence for Robust AD/ADAS Localization

E-02 Competitiveness

SAFTY-OF-LIFE (SOL)

Indoor-outdoor handover localization product for airport aprons, ports and yard logistics

Cold-weather PNT validation, benchmarking and evidence service for automated runway and off-highway operations

Under-glass PNT sensor and antenna integration platform for automated vehicles

Localization supervisor for geo-fenced shuttle and campus automation

Assured geolocation appliance for tele-operation fallback

Supervisory localization and redundancy layer for urban robotaxi operations

Localization supervision middleware for lane-level L2+/L3 highway systems

E-03 Support Member States

EU/National automated-mobility PNT resilience maps and interference monitoring

National Low-Visibility and Heavy-Rain PNT Validation Framework for Automated Mobility

ELEMENT 1: Fleet-sourced GNSS Risk Intelligence for Robust AD/ADAS Localization

ID-12

Description

Operational vehicle fleets generate GNSS quality observations that are often processed only within individual receivers or localization stacks. This study would assess how indicators such as signal strength, residuals, satellite visibility, correction status, interference flags and 3D map-aided shadowing patterns could be aggregated into a shared PNT risk intelligence layer. The objective is to identify recurring multipath, shadowing and RF-interference risk zones to support AD/ADAS ODD monitoring, fallback preparation and validation of robust PNT performance.

Root Cause from Study

GNSS degradation is often local, recurring and environment-dependent, especially in urban canyons, dense infrastructure corridors and RF-hostile areas. The study identifies availability, robustness and verification as key PNT gaps; fleet-sourced observations could turn isolated signal-quality issues into shared evidence for safer localization decisions.

Relevant Use Cases / Applications

- UC-07 | Hub-to-Hub Autonomous Trucking
- UC-40 | GNSS-Denied Resilient Navigation (site ops)
- UC-46 | Driverless Robo-Taxi / Ride-Hailing (L4)

TRL

4

- > Receiver-level interference detection and GNSS monitoring products already exist.
- > Cross-fleet intelligence for multipath, shadowing and interference risk is not yet established for road mobility.

NAVISP Relevancy

Fleet-based GNSS quality evidence could open a practical path toward shared PNT risk awareness for automated driving. The study would clarify whether aggregated signal-degradation patterns can support robust localization, ODD monitoring, fallback preparation and safety-case evidence in future NAVISP follow-on activities.

Technical:

Accuracy

Precision

Availability

Timing & Synchronization

Resilience:

Integrity

Robustness

Redundancy

Economic:

Scalability

Cost & Business Viability

Verification & Validation

ELEMENT 2: Under-glass PNT sensor and antenna integration platform for automated vehicles

ID-42

Description

Supplier-grade integration platform for placing PNT-relevant antennas, RF components and complementary AD/ADAS sensors under or within automotive glazing.

The concept investigates how windscreens, roof glazing and other glass structures can become functional PNT and sensor interfaces, supporting GNSS reception, RF-optimized antenna zones, protected LiDAR / camera placement and vehicle-level sensor packaging.

The objective is to create a validated reference integration package for OEM shuttle, robotaxi and automated-vehicle platforms.

Root Cause from Study

The study shows that AD/ADAS localization is no longer only a software or receiver problem. Reliable lane-level and safety-relevant PNT also depends on vehicle integration: antenna placement, RF transparency, multipath reduction, sensor visibility, weather protection and repeatable OEM packaging. Today, high-performing PNT and perception components often remain difficult to industrialize because integration into real vehicle bodies and glazing is not standardized, especially for shuttle, robotaxi and L2+/L3 platforms.

Relevant Use Cases / Applications

UC-03 | Automated Lane Keeping System, defin. ODD

UC-04 | Traffic Jam Chauffeur / L2+/L3

UC-46 | Driverless Robo-Taxi / Ride-Hailing

TRL

5

> Company 1 has strong building blocks in automotive glass, under-glass antenna know-how, RF simulation, validation and sensor-protection concepts.

> A validated, OEM-ready under-glass PNT and sensor integration platform for automated vehicles is still pre-product and requires vehicle-level demonstration.

NAVISP Relevancy

This is a strong NAVISP Element 2 candidate because it translates PNT performance into a concrete automotive integration product. It helps European industry move from individual GNSS, antenna and sensor components toward scalable OEM-ready vehicle packaging. The activity could position glass as a functional PNT and sensor interface for future automated vehicles, supporting better accuracy, availability and industrial deployment.

Technical:

Accuracy

Precision

Availability

Timing & Synchronization

Resilience:

Integrity

Robustness

Redundancy

Economic:

Scalability

Cost & Business Viability

Verification & Validation

ELEMENT 3: EU/National automated-mobility PNT resilience maps and interference monitoring

ID-45

Description

Support Member States in building national — and cross border connected — PNT resilience maps for the road mobility sector. It combines crowdsourced and fixed-station GNSS interference monitoring with a geospatial assessment platform that gives authorities, road operators and mobility stakeholders continuous visibility into the spatial PNT trust level along critical corridors.

The project could be structured around three workstreams: – Deployment of a national interference monitoring network — fixed and mobile sensors at key corridors and infrastructure nodes (urban, peri-urban, motorway, border crossings) – Development of a Resilience Map Platform aggregating PNT quality metrics (availability, continuity, accuracy, signal degradation events) spatially and temporally – Definition of a Corridor Readiness Index — a standardised scoring scheme for authorities to support operational approvals for automated vehicle deployments

Root Cause from Study

Public deployment remains fragmented, while the study highlights robustness and availability as major blockers. National visibility of where positioning can and cannot be trusted is a missing institutional capability. Sources: INT-07; INT-16; INT-18.

Relevant Use Cases / Applications

UC-03 | Automated Lane Keeping System (ALKS)
UC-04 | Traffic Jam Chauffeur (L2+/L3)
UC-06 | Truck Platooning (CACC)
UC-07 | Hub-to-Hub Autonomous Trucking
UC-46 | Driverless Robo-Taxi / Ride-Hailing (L4)
UC-48 | Driverless Highway Pilot for POVs (L4)

TRL

6

- > The underlying detection and mapping methods exist
- > The gap is coordinated institutional deployment and operationalization.

NAVISP Relevancy

The project aligns precisely with all three thematic pillars of NAVISP Element 3:

- PNT Resilience: Establishing a national monitoring infrastructure and an institutional situational picture for GNSS interference, a core Element 3 objective, following the precedent set by INSPIRe (UK, EL3-020) and the National GNSS Knowledge Center (NL).
- Public Services Preparation: Road authorities and certification bodies gain a data-driven, operationally actionable tool for corridor approvals, analogous in intent to the SPARK Report (UK) but delivering a live, spatial output rather than a strategic study.
- Test Ranges for Mobility: Complements existing EL3 test infrastructure (e.g. PNT Center for Automated Road Transport, IT) by extending PNT quality monitoring from controlled test sites to full-scale operational corridors.

Technical:

Accuracy

Precision

Availability

Timing & Synchronization

Resilience:

Integrity

Robustness

Redundancy

Economic:

Scalability

Cost & Business Viability

Verification & Validation



SMART MOBILITY BLUEPRINT

DESIGNING THE FUTURE OF MOVEMENT

PROJECT OVERVIEW

Integrated autonomous mobility system designed for safety, efficiency, and sustainability. Tested in real-world conditions for a smarter tomorrow.



SAFETY



CONNECTIVITY



EFFICIENCY



SUSTAINABILITY



NAVISP

Powering innovation and market uptake through seamless navigation solutions.

EDGE
COMPUTE
NODE

GALILEO SATELLITE

GALILEO SATELLITE

GALILEO SATELLITE

LIDAR 360°

4D RADAR

CAMERA ARRAY

ULTRASONIC SENSORS

COMPUTE UNIT

V2X ANTENNA

ENV. SENSOR SUITE

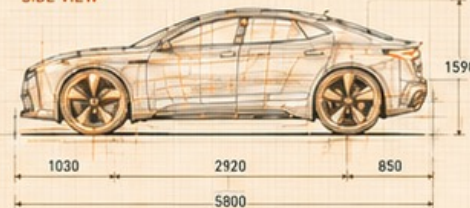
SMART INFRASTRUCTURE

- 5G / 6G + CONNECTIVITY
- ROAD COMPUTING
- SMART LIGHTING
- ADAPTIVE SIGNAGE
- PAVEMENT SENSORS
- WIRELESS CHARGING

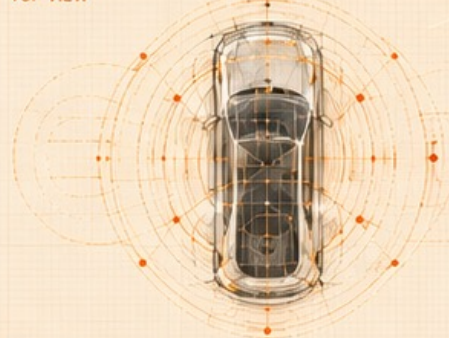
VEHICLE SPECIFICATIONS

LENGTH	4,950 mm
WIDTH	1,950 mm
HEIGHT	1,300 mm
WHEELBASE	3,020 mm
BATTERY	140 kWh
RANGE	830 km
MAX SPEED	180 km/h
SENSORS	28+
AUTONOMY LEVEL	L5

SIDE VIEW



TOP VIEW



- LIDAR 360°
- 4D RADAR
- CAMERA
- ULTRASONIC
- V2X
- ENV. SENSORS

DATA FLOW



TEST ENVIRONMENT

- URBAN ROADS
- HIGHWAYS
- INTERSECTIONS
- PEDESTRIAN AREAS
- NIGHT & WEATHER

NEXT-GEN TESTING
FOR NEXT-LEVEL IMPACT

THANK YOU

ACITOFUX