GNSS Evolutions in Automotive

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STMicroelectronics

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R&S Automotive Technology Day
June 8, 2017, Paris

About ST

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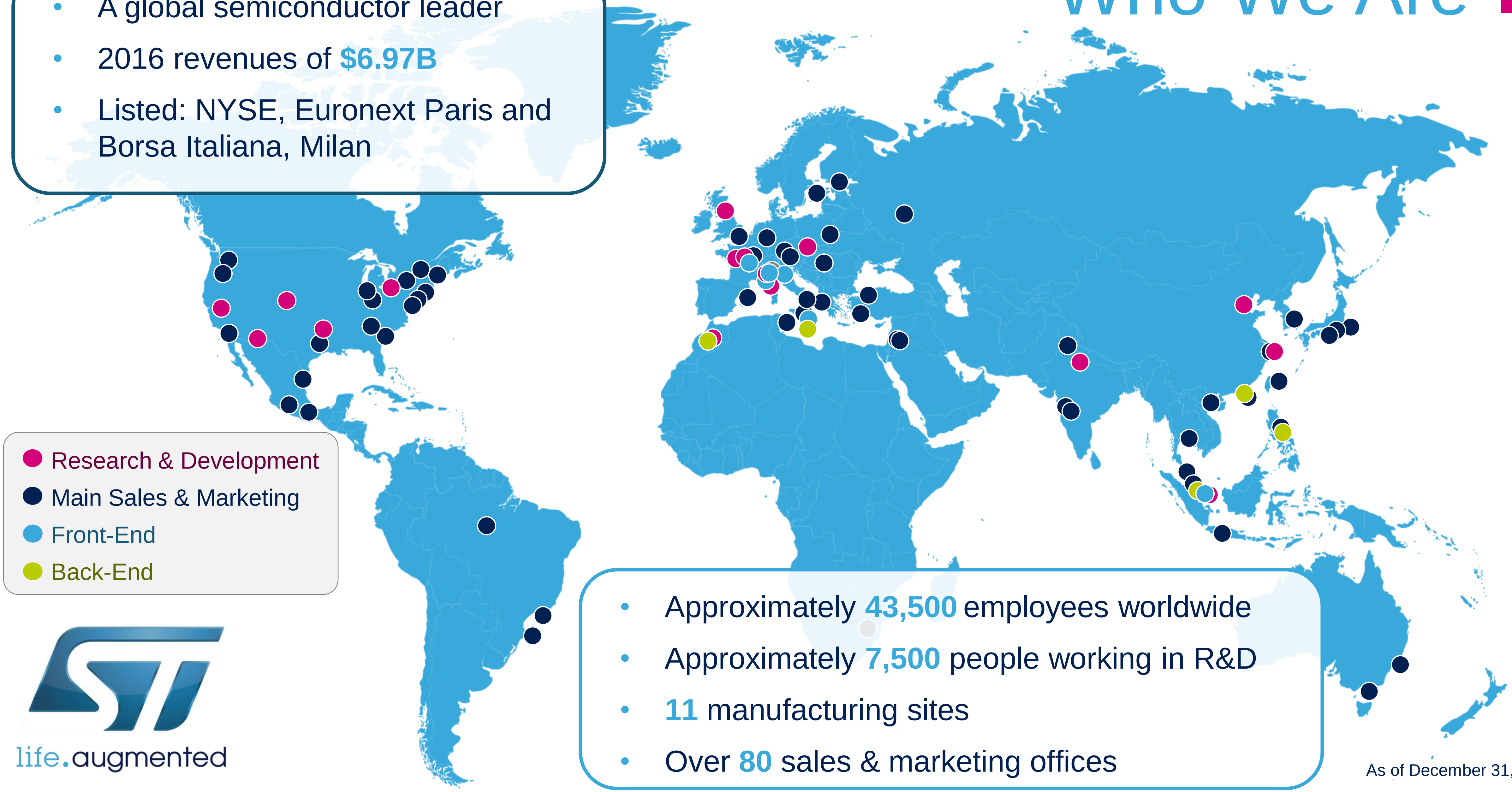
Who We Are

- A global semiconductor leader
- 2016 revenues of **$6.97B**
- Listed: NYSE, Euronext Paris and Borsa Italiana, Milan



- Approximately **43,500** employees worldwide
- Approximately **7,500** people working in R&D
- **11** manufacturing sites
- Over **80** sales & marketing offices

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As of December 31, 2016

Application Strategic Focus

The leading provider of products and solutions
for Smart Driving and the Internet of Things

Internet of Things

Smart Driving

Smart Things

Smart Home & City

Smart Industry

Smart Driving

ST: Global and Diversified Automotive Leader

with over 30 years experience

Broad Automotive Offer

- Automotive Microcontrollers
- Infotainment and Telematics
- V2X
- Radar & Vision ADAS
- Automotive Sensors
- Power & Smart Power

32% of ST revenue

Market Share (on SAM) **9%**

2016

>$2.2B Revenue

+6% Y-o-Y

2015

$2.1B Revenue

#1

- Engine Management
- 24 GHz RADAR
- ADAS Safety
- Entry & Mid-end Telematics
- Car Audio Amplifiers
- GNSS
- Smart Power

ST Leadership in key Automotive Applications

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Source: Strategy Analytics, ST

Strong Commitment to Automotive

~35 components on average for each new car produced
Up to 800 components in premium models

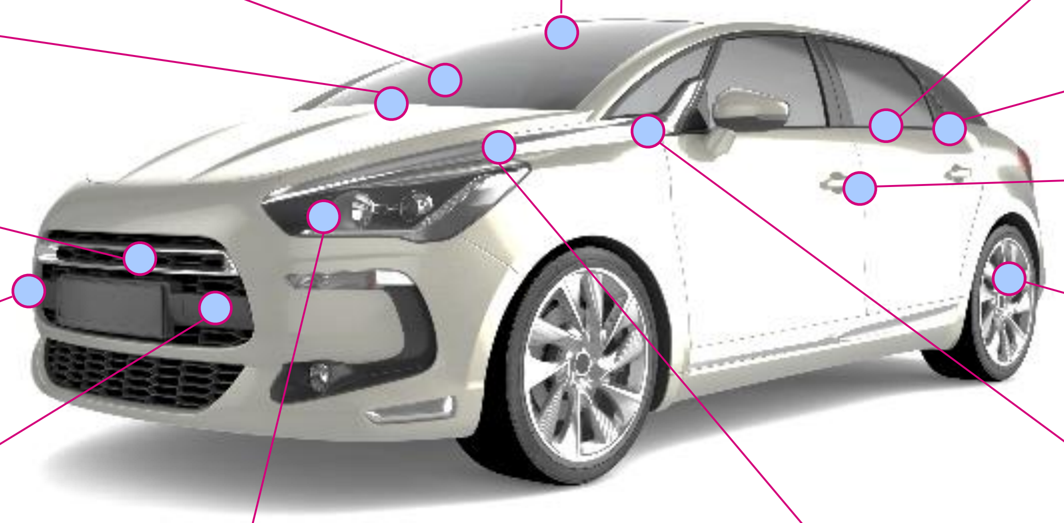
Market Leader in US satellite radio market

8 out of 10 cars shipped with an ADAS system on board had an ST ADAS on board

>10 Million cars equipped with ST RADAR Transceivers

10 Million car radio Processors shipped

>50 Million 32-bit MCUs shipped



3 out of 4 cars produced have at least one ST component in Engine Management

420 Million Power Transistors shipped

2 out of 3 cars produced had at least one ST component in braking

2 Million Protection Diodes & Filters shipped every day

3 Million VIPower chips shipped every day

1 Billion Lamps (1 out of 2) driven by ST

1 out of 4 Infotainment systems had an ST GNSS receiver and 1 out of 5 had an ST Motion MEMS

2 out of 3 cars produced are equipped with an ST Sound System

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GNSS Evolutions in Automotive

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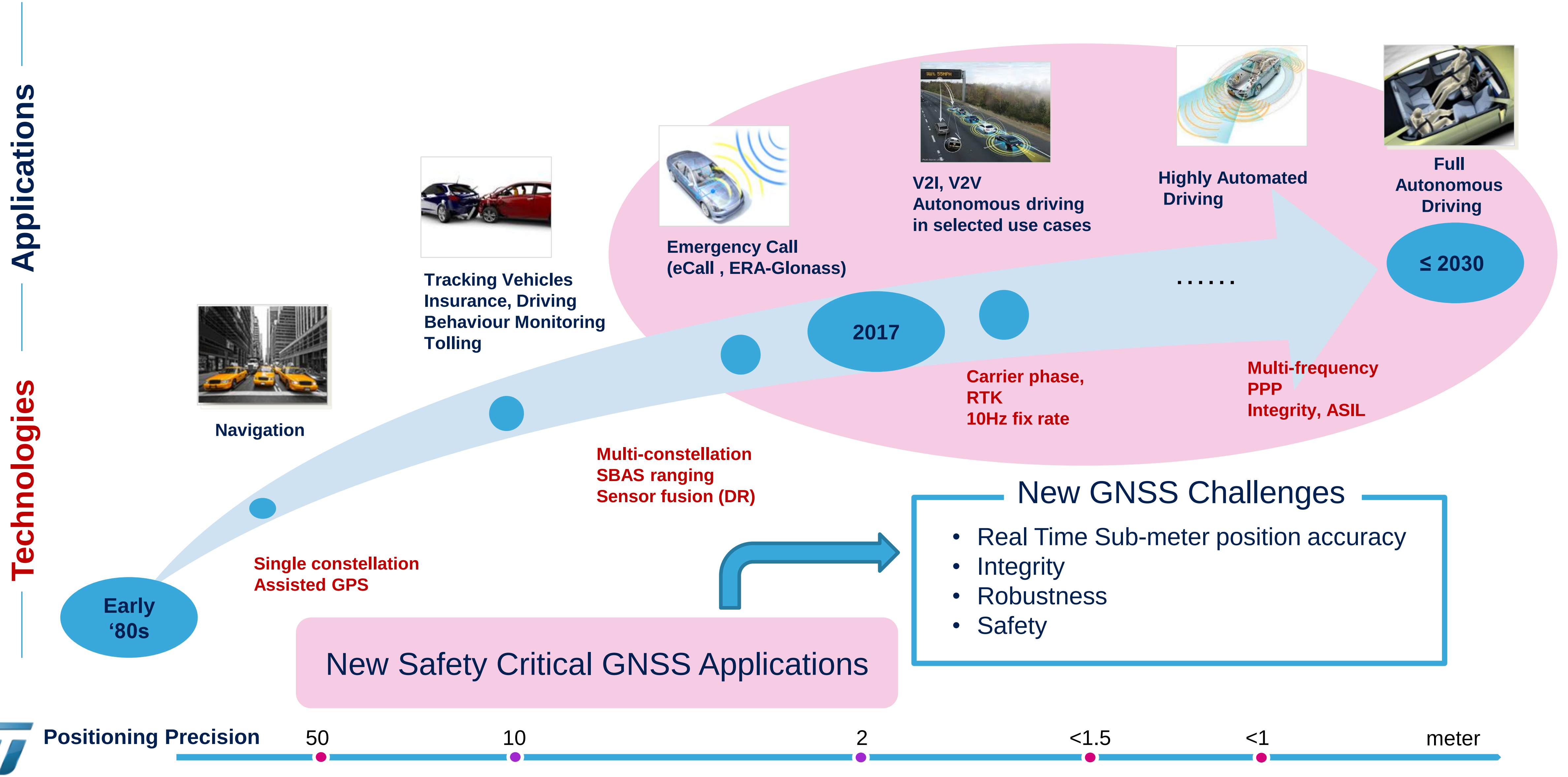
GNSS Evolutions Overview in Automotive



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GNSS Evolutions Overview in Automotive

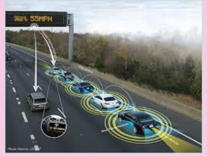
Applications

Technologies

Navigation

Tracking Vehicles
Insurance, Driving Behaviour Monitoring
Tolling

Emergency Call (eCall , ERA-Glonass)



V2I, V2V
Autonomous driving in selected use cases

Highly Automated Driving

Full Autonomous Driving

Early '80s

Single constellation
Assisted GPS

Multi-constellation
SBAS ranging
Sensor fusion (DR)

2017

Carrier phase,
RTK
10Hz fix rate

……

Multi-frequency
PPP
Integrity, ASIL

≤ 2030

New Safety Critical GNSS Applications

New Standards and Regulations

- **Emergency Call:**
  - eCall (EU)
  - ERA-Glonass/GOST (RU)
- **Intelligent Transport system (ITS) – V2X**
  - ETSI with C2CC (EU)
  - SAE with CAMP/USDOT (US)

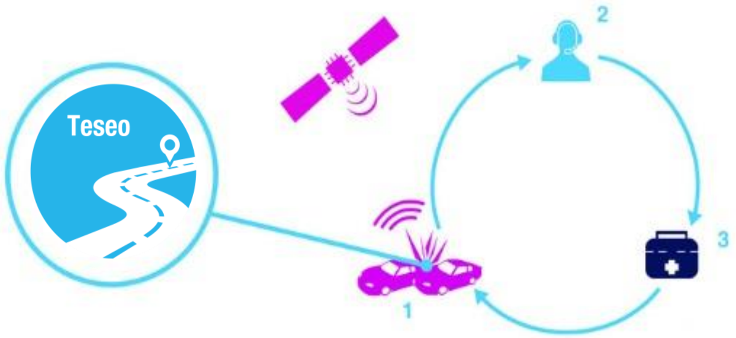
Positioning Precision 50 · 10 · 2 · <1.5 · <1 · meter

Emergency Call

- Emergency Call is a service provided in Europe with the goal of reducing response times for accidents or other emergencies on the roadways by providing automatic and manual calls in case of an incident. **This service does not prevent accidents but can be considered as Safety Critical System**.

- ERA-GLONASS is the Russian Emergency Call service based on GLONASS and GPS. Deployment started.
    - Cooperation with R&S on Era-GLONASS Test Suite testing

- eCall is the European Emergency Call service based on Galileo, EGNOS (European SBAS) and GPS.
    - Teseo did the first fix on Galileo in 2013
    - JRC/GSA eCall pre-certification for Teseo is in place
    - EU regulation 2015/758 mandating eCall on new vehicles from **April 2018**



Accuracy requirement: < 15m @95%

Galileo usage mandatory for eCall

JRC: *Joint Research Center*
GSA: European GNSS Agency

Cooperative Intelligent Transport System (C-ITS)

- Enabling information exchange (vehicle position, speed, heading, acceleration…) between vehicle and vehicles (V2V), and infrastructures (V2I) and pedestrians (V2P) and Motorcycles (V2M). **The information exchanged are used to improve safety and mobility**.

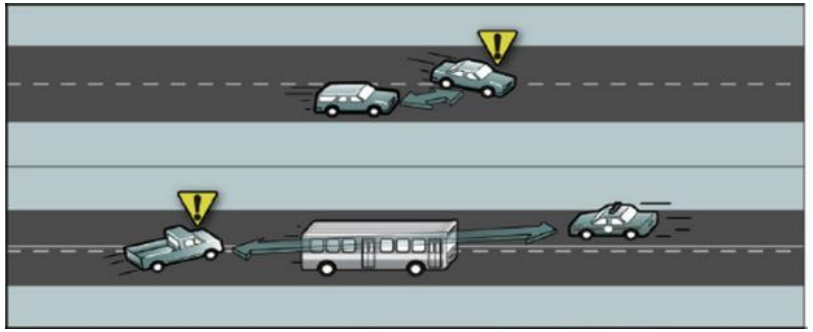
- **GNSS is the solution for reliable absolute positioning (V2I) and Timing source**. GNSS is also used for relative position in a cooperative environment (V2V) as complement of other sensors like camera, Lidar, Radar.

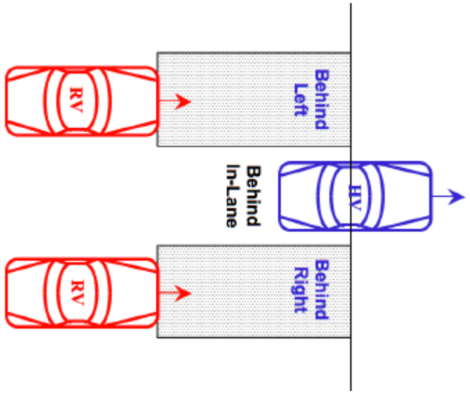
- Vehicle broadcast every 100ms (10Hz) real time absolute position and time using low latency DSRC radio (802.11p)

- Vehicles are classified as:
  - Traveling in same direction, opposite or other
  - Same lane or adjacent lane

Cooperative Intelligent Transport System (C-ITS)

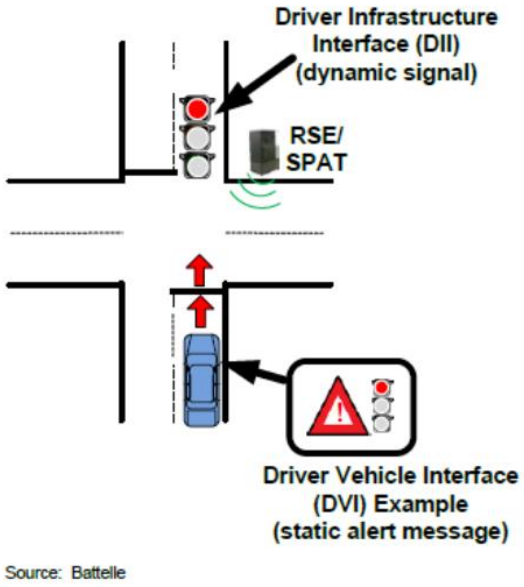
- Vehicle-to-Vehicle (V2V) Safety Applications:
  - Blind Spot Warning (BSW)/ Lane Change Warning/Assist (LCW)





Relative position accuracy requirements for V2V

- Vehicle-to-Infrastructure (V2I) Safety Applications
  - Red Light Violation Warning (RLVW)



Absolute position accuracy requirements for V2I

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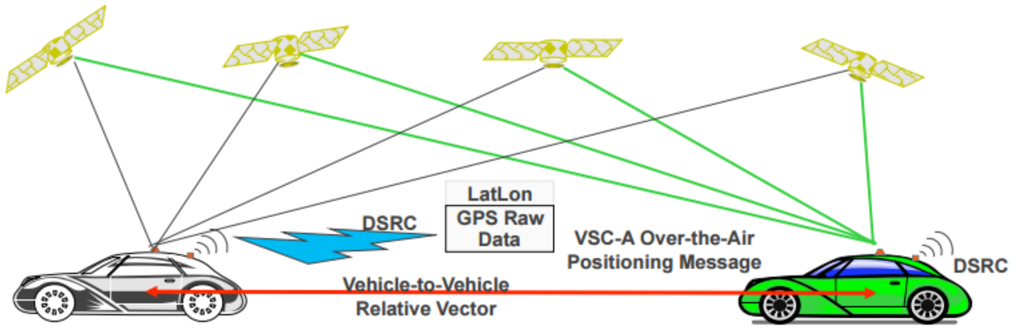
Cooperative Intelligent Transport System (C-ITS)

- Three **absolute position** accuracy levels have been defined according to the use case:

1. Road level: <5m
2. Lane level: <1,5m
3. Where in lane level: <1m

- **Relative position** accuracy will be improved by using GNSS raw data exchanges (RTCM format)



Better performances expected in V2V

Only 68% occurrence in V2I

SAE J2945
2D **absolute** accuracy requirements:
1.5m at **68% under open sky** conditions

Downtown conditions not covered

Which dynamic conditions (speed, acceleration…)?

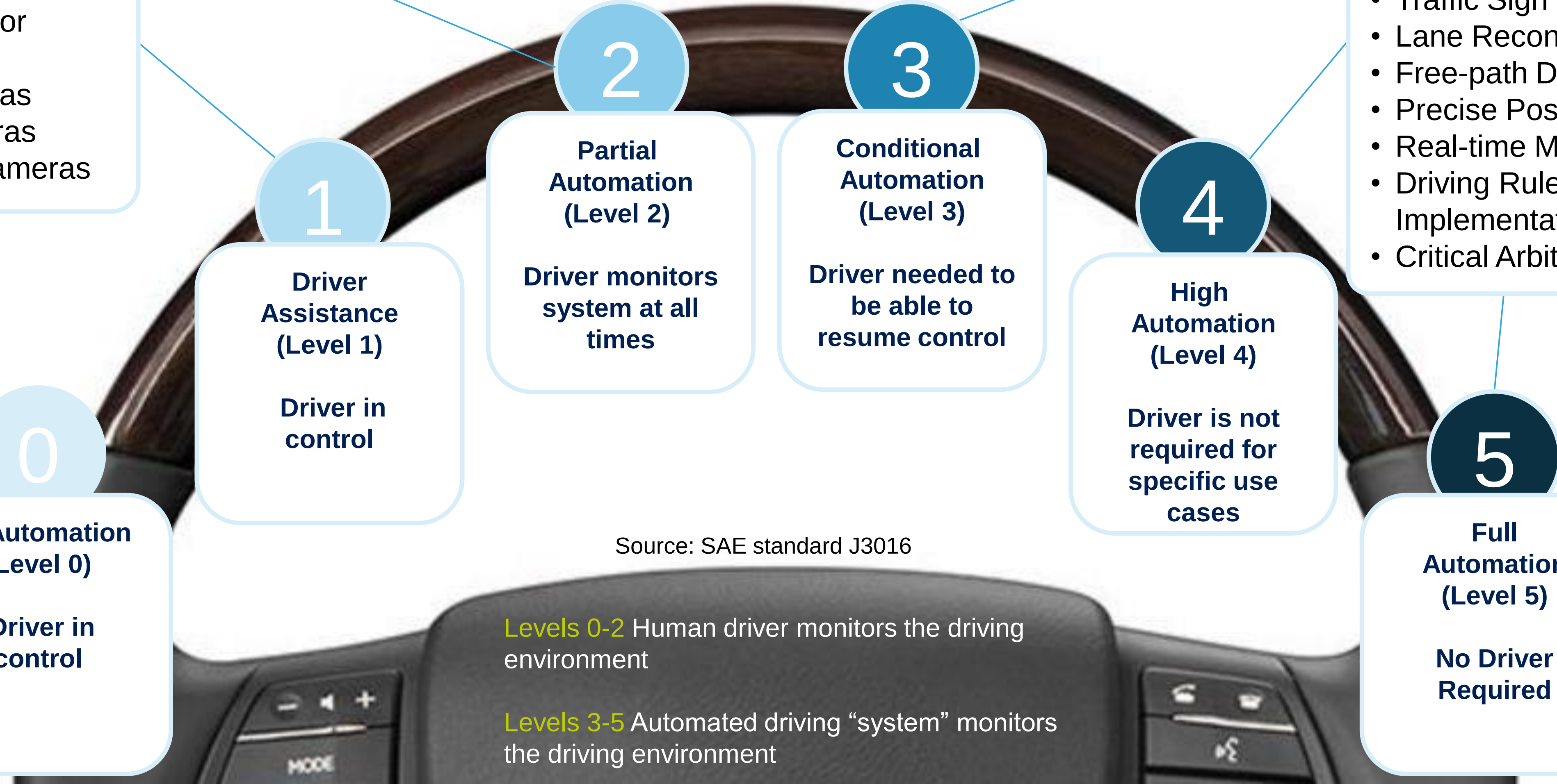
The 5 Levels of Vehicle Automation

Adding Senses

- Accelerometers and Gyro
- Steering Wheel Angle
- Ultrasonic sensors
- Front Radar Sensor
- Blind Spot sensor
- Rear View Cameras
- Front View Cameras
- Surround View Cameras

Learning to Drive

- Systems Networking
- Sensor Fusion
- Distance Measurement
- Traffic Sign Recognition
- Lane Reconstruction
- Free-path Definition
- Precise Positioning
- Real-time Mapping
- Driving Rules Implementation
- Critical Arbitration



0 — **No Automation (Level 0)**

Driver in control

1 — **Driver Assistance (Level 1)**

Driver in control

2 — **Partial Automation (Level 2)**

Driver monitors system at all times

3 — **Conditional Automation (Level 3)**

Driver needed to be able to resume control

4 — **High Automation (Level 4)**

Driver is not required for specific use cases

5 — **Full Automation (Level 5)**

No Driver Required

Source: SAE standard J3016

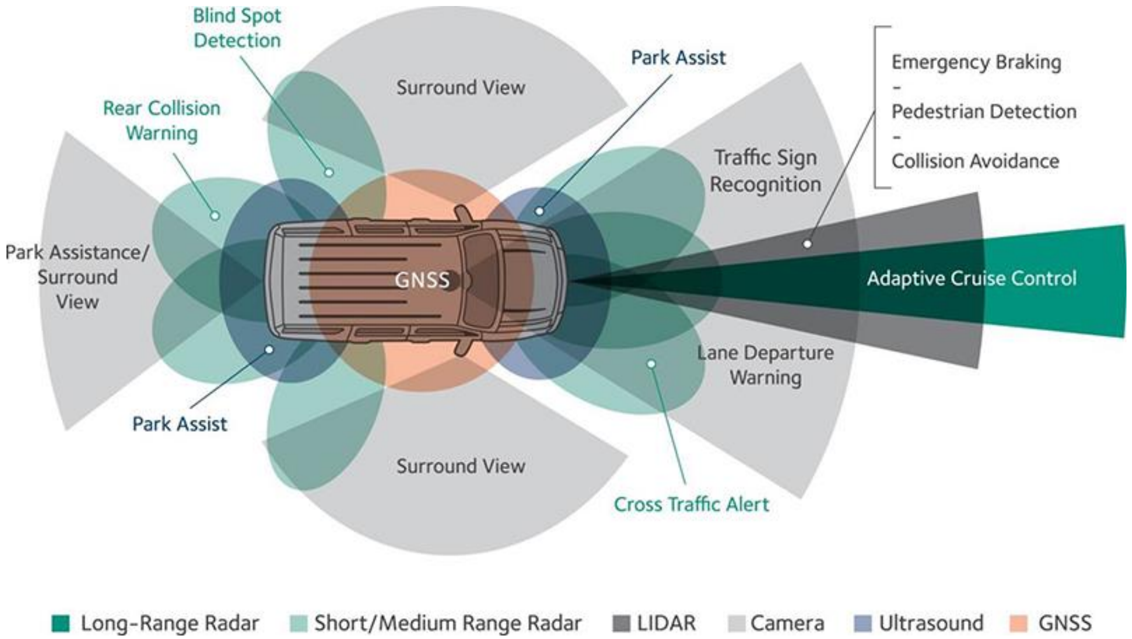
Levels 0-2 Human driver monitors the driving environment

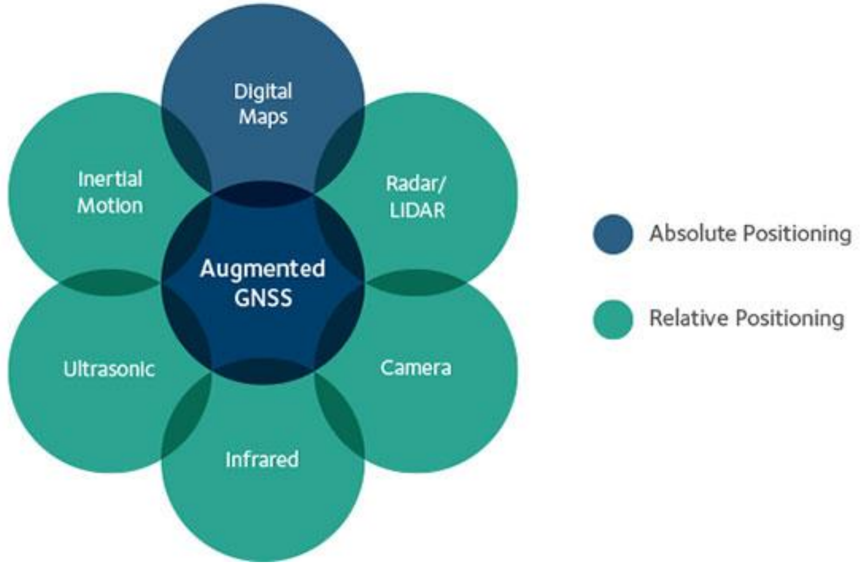
Levels 3-5 Automated driving “system” monitors the driving environment

Autonomous Driving

A fusion of different position technologies are used to meet all requirements

GNSS technologies provides absolute position, absolute time and absolute velocity, heading





Novatel source

Autonomous Driving

Main GNSS challenges for Autonomous driving

Precise Position and velocity

- 2D accuracy <1m @95%
- Real time
- Anytime
- In any conditions
- Fast convergence (turn on delay)
- Availability
- Continuity

Integrity

- Protection level
- Integrity risk
- Alarm

Robustness

- Spoofing
- Jamming

Safety

- ASIL

Autonomous Driving

GNSS Precise Positioning

- Traditional highly-integrated and low cost GNSS receivers are essentially single-band with some recognized areas of improvement
  - Multiple constellation (GPS, GLONASS, BeiDou, Galileo)
  - Use of SBAS Satellites for ranging
  - Integration of Sensors to perform Dead Reckoning and augmentation

- The accuracy of these systems is adequate for mainstream Automotive and ITS applications that are cost-sensitive and not extremely accuracy/integrity critical
  - Turn by turn navigation, eCall
  - Vehicle-oriented LBS (PPU/PHYD insurance, Stolen Car Recovery, Tracking)

New positioning techniques are needed to meet accuracy requirements of Autonomous Driving

Autonomous Driving

GNSS Precise Positioning

- Traditional topographic (or geodesic) applications have achieved high accuracy **for static or low-dynamic assets positioning** with the combined use of different techniques
  - Carrier-phase measurements
  - Dual Frequency receiver
  - Connection to Server-based network of Reference stations
  - Real Time Kinematics (RTK) via differential correction with a local Ref station

- The objective of different techniques is to improve ranging accuracy and to get rid from the GNSS error sources.

Some of the above techniques can be applied in the creation of a cost-effective precise positioning solution for dynamic Automotive applications

Common GNSS Error sources in open sky	Approximate error values
Space segment	
Orbits errors	+/- 2.5m
Satellites clocks	+/- 2.0m
Propagation in atmosphere	
Ionospheric delay	+/- 5.0m
Tropospheric Delay	+/- 0.5m
Total	**+/- 10m**

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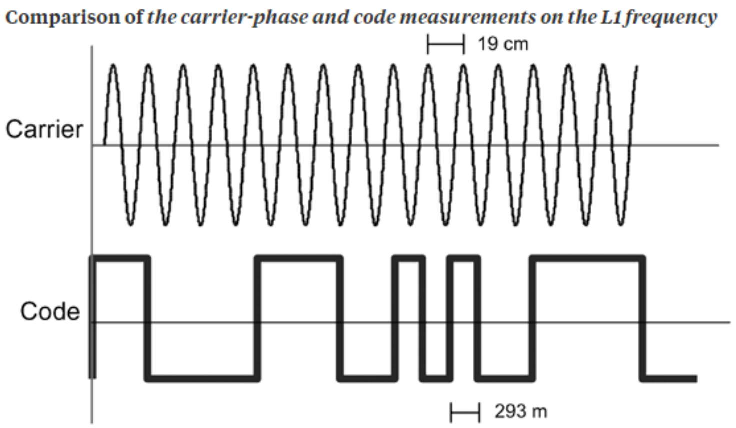
Autonomous Driving

The Ingredients for GNSS Precise Positioning

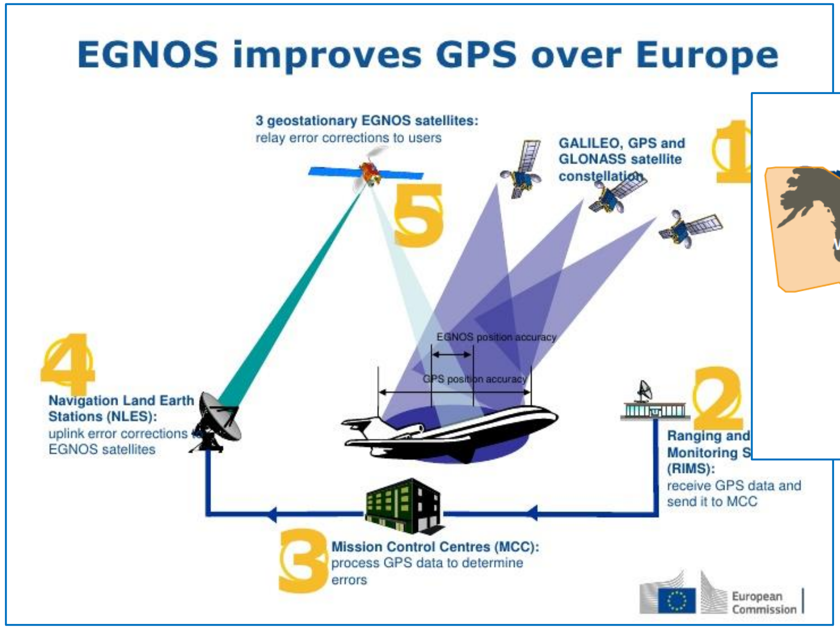
Carrier-Phase

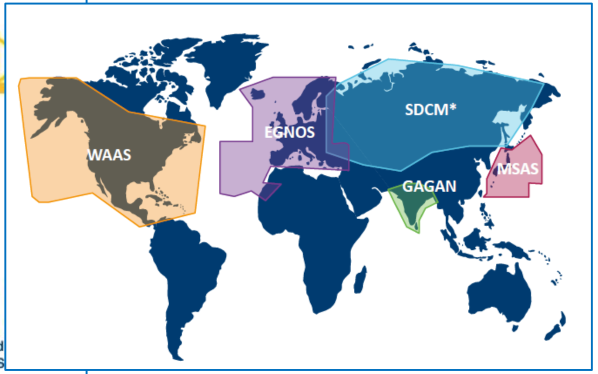
- Carrier-Phase smoothing of code-phase
- Centimeter level ranging accuracy



Satellite Based Augmentation (SBAS)

- Multiple SBAS available for clock and ephemeris corrections and Ionospheric Grid Decoding (GPS model improved)
- Provides Satellite correction data for L1 GPS mainly, GLONASS/Galileo/BeiDou becoming available.
- Integrity Indicators





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Autonomous Driving

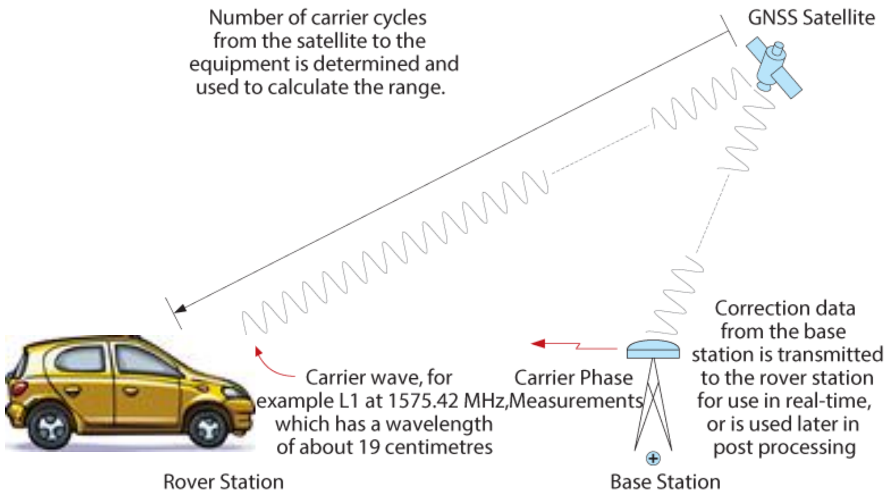
The Ingredients for GNSS Precise Positioning

Real Time Kinematic (RTK)

- Differential correction with a nearby local Reference station (known position)
- Correction data received via RTCM or Internet based (NTRIP) data protocols
- Ephemeris and clock corrections
- Ionospheric grid information
- Networked solution (N-RTK) from a grid of reference stations (eg. SAPOS (D), OSnet (UK). ITPOS(I))

Precise Point Positioning (PPP)

- No local reference station (single receiver)
- Based on precise orbits and clock estimates provided via proprietary service signals in L band or IP/Cellular (eg. Omnistar and Terrastar in US) or Galileo E6.
- More expensive (HW/license) but wider coverage than local networks



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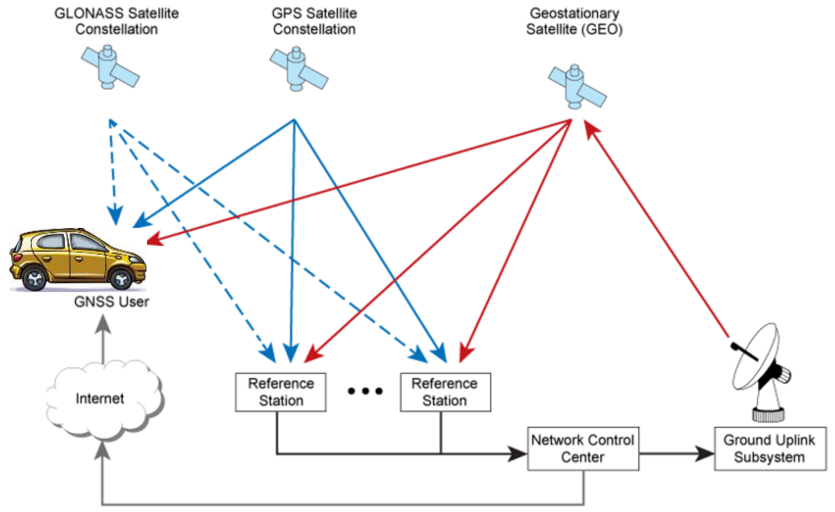

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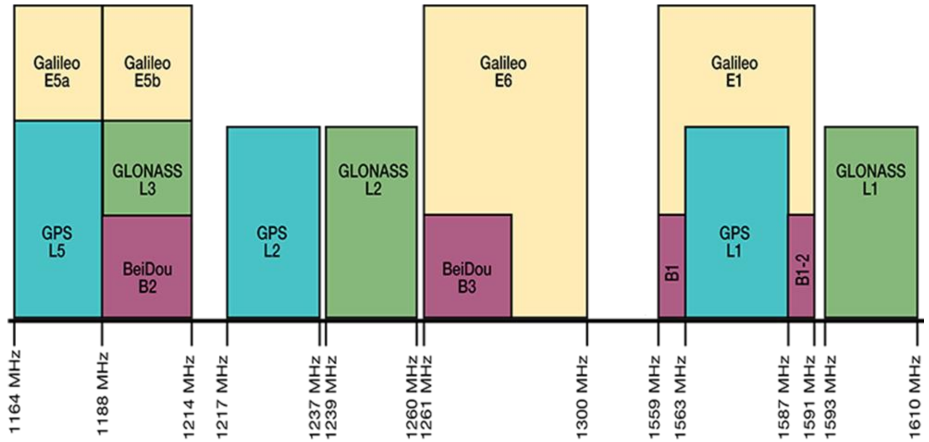
Autonomous Driving

The Ingredients for GNSS Precise Positioning

Dual Frequency Receiver

- L1+L2C or L1/E1+L5/E5
- Allows closed-loop autonomous characterization of iono delay and carrier phase faster convergence (ambiguity solving)
- Signals with new Modulation to enable more precise range measurement.
- Can be combined with any of the previous to achieve double differencing



Augmentation by inertial navigation sensors

- Loosely coupled GNSS + INS
- Tightly coupled GNSS + INS
- Tracking loop aiding with ultra tightly coupled GNSS

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Autonomous Driving - GNSS Integrity

Integrity is the most relevant positioning performance requirement for Autonomous Driving

Accuracy

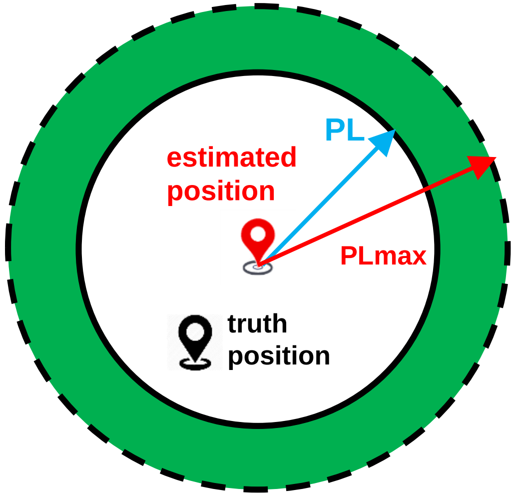
Degree to which the estimated solution from a navigation system conforms to the true solution

VS.

Integrity

Degree to which you can trust the information being provided by a navigation system

- The integrity is implemented through the concept of protection level (output of integrity) as in civil aviation
  - With PVT estimate, the Protection Level (PL) which defined a bound on the position error with a probability derived from the integrity requirement is also provided.
  - For critical safety applications, the integrity risk (or error probability) is in the range of 10^{-6} or 10^{-7} **in all conditions**.



In Automotive, the integrity risk must be small even with bad signal reception conditions like in urban canyon
→ **new integrity models are needed covering whole GNSS chain**

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Autonomous Driving - GNSS Robustness

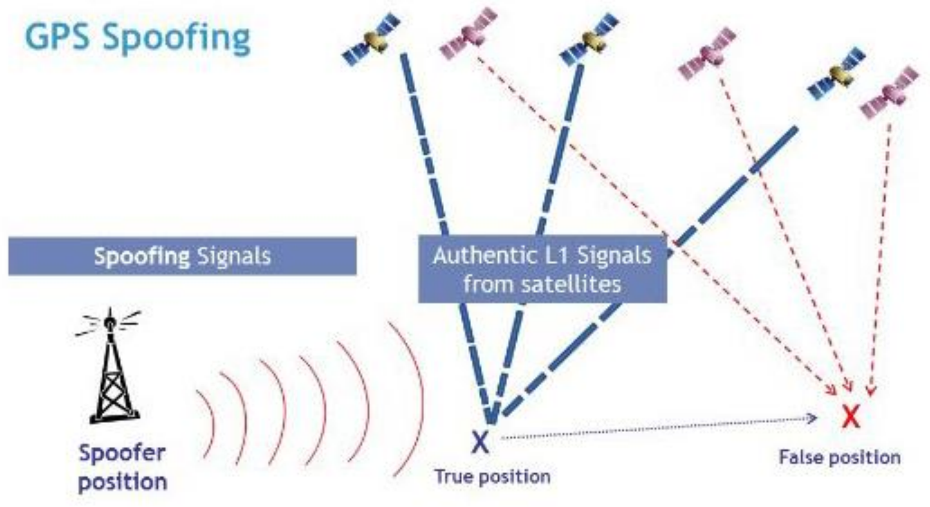
- GNSS receivers are vulnerable to jamming and spoofing
  - **Spoofing** is a deliberate transmission of fake GNSS signals with the intention of fooling a GNSS receiver into providing false Position, Velocity and Time (PVT) information. **Successful spoofing is not detected**.
  - **Jamming** is the act of intentionally directing electromagnetic energy towards a communication (and navigation) system to disrupt or prevent signal transmission

Anti-spoofing

- Galileo Signal authentication
  - E1B: Navigation Message Authentication (NMA) – OS Authentication
  - E6BC: Spreading Code Encryption (SCE) – CS Authentication
- Mitigation with multi-constellation
- Mitigation with sensor data

Anti-jamming

- Mitigation with multi-frequency
- RF and BB signal processing



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ST GNSS and Telematics Portfolio Overview

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Teseo Family

A complete GNSS solution offer

Teseo Evolution

Multiconstellation (GPS, Galileo, Glonass, Beidou)

Simultaneous usage of more than one constellation **multiplies the number of satellites** improving positioning accuracy, integrity and time to first fix

Multiband (L1, L2, L5, E6)

Simultaneous usage of more than one band **compensates ionosphere error** and **faster ambiguity resolution**

2007 Teseo I

Single Constellation
Single Band

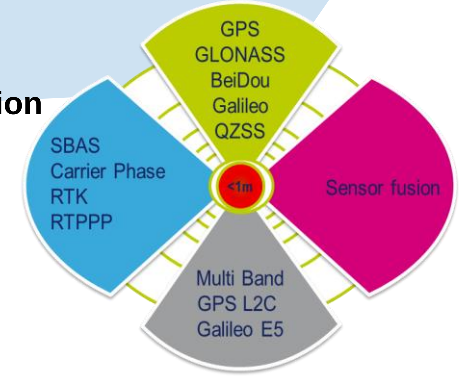
2011 Teseo II

2015 Teseo III

Multi Constellation
Single Band

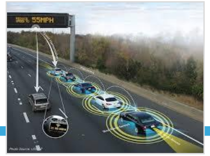
2019 Teseo V, TeseoAPP

Multi Constellation
Multi Band



Positioning Precision

<1.5



V2I, V2V
Emergency call

<1

Autonomous driving

meter

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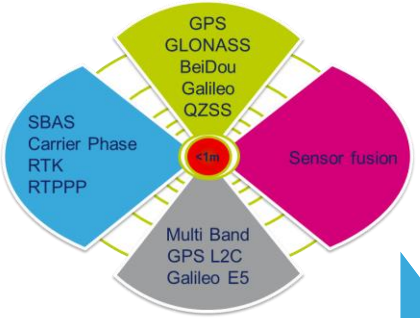
ST Leadership in GNSS Solutions



Teseo GNSS (in production)

- Multi-constellation capability
- Navigation
- Data collection
- Flexible architecture
    - standalone / SDK

Teseo III

Teseo II

ST Technology Expertise

Teseo APP - Automotive Precise Positioning
Sampling Q4 2017

- Multi-constellation capability
- Decimeter precise vehicle positioning
- Highway Autopilot, Autonomous Driving
- Valet / Automatic Parking
- Data Mining with Driver & Roads Profiling
- Black box full functionality

Teseo V

TeseoAPP

GNSS solutions widely deployed in Automotive market

- +25 years of experience
- > 20% Market share (*)
- Leading with Major OEMs

Continental, Clarion, Trimble, HARMAN, BOSCH, MAGNETI MARELLI, Visteon, DESAY, ALPINE, HYUNDAI MnSOFT, novero, LG Electronics

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Source: Strategy Analytics & ST

Telematics

Automotive Telematics and connectivity processors

- TELEMACO Family
  - Powerful multi-core processor with enhanced security
  - Advanced automotive connectivity interfaces
    - CAN FD, Ethernet AVB
  - Embedded hardware cryptographic engine
  - Rich OS Support with Teseo GNSS/DR pre-integration
  - Automotive grade

TELEMACO

Cloud Connectivity · Anti-theft · Emergency call · Insurance · Road Tolling · Fleet Management · Remote Diagnostics · Vehicle Sharing

Vehicle to Vehicle Communications

Advanced Driver Assistance Systems

V2X – Vehicle to everything, V2V – Vehicle to Vehicle

Complete and global V2X hardware and software solution

Most comprehensive V2X offering available

- High level of integration assures low effort and quick time to market
- Pre-integrated with complementing technologies by ST
  - Teseo: GNSS receivers for positioning
  - BlueNRG: BLE transceiver and miniaturized integrated RF Balun
  - Telemaco: host ECU for V2X Add-on

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Towards autonomous driving

- Automotive qualified hardware and software
- Agile cryptographic security engines supporting field upgrades against future threats
- Designed to meet the rigorous requirements for sensor fusion systems and autonomous vehicles

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Takeaways

- Coming Automotive applications are bringing new major GNSS requirements
  - Sub-meter position accuracy
  - Integrity
  - Robustness
  - Safety
- ST portfolio in GNSS, Telematics and V2X offers a complete set of solutions with all the key technologies needed to cover the emerging Automotive applications

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Appendix

Emergency Call –Standards/Regulations relative to GNSS

- eCall:
  - European Commission
    - Commission Delegated Regulation (EU) 2017/79 ANNEX VI (published the 17th January 2017)
  - UNECE/AECS
    - The United Nations Informal Working Group AECS (Accident Emergency Call Systems) is in the process of drafting a new UN Regulation on the type-approval of accident emergency call systems (in the following referred to as Draft UN Regulation No. XX on AECD/AECS).
    - AECS-02-02 is the main working document which described GNSS requirements and GNSS testing procedure (Annex).

- ERA-Glonass:
  - GOST R 54620-2011: “General technical requirements”
  - GOST R 55534-2013: “Test methods for navigation module of in-vehicle emergency call system”

C-ITS – Standards relative to GNSS

EU

ETSI

- **ETSI TS 101 539** : Intelligent Transport Systems (ITS); V2X Application
- **ETSI TR 102 638** : Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications
- **ETSI EN 302 637** : Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications
- **ETSI TS 102 890-3** : Intelligent Transport Systems (ITS); Facilities layer function; Facility Position and time management

CAR 2 CAR Communication Consortium (C2CC)

- CAR 2 CAR members focus on wireless V2V communication applications based on ITS-G5 and concentrate all efforts on creating standard ensuring the interoperability of cooperative systems spanning all vehicles classes, across borders and brands. As key contributor, the C2C-CC works in close cooperation with the European and international standardization organizations like ETSI and CEN.

ETSI World Class Standards

CAR 2 CAR COMMUNICATION CONSORTIUM

US

Society of Automotive Engineers (SAE)

- **SAE J2735** : Dedicated Short Range Communications (DSRC) Message Set Dictionary
- **SAE J2945** : On-board System Requirements for V2V Safety Communications

Crash Avoidance Metrics Partnership consortium (CAMP) partnership with USDOT (NHTSA)

- The Crash Avoidance Metrics Partnership - Vehicle Safety Communications 2 (CAMP VSC2) Consortium and USDOT (NHTSA) initiated, in December 2006, a 3-year collaborative effort in the area of wirelessbased safety applications under the VSC-A Project.

SAE INTERNATIONAL Member Connection™

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