Positioning Challenges in Automation

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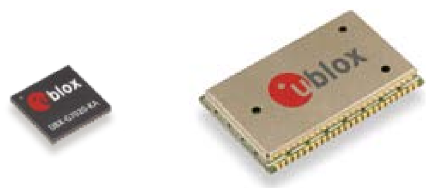
u-blox at a Glance

Swiss semiconductor company

- Founded in 1997
- Stock listed since 2007 (SIX:UBXN)
- **800+** employees, 58% in R&D
- Annual sales of **350 Million** USD (2015)
- **12 years** of continuous **profitability** and **strong growth**
- Fabless operation

Commercial, off-the-shelf chips and modules



- Positioning
- Cellular
- Short Range (Bluetooth, Wi-Fi, V2X)

Example Automation Applications Requiring Positioning

Cars

Container
Handling

UAVs

Factories &
Warehouses

Mining
Machinery

Agricultural
Machinery

Example Automation Application Needs

	Accuracy Need	Integrity Need	Price Sensitivity	Environment
Cars	1m/95%	Very High	High	Urban
UAVs	dm to m	High	High	Urban
Agriculture	dm	Low	Medium	Relatively open
Open cut mining	dm	Moderate	Low	High wall
Factory automation	dm	Low	Medium	Congested Indoor
Warehousing	dm	Low	Medium	Congested indooor

- Most automation applications need high accuracy
- Some need high integrity (ie reporting of ‘guaranteed’ maximum error)
- Many also require timing/synchronization to various degrees of precision
- Most present cluttered environments
- Despite this, nearly all require mass market price points

Unmet Needs

- Standard grade GNSS positioning meets the price requirements
  - But fails to meet the accuracy and integrity requirements
- High precision GNSS receivers are expensive
  - And require expensive correction services
  - These also do not offer high integrity
- Aviation receivers provide high integrity
  - But not under surface positioning conditions where multipath is prevalent
  - And do not offer high accuracy
  - And are expensive

- **A new paradigm in GNSS-based positioning is needed**

- Mass market indoor positioning suitable for automation remains an unmet need

Accuracy in Cluttered Environments

- New GNSS signals (eg L5,E5) are less susceptible to multipath
- “Dead Reckoning” has long been used in conjunction with GNSS
  - Inertial sensors supplement the GNSS measurements
  - Allowing positioning when GPS signals are denied
- Today rigorous INS mechanization is used to achieve
  - 3D hybrid GNSS/INS positioning
  - For multipath mitigation
  - And to allow accurate positioning in GPS-denied environments
- Positioning based on carrier phase measurements is less susceptible to multipath
- High precision RTK (carrier phase based positioning) is being adapted
  - For fast convergence allowing its use in more cluttered environments
  - For use with wide area corrections (PPP and SSR-RTK)
  - For use with INS to bridge carrier phase lock outages
- A wide range of sensors are being adapted for relative positioning
  - Eg RADAR, LIDAR, Vision

Integrity in Cluttered Environments

- GNSS integrity schemes have long been used in aviation
- Now they are required for use in cluttered environments
  - Where environmental factors cause outliers
    - Eg multipath
    - Not just system failures
  - For safety critical applications
- Entirely new approaches are being developed
  - To cope with non-Gaussian nominal error distributions
  - To cope with multiple concurrent outliers – possibly correlated
  - To cope with ambiguity errors in carrier phase based positioning
  - To cope with time-correlated errors

Indoor Positioning

- Multiple technologies are being used
    - Cellular
    - Magnetic sensing
    - Pedestrian Dead Reckoning using inertial sensors
    - 'Standard' Wifi & other proprietary non-ranging beacons
    - Multi-band WiFi
    - UWB
    - Locata-style GNSS-like positioning
- All but the last three fail to meet the accuracy needs of automation
- The eco-system does not exist for indoor positioning suitable for automation
    - Indoor mapping is needed
    - Infrastructure is needed
    - Very wide bandwidth or beamforming is required
        - to cope with short range multipath
    - Careful beacon placement is needed to optimise geometry, coverage and accuracy
- This makes deployment expensive and not scalable to the mass market
    - Hence deployment remains project oriented

A Use Case - Automated Driving

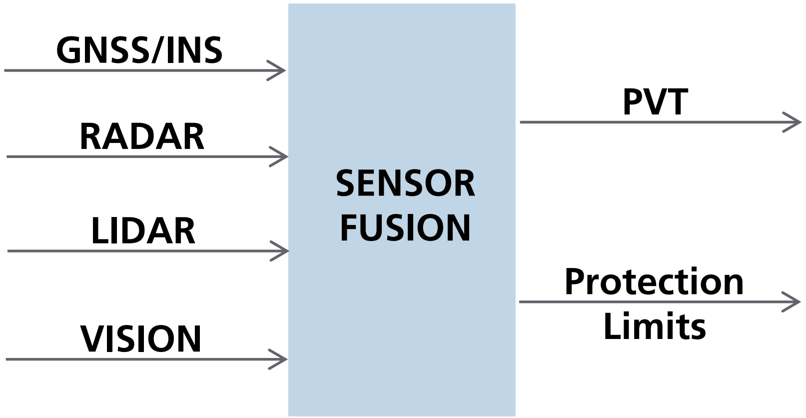
GNSS for Autonomous Driving

	Lane departure warning	Lane keeping assistant	Traffic jam pilot	Highway driving assistant	Highway pilot	Robot taxi
Levels of driving automation	Driver only	Assisted	Partially automated	Highly automated	Fully automated	Autonomous
	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
Driver in the loop	Yes			Not required		
Driver reaction time	~1s			**A few s**	**A few minutes**	
Non-driving tasks	Not permitted			**Some**	**Permitted (incl. sleeping)**	
End-to-end navigation	No					Yes
GNSS	Optional			Required		
Accuracy	Street level				Lane level	
Functional safety	No			**ASIL B (or higher)**		
u-blox solutions	u-blox M8 GNSS. Optional 3D ADR				Next gen. u-blox GNSS	

Autonomous driving system

- Requires highly accurate position and velocity
  - Anywhere, anytime
  - In any condition
  - With 100% availability

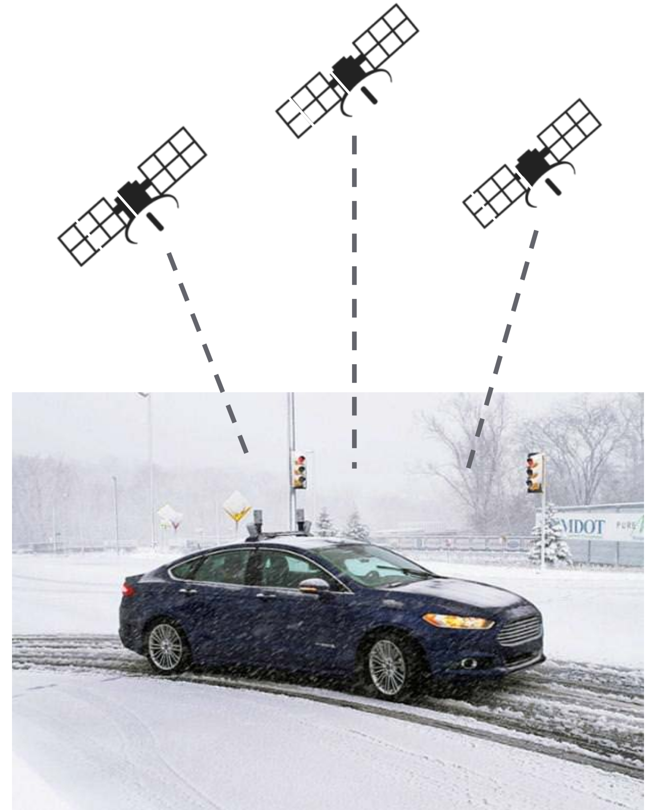
- Multiple positioning technologies are available:
  - Landmark positioning
    - High quality maps fused with
    - Sensors (cameras, RADAR, LiDAR, etc.)
  - GNSS with 3D Dead Reckoning
- None of them meets all criteria



A combination of technologies is required for fully automated and autonomous driving

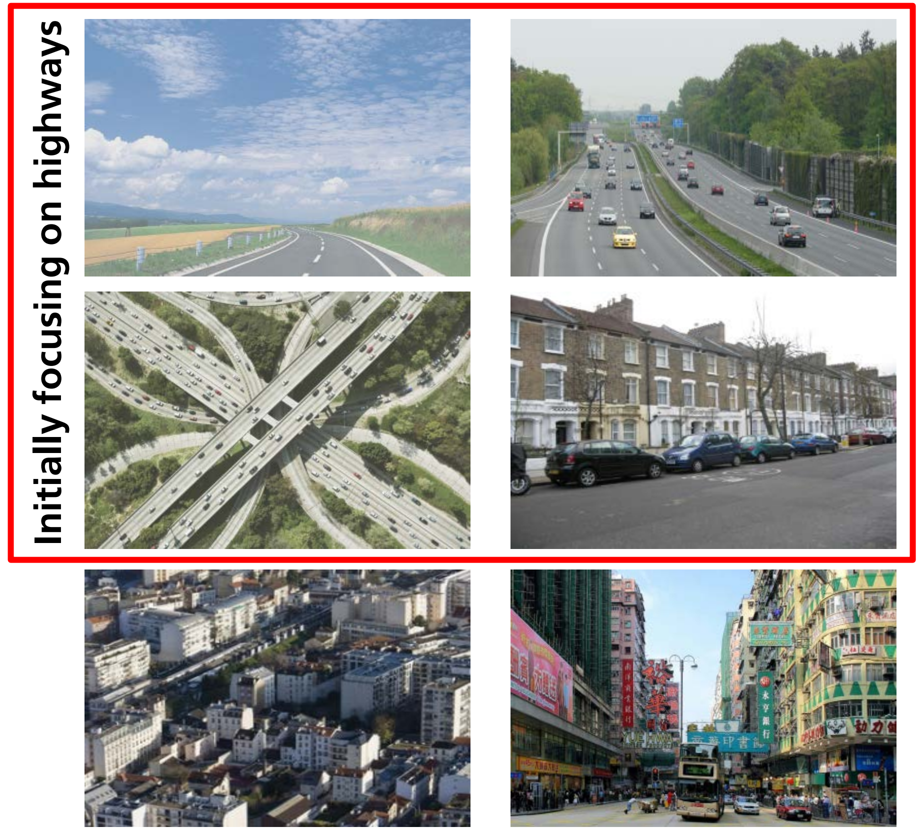
Autonomous driving system

- A lane-accurate, high-integrity GNSS is instrumental:
  - Only source of absolute position, absolute time
  - Only source of absolute velocity, heading
- Benefits:
  - Works in any weather conditions
  - Works in areas w/o landmark (desert problem)
  - Reduces map costs (less details required)
  - Enables crowd sourcing of maps
  - Enables calibration of vehicle sensors
  - Allows for decomposition of safety requirements



GNSS requirements for Autonomous Driving

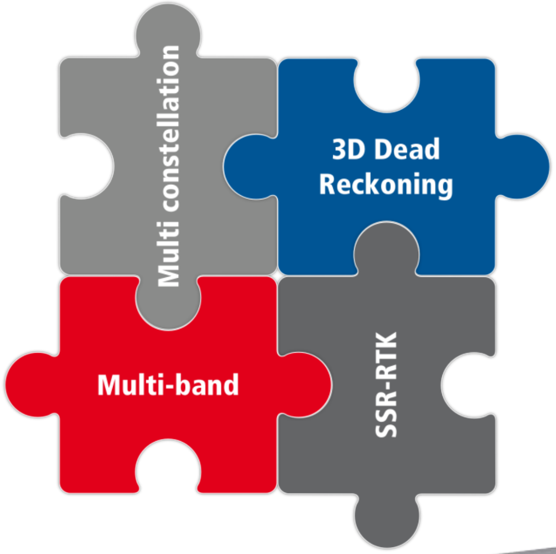
- Horizontal Accuracy:
  - Open highways: ±0.1m / 50%
  - Urban highways: ±1.0m / 95%
- Position update rate
  - GNSS: >= 10Hz
- Safety and integrity:
  - Functional safety
  - Protection levels
  - End-to-end integrity including correction service
- Cost level enabling mass deployment



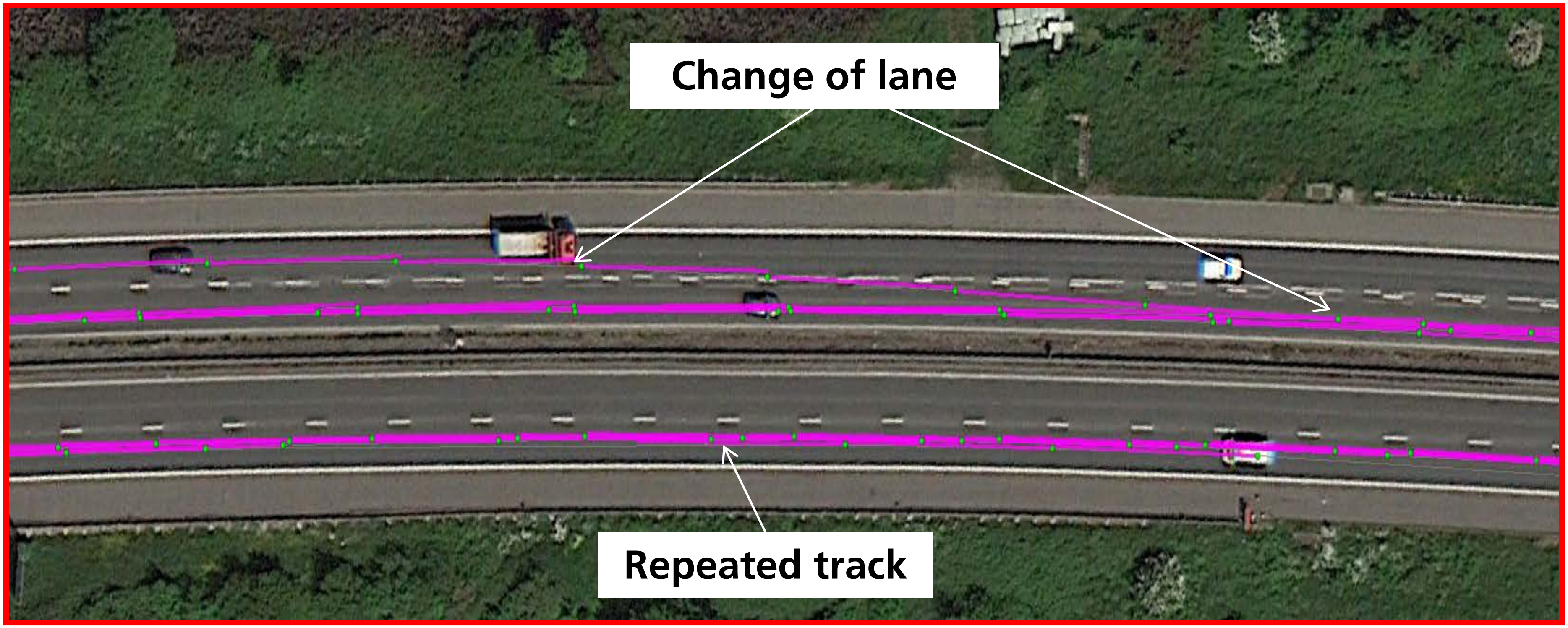
GNSS Technology

- There is no single technology capable of providing required position accuracy in all environments

- A combination of core GNSS technologies is needed:
    - SSR-RTK with correction data brings accuracy of <<1m
    - Multi-GNSS for large number of measurements
    - Multi-band reception for minimal convergence time
    - 3D Automotive Dead Reckoning:
        - to smooth multipath effects
        - to bridge obstructions
        - to maintain positioning in tunnels and parking



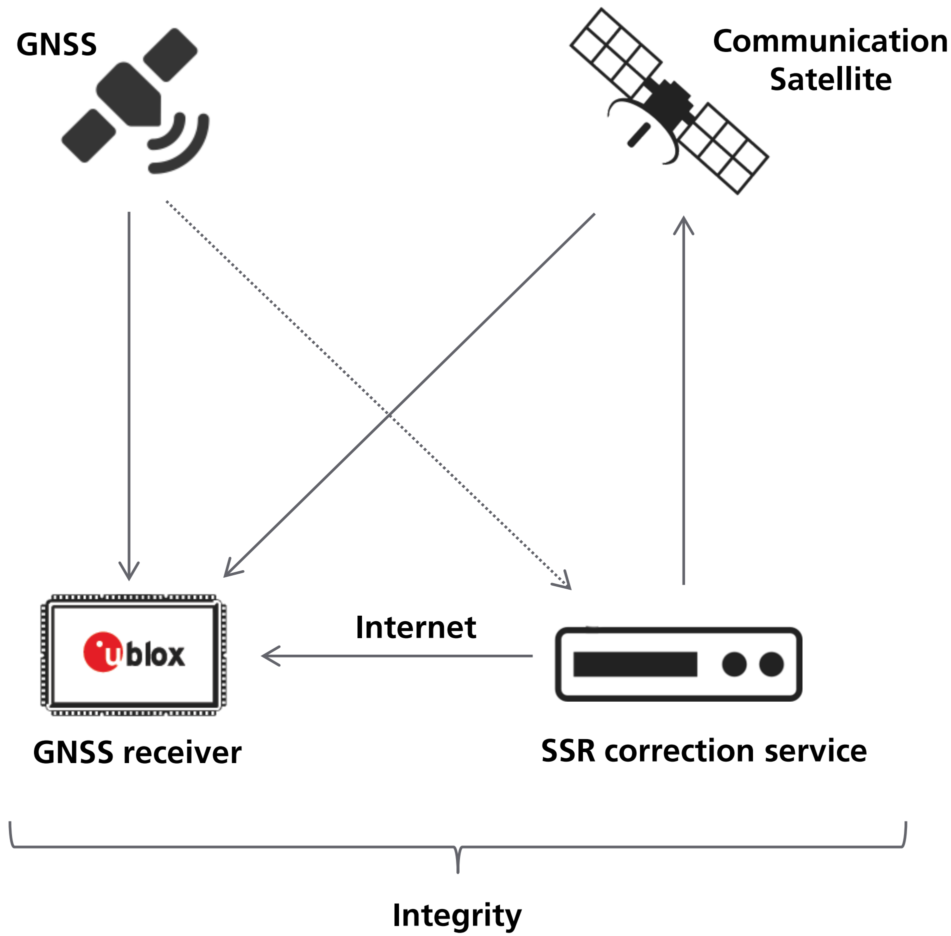
GNSS Technology



A change of lane is recognized accurately with the right combination of GNSS technologies

GNSS system view

- System consists of
  - Functionally safe GNSS receiver
  - Satellite communication receiver
  - Correction service
  - Internet connectivity

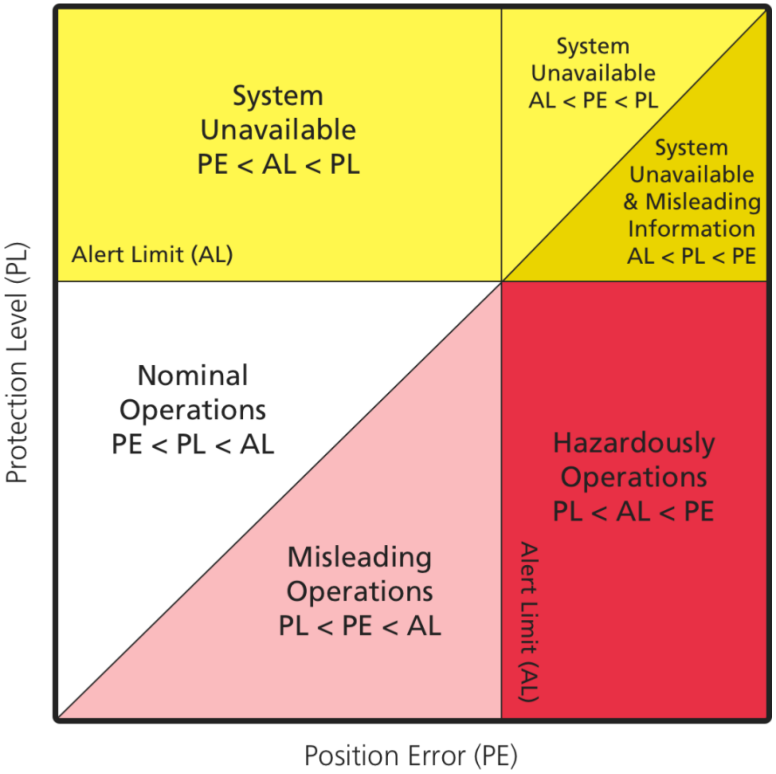


Integrity as prerequisite for Autonomous Driving

- GNSS receiver must report:
  - Position
  - Protection Level (output of integrity)
    - Dealing with all error sources
    - Including multipath

- Integrity risk must be small (e.g. 10^{-6}/h) even with
  - Multipaths
  - Poor sky visibility

- This demands a drastic change
  - cf Current receivers for road navigation
  - cf Integrity approaches for aviation



Hurdles in the path to integrity for autonomous driving

- Current algorithms for protection limit assume nominal errors are Gaussian
- The use of Gaussian over-bounding is likely too conservative
    - Given alarm limits of a few meters at integrity risk of 10^{-6}/h
- Which leaves us with a formidable list of questions:
    - How to model ambiguity errors
    - How to model non-Gaussian pseudorange errors
        - Including accuracy far out in the tail of the distribution
    - How to estimate measurement error statistics in realtime
    - How to derive state error statistics from measurement error statistics
    - How to deal with error correlations amongst the measurements and over time

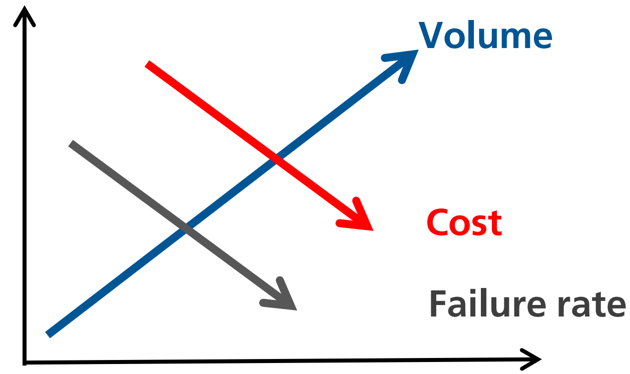
Correction Service Needs for Mass-Market Adoption

- **Global** or semi-global correction service coverage
  - All densely populated regions are covered (where the vast majority of cars drive)
- **Affordable**
  - Business model fostering mass adoption
- **Readily available**
  - Available wherever a device is
- **Safe**
  - Some applications are life critical
- With a **long lifetime**
  - Some devices have service life of >15 years
- **Operational** in 2018
  - Test operation from Q1/2017 onwards

Mass market

- Volumes in autonomous driving will grow slowly

- However:
    - Costs scale with volume
    - Reliability strategy builds on high volumes

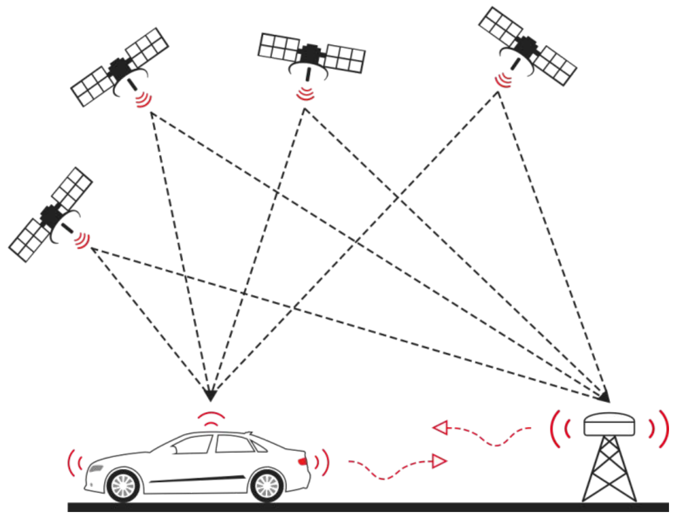


- Without affordable costs and high quality, the market cannot take off

- u-blox as market leader for automotive GNSS is perfectly able to "bridge" this chasm

Summary

- u-blox is solving these challenges



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Thank you