

ION GNSS+ 2017

TRENDS, INNOVATIONS AND ENHANCEMENTS FOR LOW-COST PPP

September 27TH , 2017

Session A1: Applications of Raw GNSS Measurements from Smartphones

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OUTLINE

GNSS & Smartphones

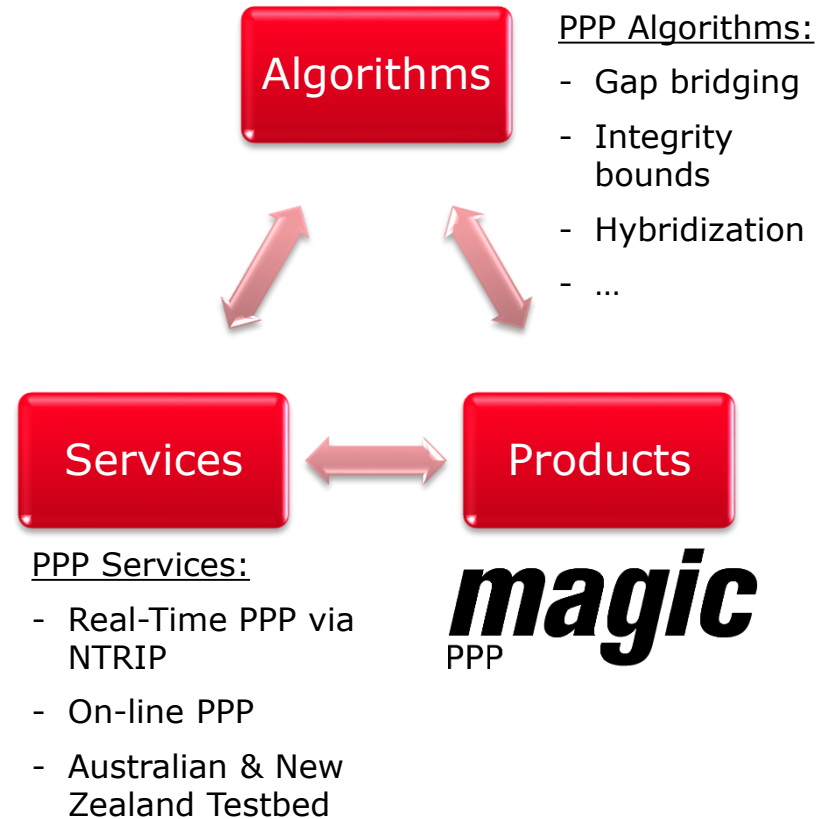
magicGNSS Evolutions

Test Campaign

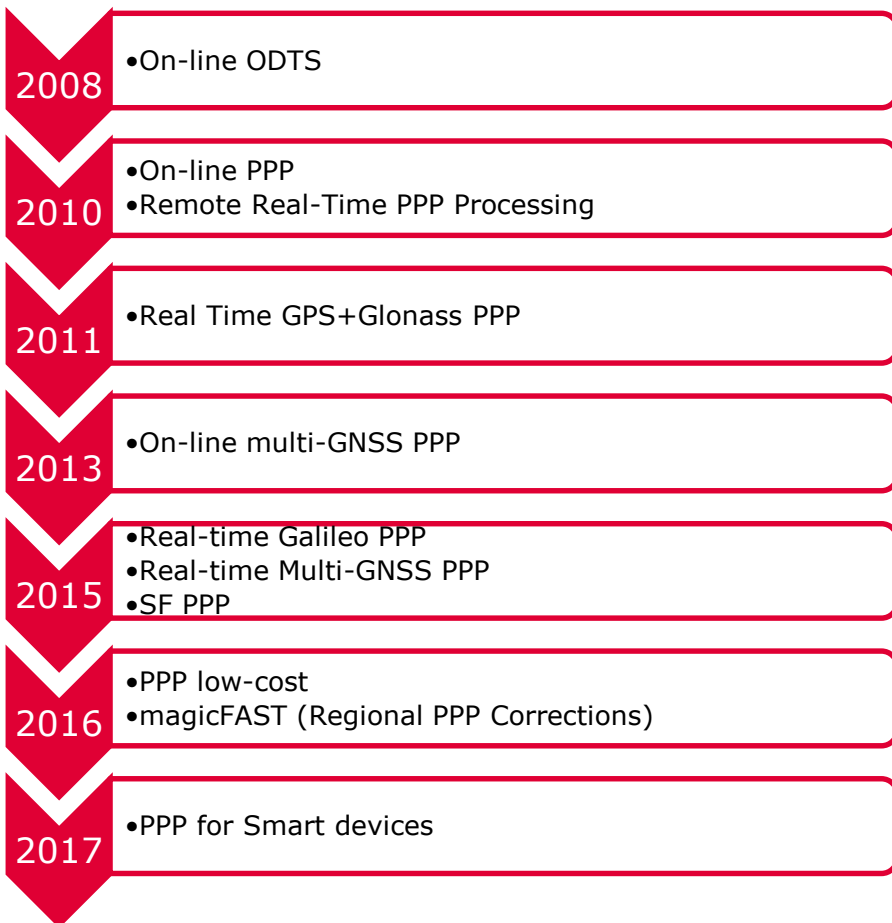
Conclusions and Way-Forward

ION GNSS+ 2017 GNSS & SMARTPHONES

GMV IN PRECISE POINT POSITIONING



GMV IN PRECISE POINT POSITIONING



Algorithms

PPP Algorithms:

- Gap bridging
- Integrity bounds
- Hybridization
- ...

Services

Products

PPP Services:

- Real-Time PPP via NTRIP
- On-line PPP
- Australian & New Zealand Testbed

magic
PPP

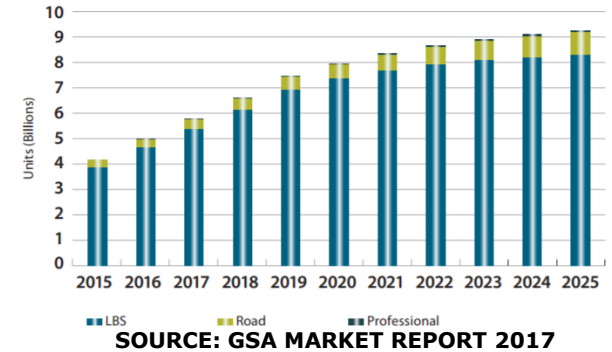
GNSS CHIPS FOR SMARTPHONES

- Low-cost GNSS in our daily lives:
 - Gmaps, Waze, Car Navigation, SportTracking...
 - Currently 6B devices and growing!
 - Smart-devices market is a huge pie
 - Renewal of devices allows to introduce new capabilities

- Smartphone GNSS chips are evolving:
 - Multi-constellation
 - Reduced power consumption
 - Carrier-phase tracking
 - Fusion with other sensors (IMU, Compass)
 - Raw measurements provision
 - Multi-frequency

- Market Opportunity → Accurate positioning is possible for mass-market users.

Smartphones account for almost 80% of the global installed base of GNSS devices



ACCESS TO GNSS RAW DATA

- Where?
 - Android 7.0 or later
 - Embedded receiver able to provide the raw measurements
 - Location Services API
- What?
 - Pseudoranges, Doppler, C/N0
 - Carrier Phase... but the duty-cycle...
- How?
 - Basic: Our own code-based PVT solution
 - Advance: what about using carrier-phase for precise point positioning?
 - Proficiency: what else is available in a Smartphone... fusing sensors!



FUSING SENSORS

- Smartphones usually feature a MEMS Inertial Measurement Unit
 - 3D accelerometer and gyroscope sensors
 - Small size (a few mm)
- IMU can be used to improve GNSS navigation solution:
 - Better accuracy in harsh environments
 - Dead-reckoning
 - Higher rate solution ($> 1\text{Hz}$)
- Integrated Compass
 - Additional information to improve the solution

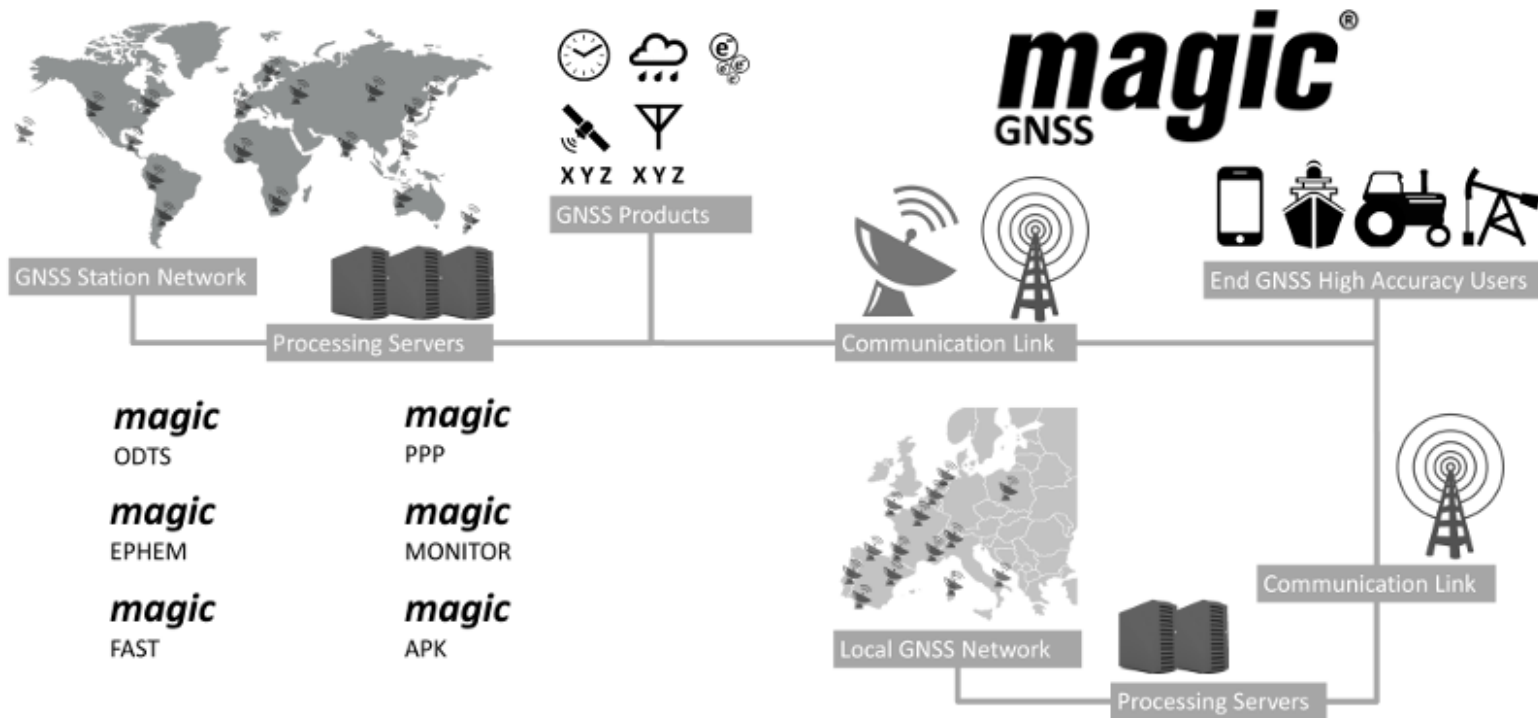


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EVOLUTIONS



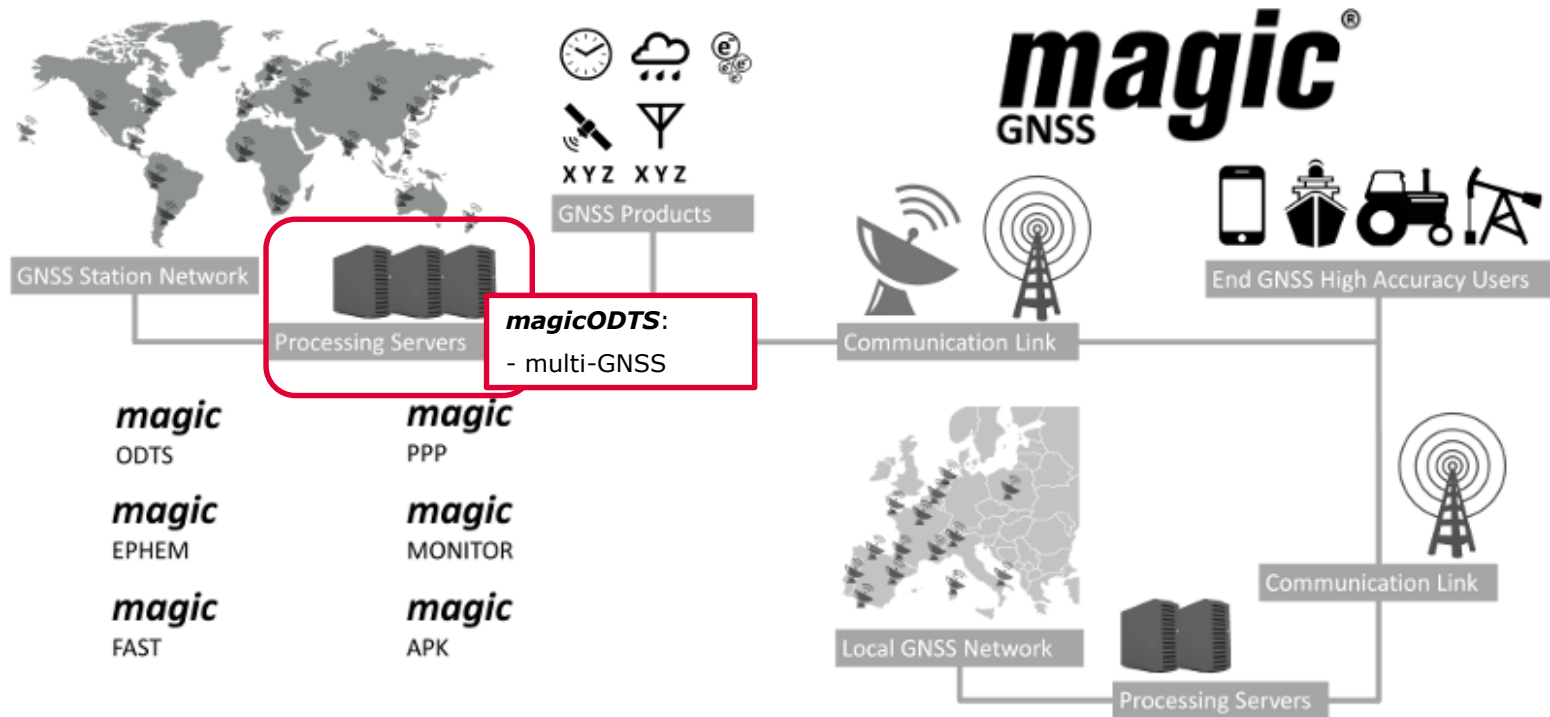
magicGNSS' REAL TIME INFRASTRUCTURE

END-TO-END PPP SERVICE



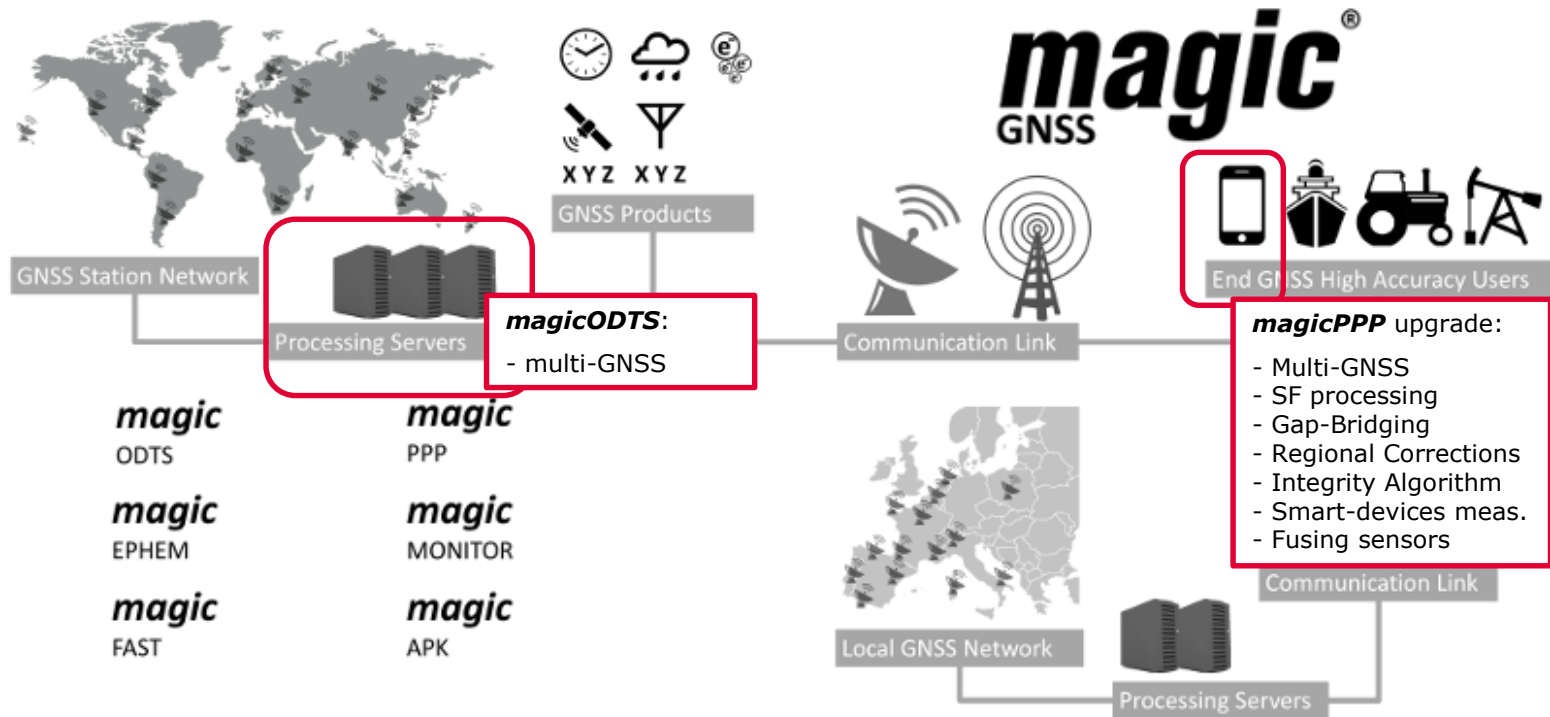
magicGNSS' REAL TIME INFRASTRUCTURE

UPGRADES FOR LOW-COST PPP



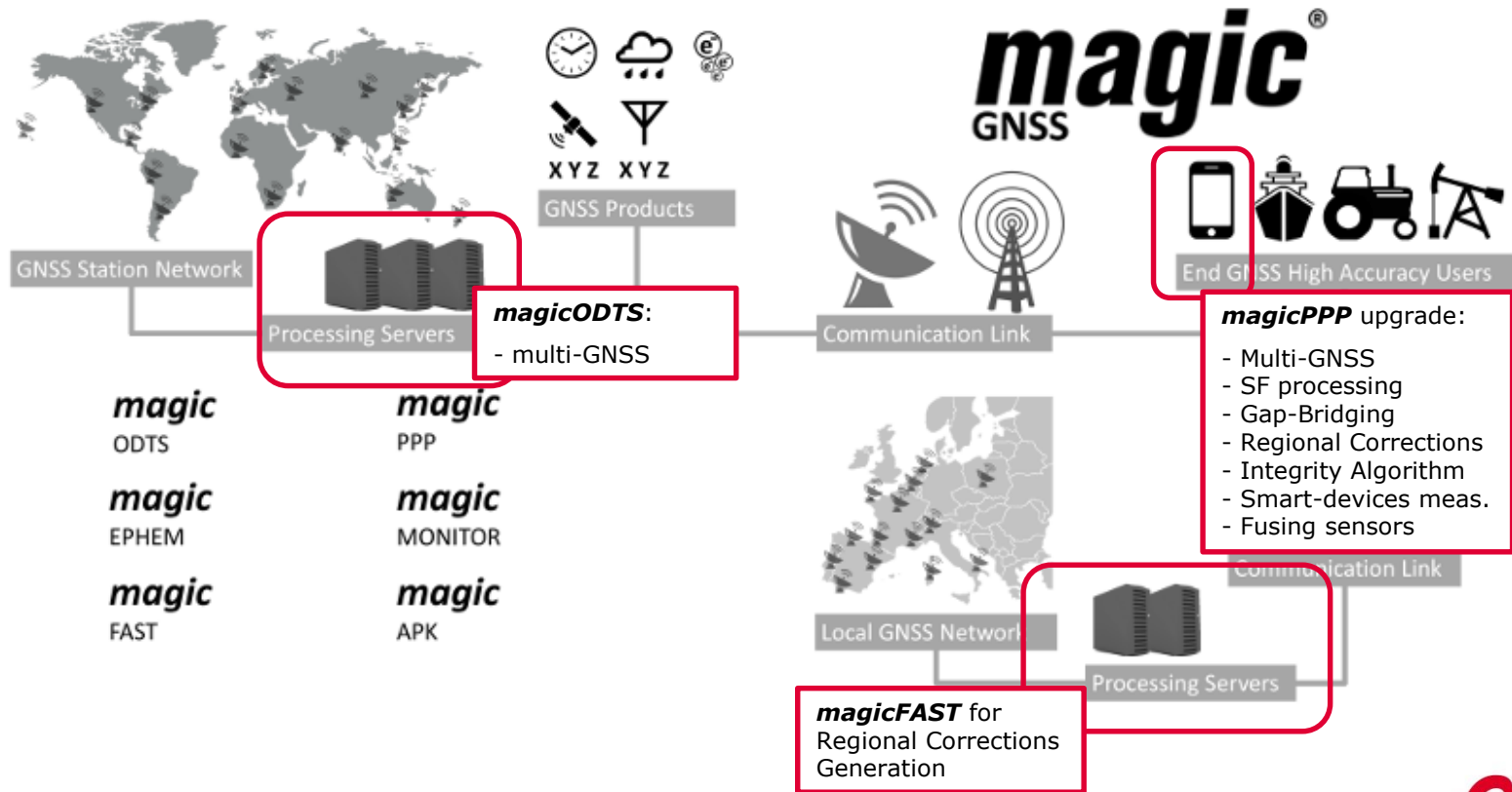
magicGNSS' REAL TIME INFRASTRUCTURE

UPGRADES FOR LOW-COST PPP



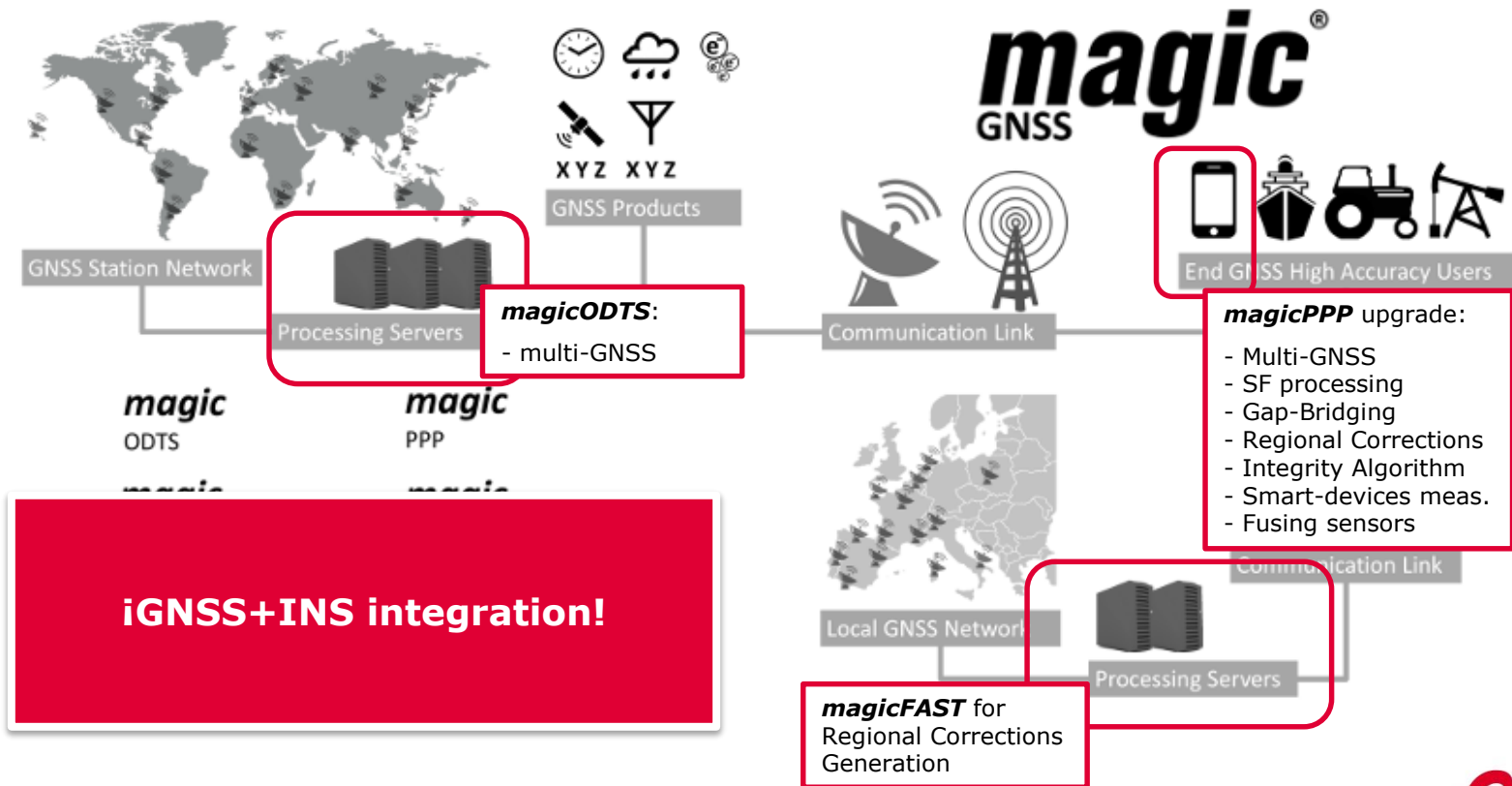
magicGNSS' REAL TIME INFRASTRUCTURE

UPGRADES FOR LOW-COST PPP



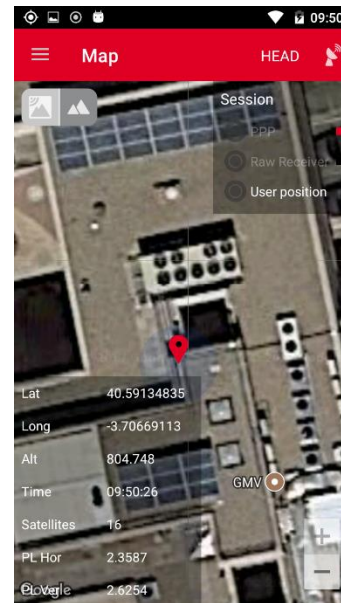
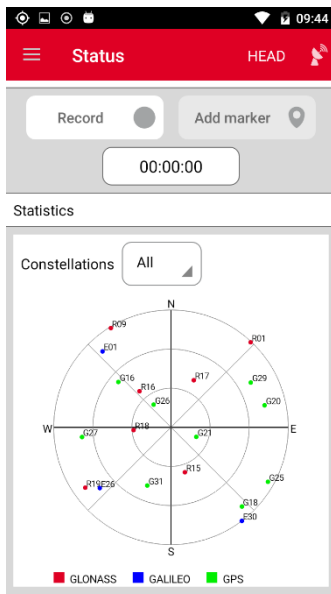
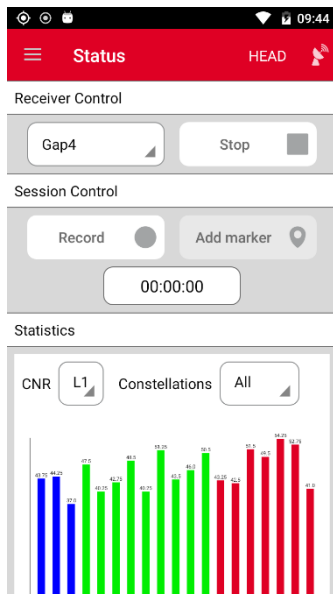
magicGNSS' REAL TIME INFRASTRUCTURE

UPGRADES FOR LOW-COST PPP



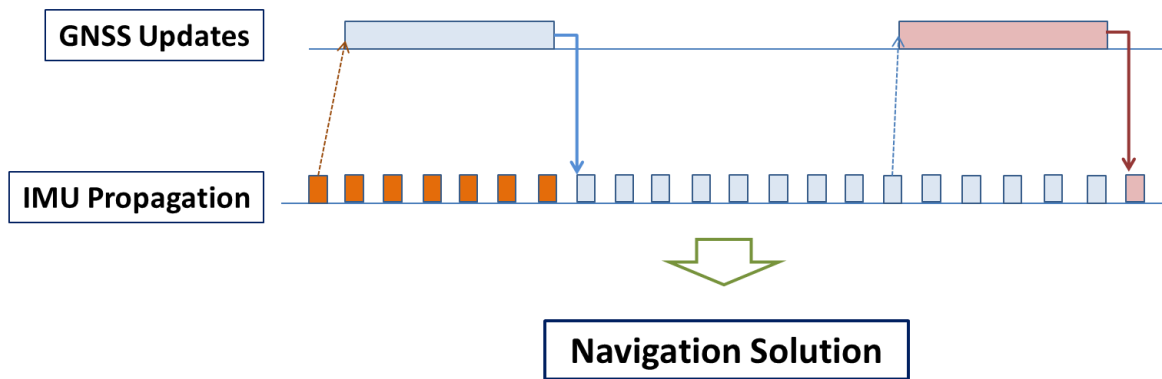
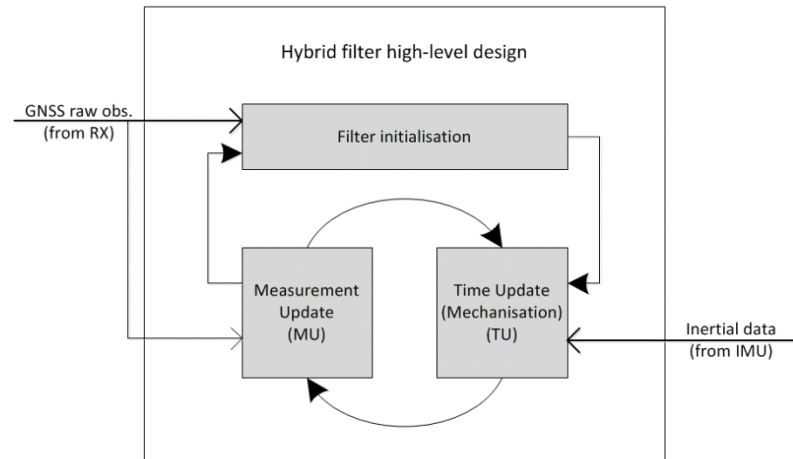
magicPPP EVOLUTION

- Android Application evolved to:
 - Support the retrieval of raw measurements provided by the internal GNSS chip and antenna through the LocationServices API (1Hz)
 - Obtain the accelerometers and gyroscope information through the Sensors API (high frequency >> 1Hz)



PPP+IMU HYBRIDIZATION

- **magicPPP + IMU** data integration
 - Tight coupling
 - Navigation solution provided at IMU rate
 - Accurate heading/roll/pitch output
 - *magicPPP* integrity algorithm (KIPL) extended to solution propagated by IMU
 - Offline and Real-time implementation

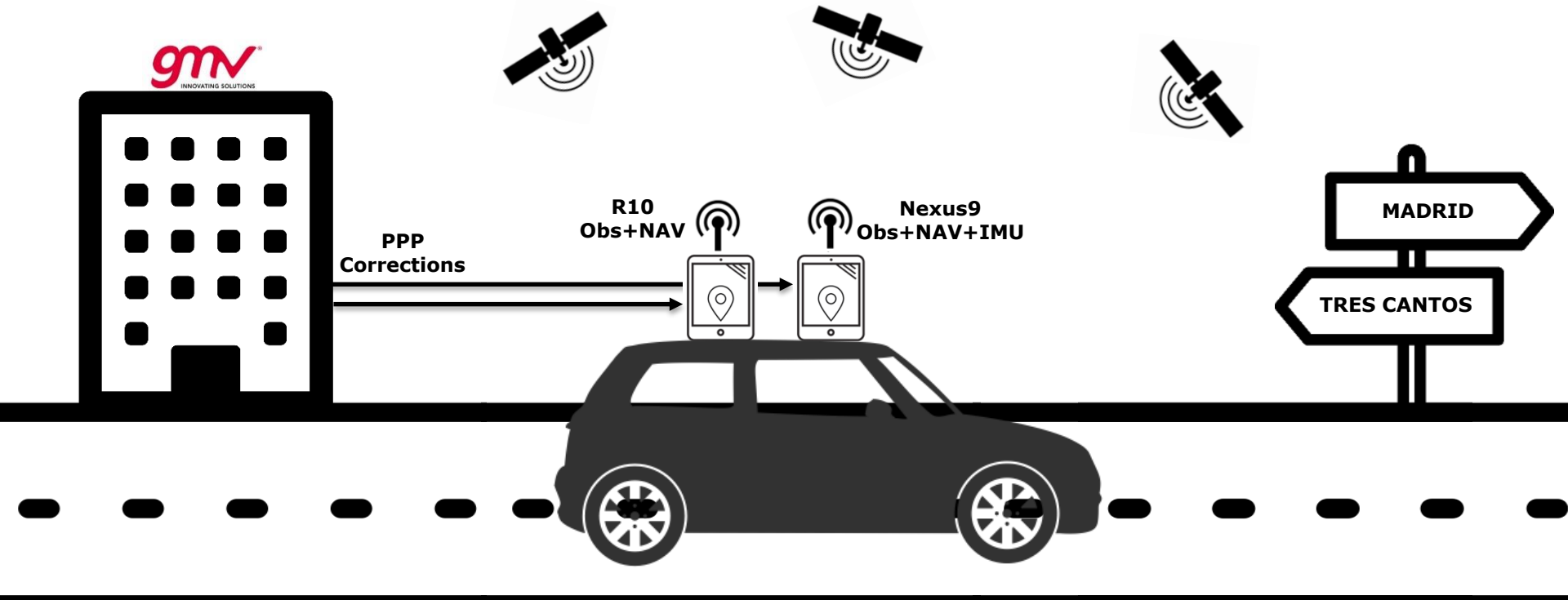


ION GNSS+ 2017 TEST CAMPAIGN



DEVICES UNDER TESTING - DEFINITION

- Device #1 (**Reference**): Trimble R10 + PPP Android Application
- Device #2 (**Tested**): Tablet Nexus 9 + PPP Android Application



DEVICES UNDER TESTING - EXECUTION

**TRIMBLE
R10**

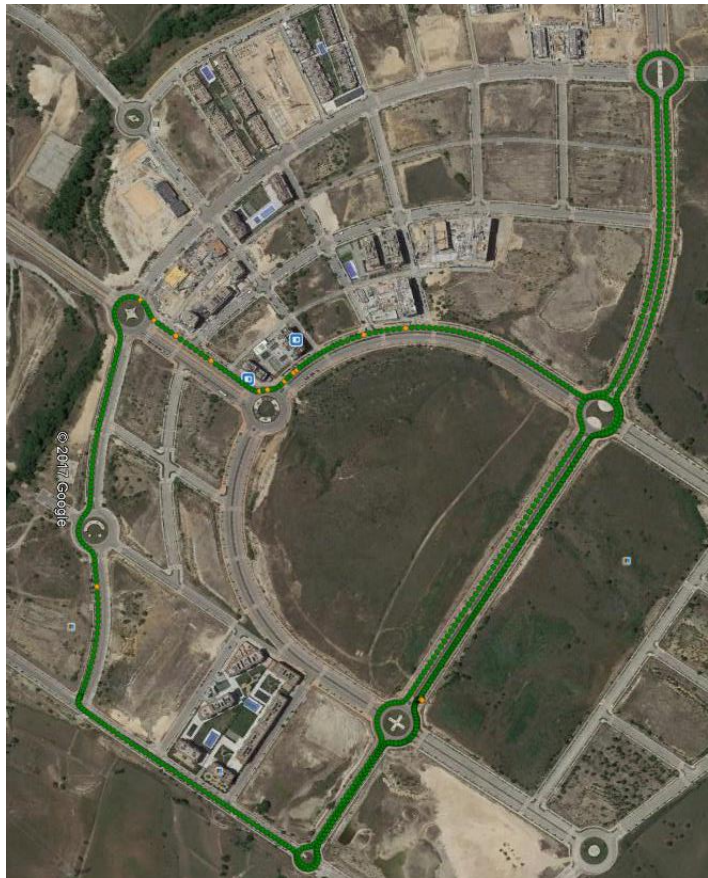


**NEXUS 9
(perfectly
fixed)**

DEVICES UNDER TESTING - SCENARIOS

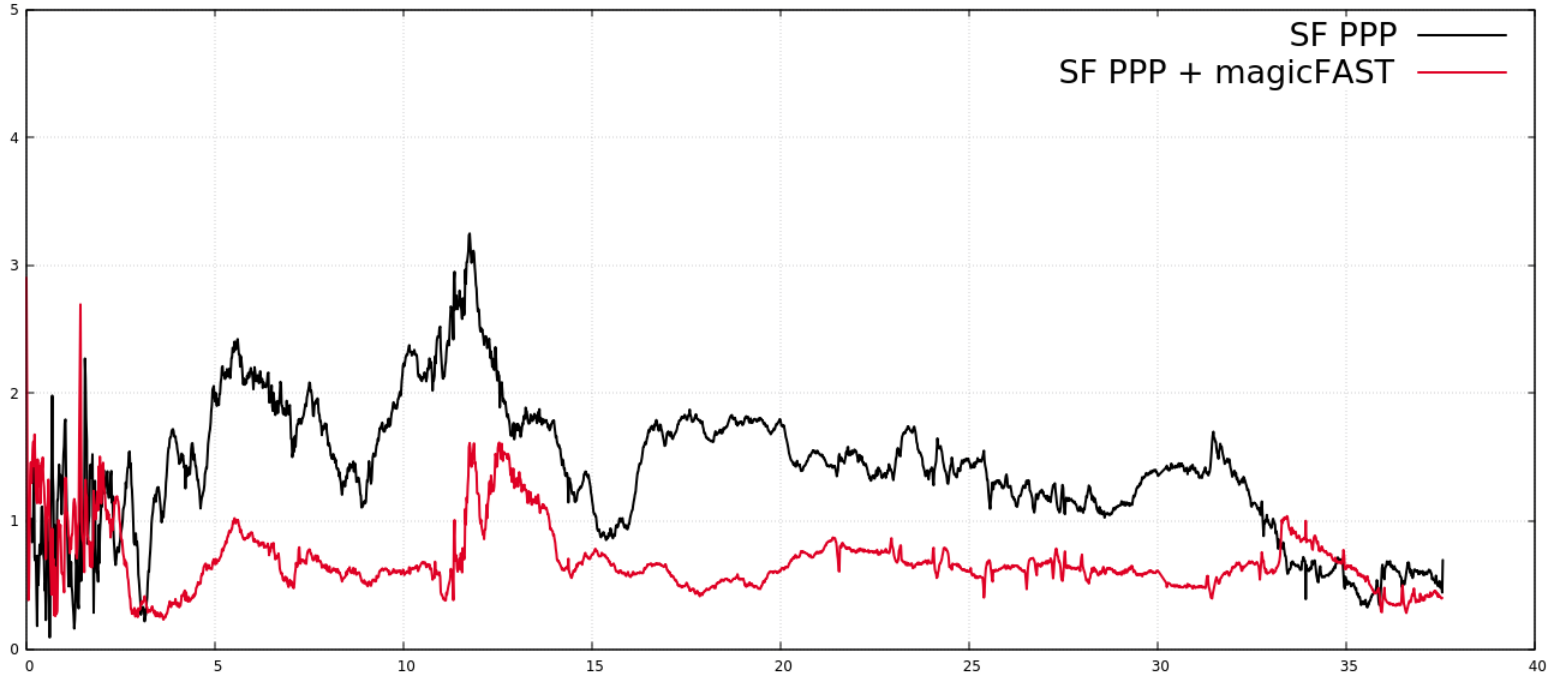
- **Two** kinematic scenarios:
 - Open sky + suburban conditions
 - Duration ~ 40 minutes
- Nexus 9 Tablet+ internal antenna and Trimble R10 placed on top of a car
- GPS+GLONASS, single-frequency
- Nexus 9 Tablet has duty-cycling disabled
- Reference trajectory obtained with Trimble R10 + RTKLib. Applied correction between antenna positions.
- Regional corrections: *magicFAST*

TEST #1 – DESCRIPTION



- Kinematic scenario:
 - Open sky + suburban conditions
 - Duration ~ 40 minutes
 - During the first 21 minutes the car is at rest
- Data from tablet's IMU too sparse to be useful
- Frequent cycle slips found in carrier-phase measurements

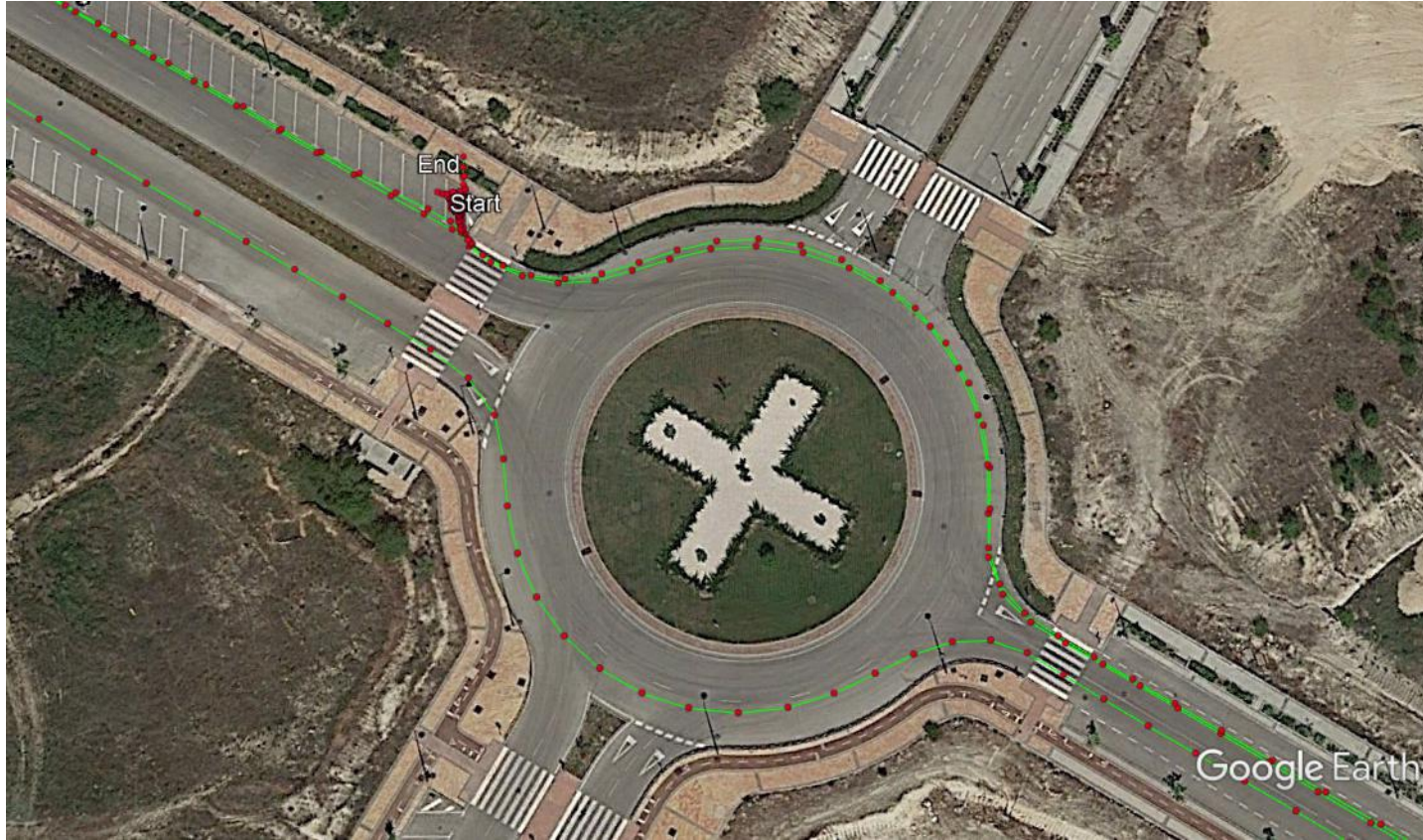
TEST #1 – RESULTS



2D RMS SF PPP: 1.51m
2D RMS SF PPP+magicFast: 0.76m



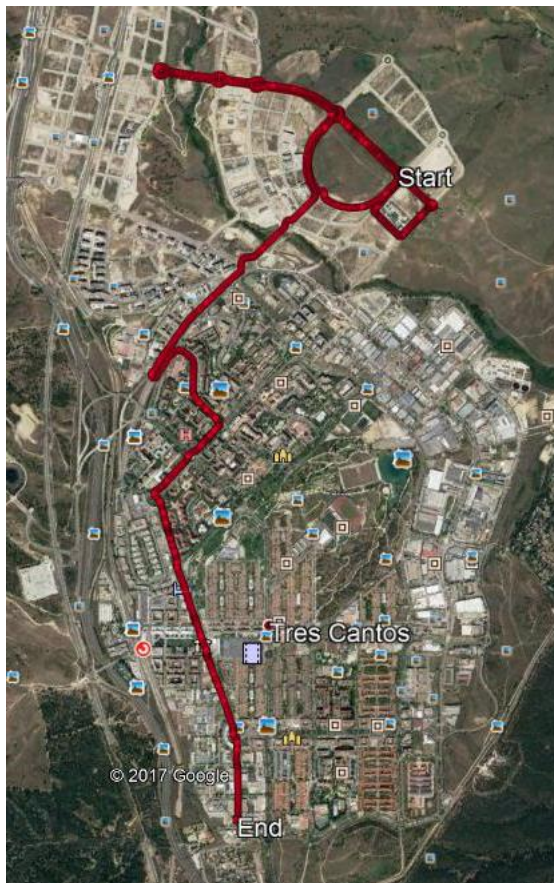
TEST #1 – RESULTS



TEST #1 – RESULTS

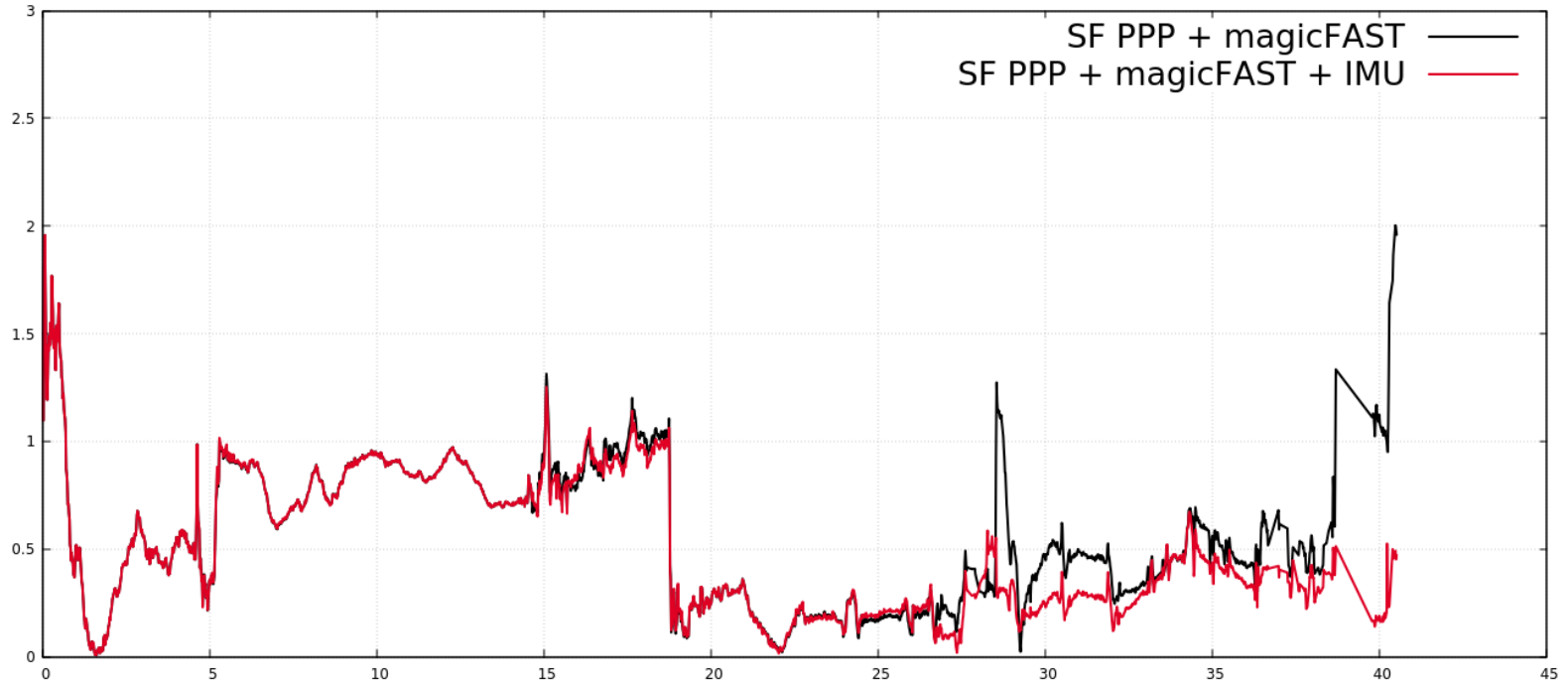


TEST #2 – DESCRIPTION



- Kinematic scenario:
 - Open sky + suburban conditions
 - Duration ~ 50 minutes
 - During the first 22 minutes the car is at rest
- IMU data from tablet (3-axis accelerometer and gyro) at 500Hz
- Frequent cycle slips found in carrier-phase measurements

TEST #2 – RESULTS

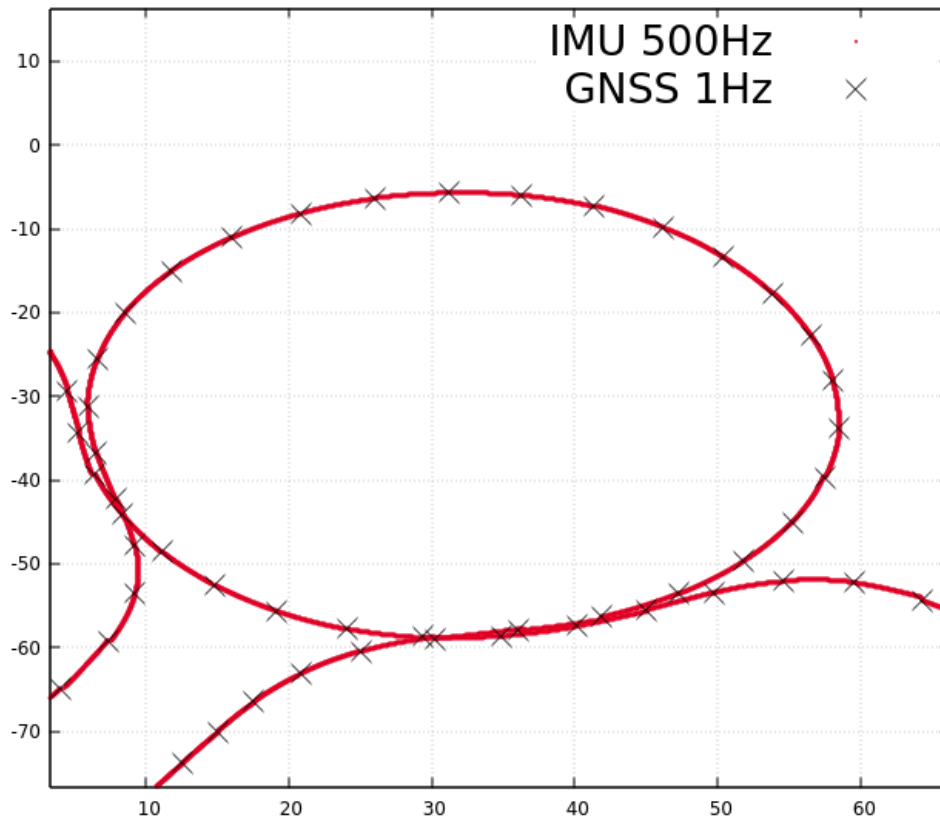
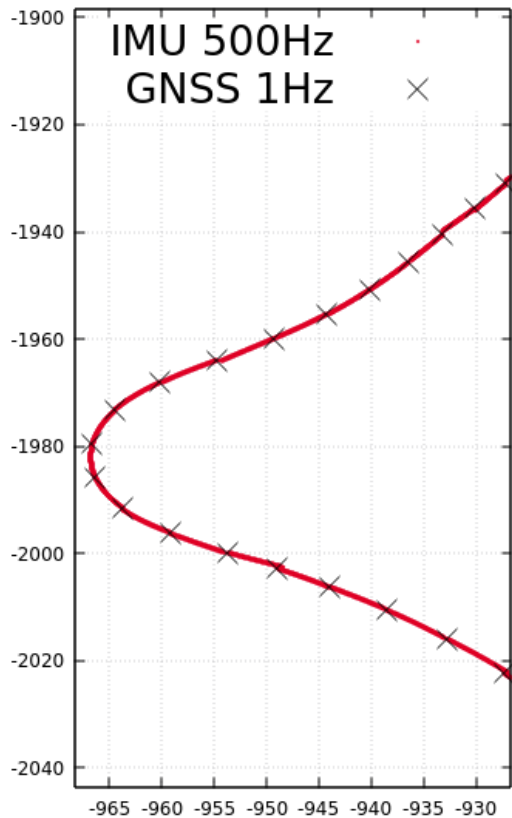


2D RMS SF PPP+magicFast: 0.65m
2D RMS SF PPP+magicFast+IMU: 0.61m

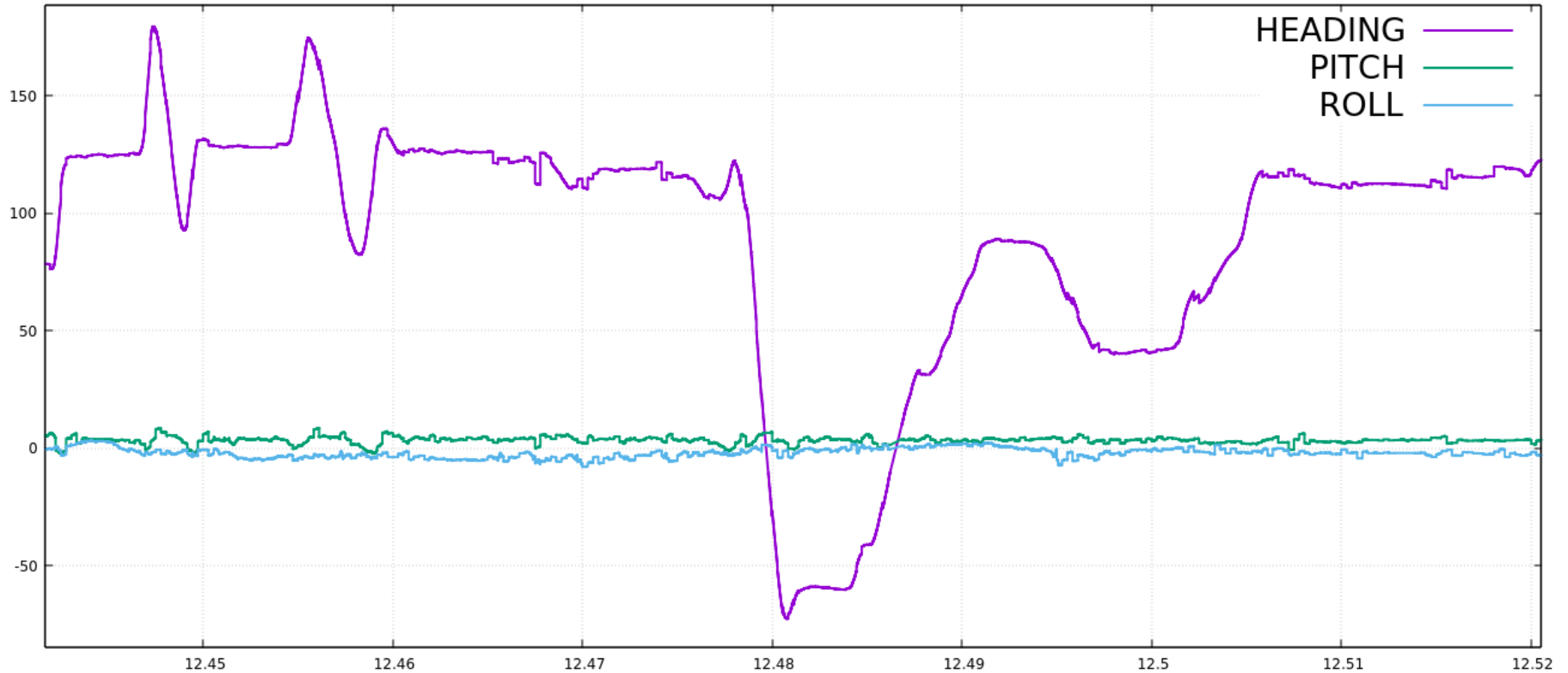
TEST #2 – RESULTS



TEST #2 – RESULTS



TEST #2 – RESULTS



ION GNSS+ 2017 CONCLUSIONS

CONCLUSIONS AND WAY-FORWARD

- Accurate GNSS navigation with smart devices is becoming possible with current and future chips
- *magicPPP* has a solution for smartphones/tablets. It uses IMU data to improve both quality and rate of the navigation solution
- First results are encouraging and show the validity of the approach
- Importance of reducing number of cycle slips

- Next steps:
 - Some future chips will support two GNSS frequencies (e.g. L1/L5). Use multi-frequency PPP
 - Enhance PPP algorithm for smartphone chips through experimentation
 - Improve IMU data processing, incorporate 3-axis compass

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