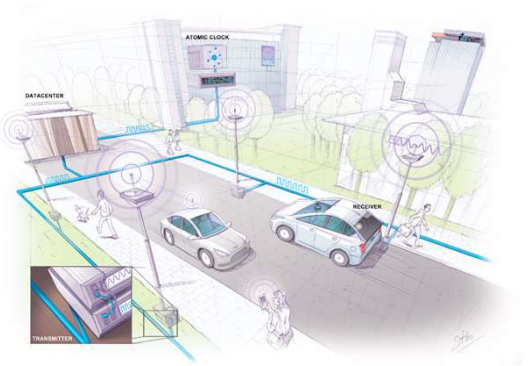
SuperGPS

Workshop GNSS voor nieuwe toepassingen

vrijdag 20 mei 2022 – TU Delft

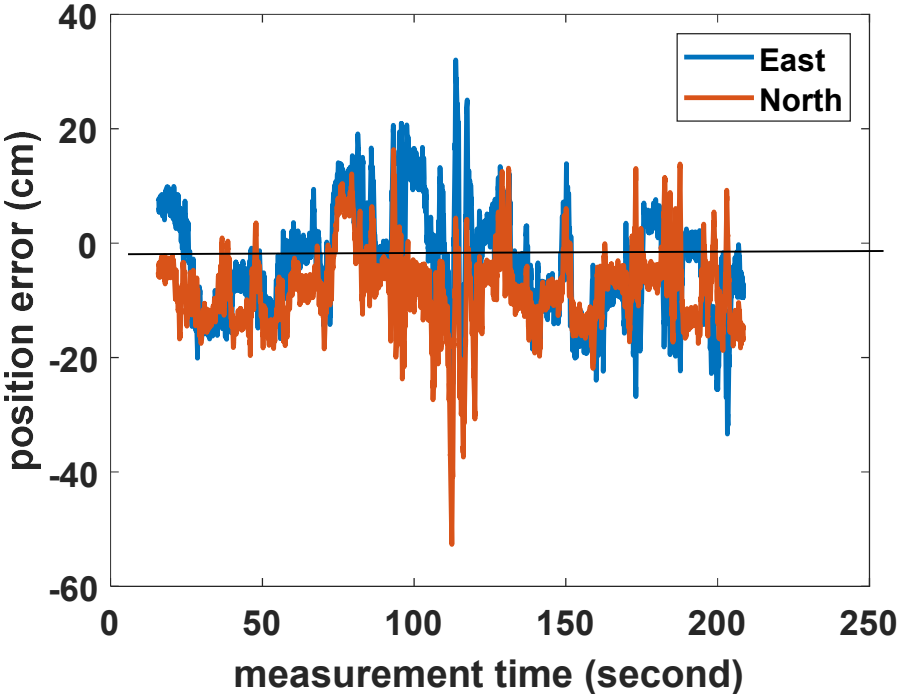


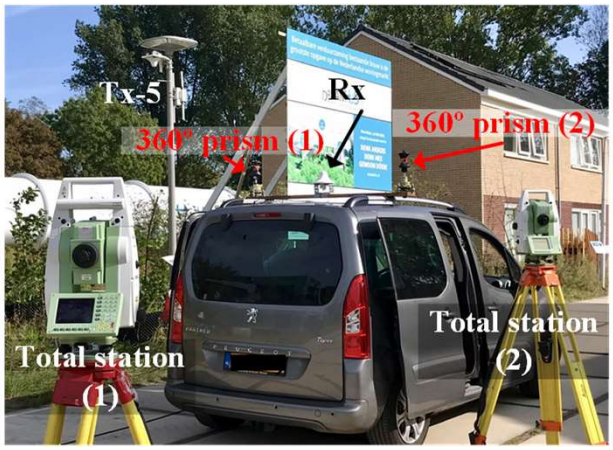
Christian Tiberius

TU Delft

experimental results – first impression

position error of receiver trajectory on trolley





RMS: East: 0.10 m

North: 0.11 m

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SuperGPS project

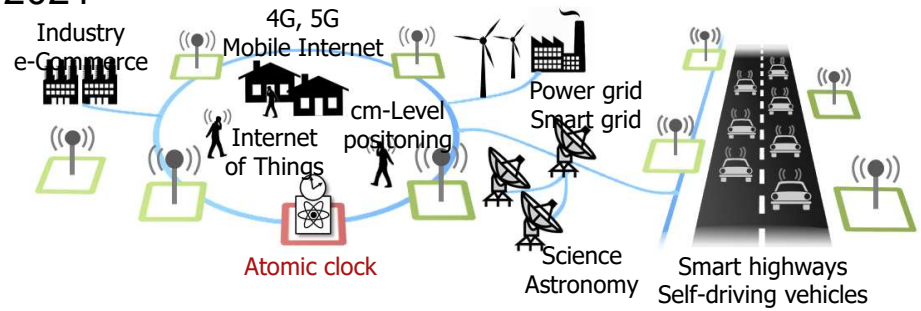
NWO (STW) SuperGPS project: TU Delft and VU Amsterdam

VU Vrije Universiteit Amsterdam · LaserLaB Amsterdam · NWO STW Enabling new technology · kpn · VSL · opnt. Time Provisioning · Fugro

TU Delft CEG & EEMCS

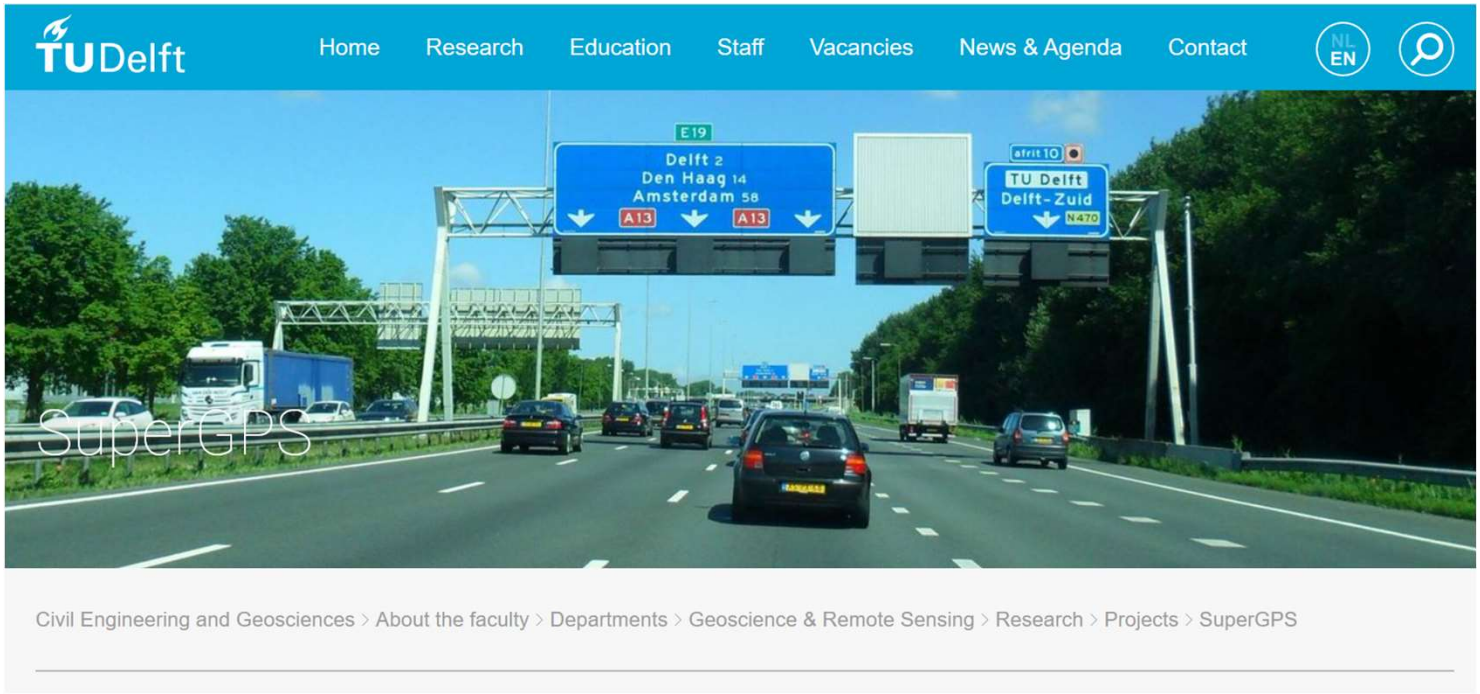
4 years, 3 PhD students, 1 Postdoc; incl. prototype system development

Fall 2016 – Summer 2021



- < 10 cm position accuracy (≡ 0.3 ns timing)
- wideband radio → 'short' pulses (to get around multipath reflections)

SuperGPS-website



GRS-website / Research / Geodesy / Positioning systems and geo-referencing / SuperGPS
https://www.tudelft.nl/en/ceg/about-faculty/departments/geoscience-remote-sensing/research/projects/supergps/

GPS World – overview paper

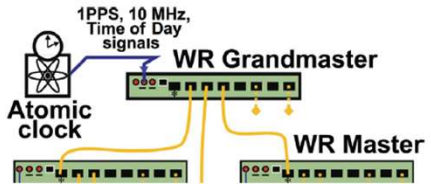
INNOVATION WITH RICHARD B. LANGLEY

A TERRESTRIAL NETWORKED POSITIONING SYSTEM

Better Performance Combining Fiber Optics and Wideband Radio

BY CHERIF DIOUF, HAN DUN, GERARD JANSSEN, ERIK DIERIKX, JEROEN KOELEMEIJ AND CHRISTIAN TIBERIUS

GPS is undoubtedly the most popular system providing positioning, navigation and timing (PNT) services to a host of applications, industries and infrastructures. GPS is mass-adopted, has worldwide coverage, has an impressive up-time and can be used with a wide range of receiver devices, featuring low to high cost and low to high precision.



All figures provided by the author

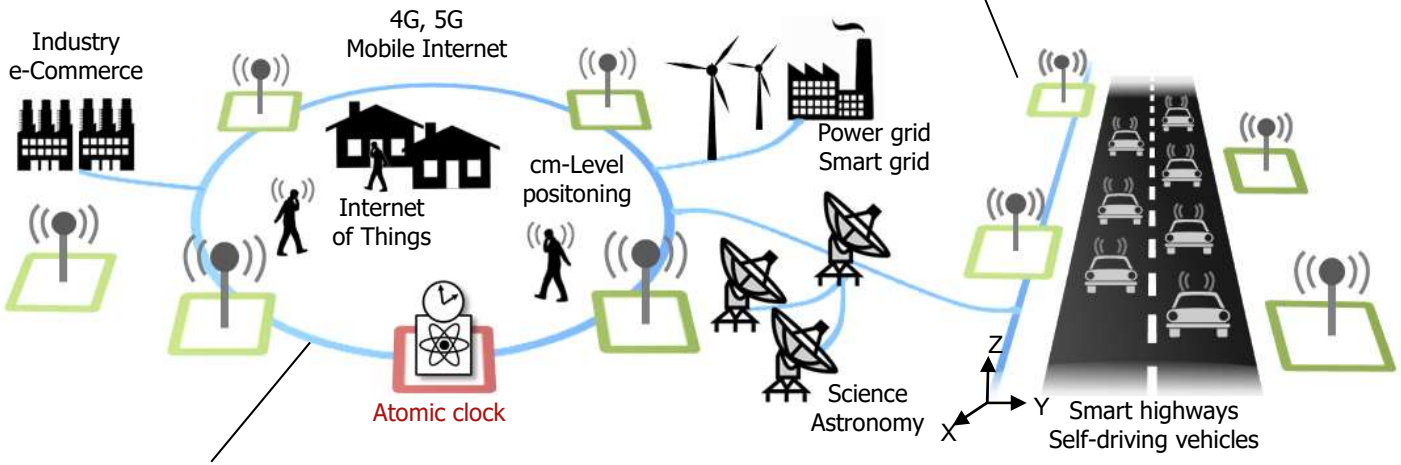
GPS World magazine - May 2022, Innovation column, pages 44-49
https://www.gpsworld.com/ *Magazine / Digital Editions / May 2022*
https://editions.mydigitalpublication.com/publication/?m=59713&i=746327&p=44&ver=html5

SuperGPS

SuperLPS …

Terrestrial Networked Positioning System (TNPS)

2) wideband radio transmitter



1) time & frequency distributed over optical-fibre

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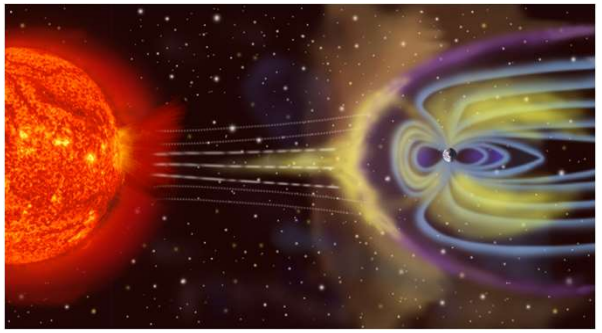
issues with GPS/GNSS

- weak signal: jamming, spoofing
- space-born transmitters: signal reception subject to space weather



- fairly narrow band: poor performance in built-up areas

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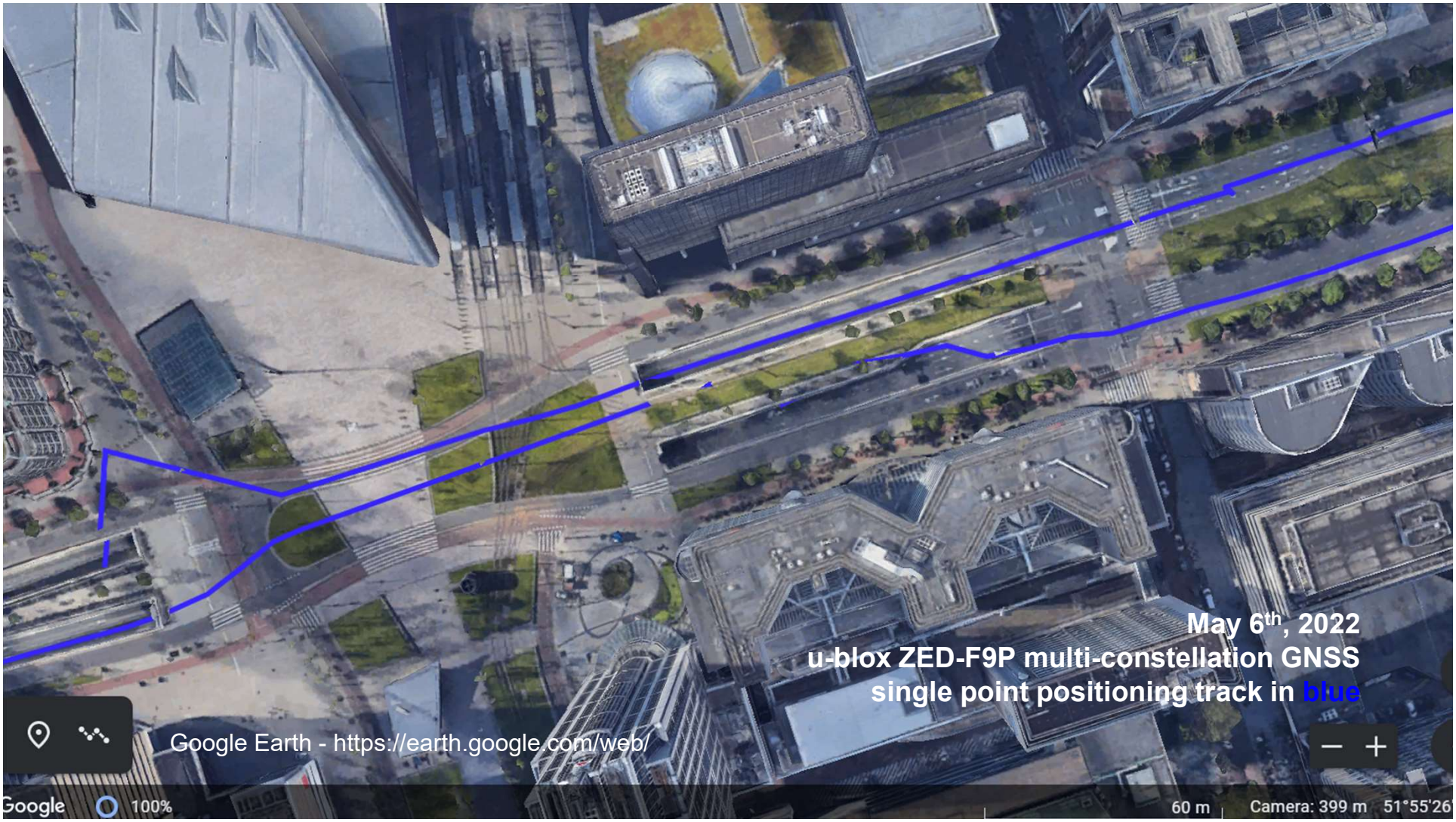
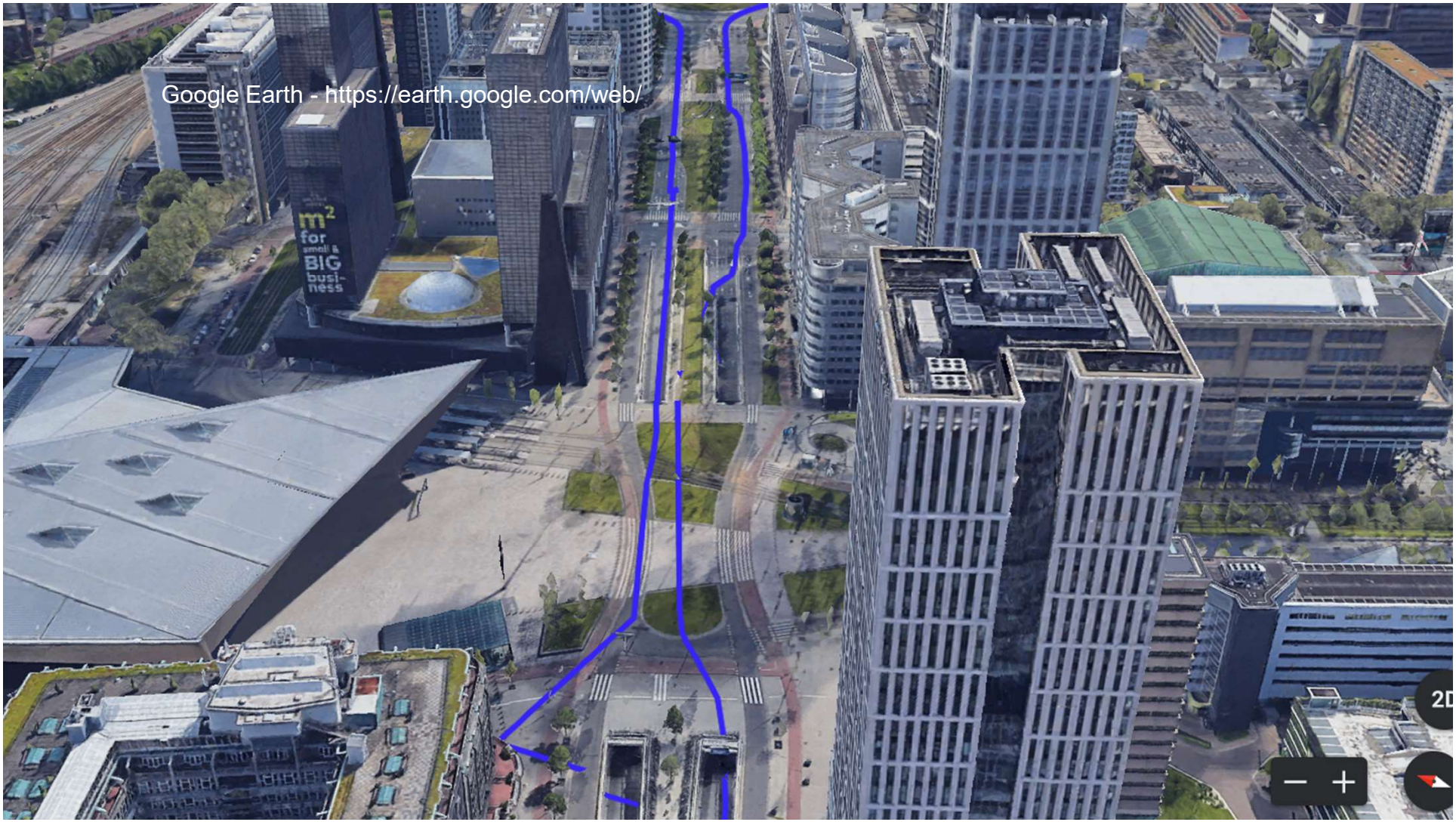
issues with GPS/GNSS

GPS/GNSS perform worst,

where you need them most …


May 6th, 2022
u-blox ZED-F9P multi-constellation GNSS
single point positioning track in blue
Google Earth - https://earth.google.com/web/
Google
100%
60 m
Camera: 399 m
51°55'26


Google Earth - https://earth.google.com/web/
m²
for
small &
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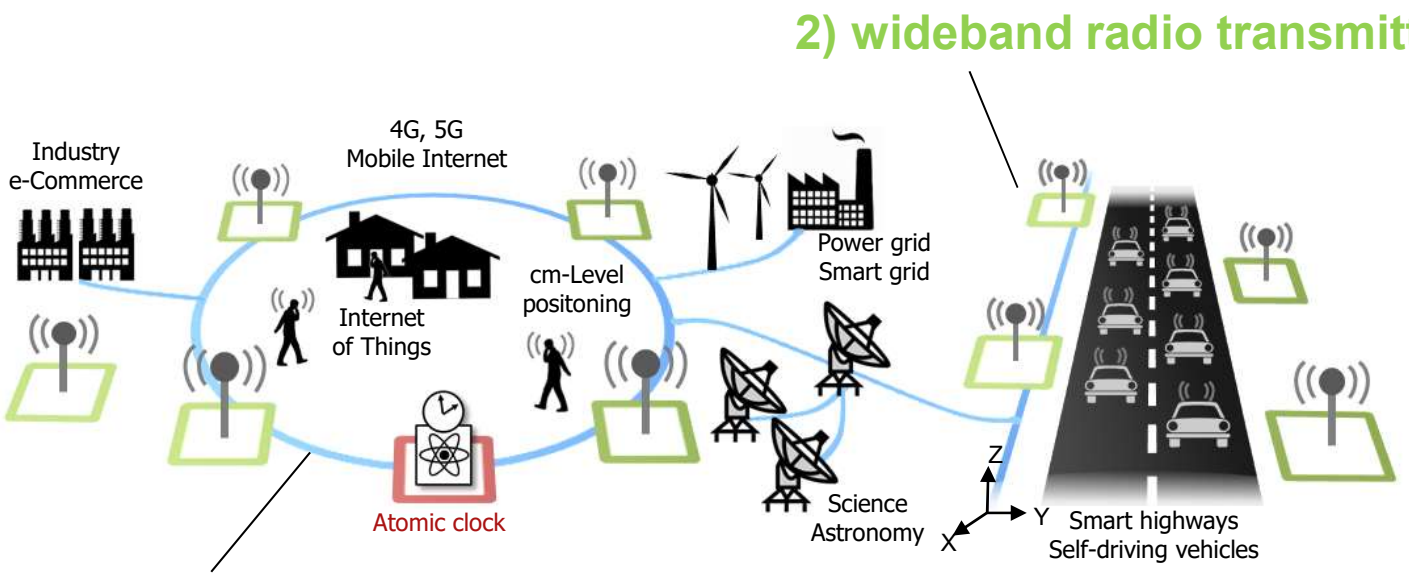
SuperGPS



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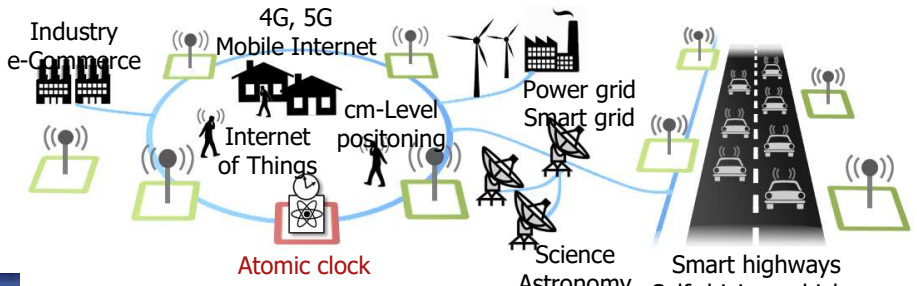


Cesium clocks
UTC(VSL)

VSL

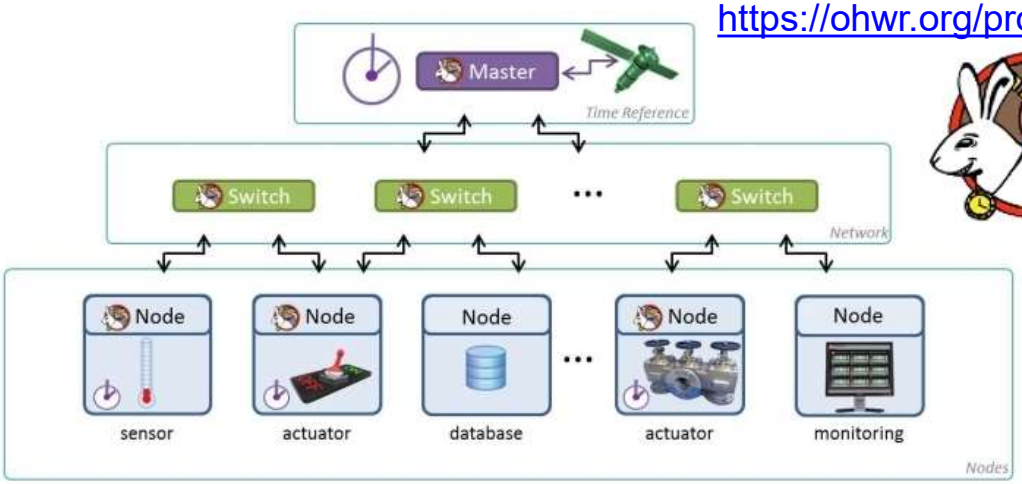
time & frequency distributed over optical-fibre

TU Delft

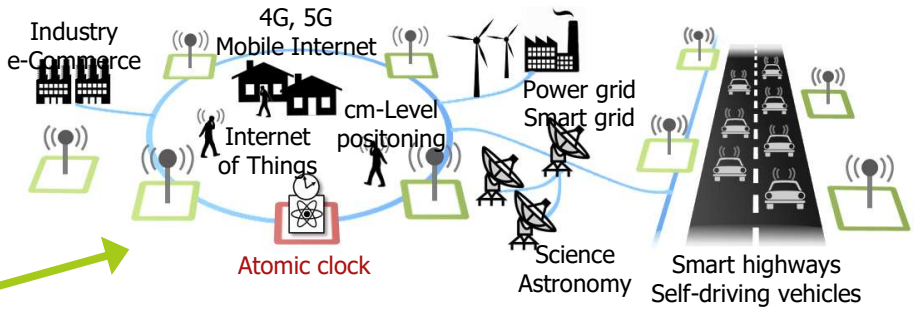
White Rabbit: time distribution

fully deterministic Ethernet-based network for general purpose data transfer and synchronization; it can synchronize over 1000 nodes with sub-ns accuracy over fiber lengths of up to 10 km

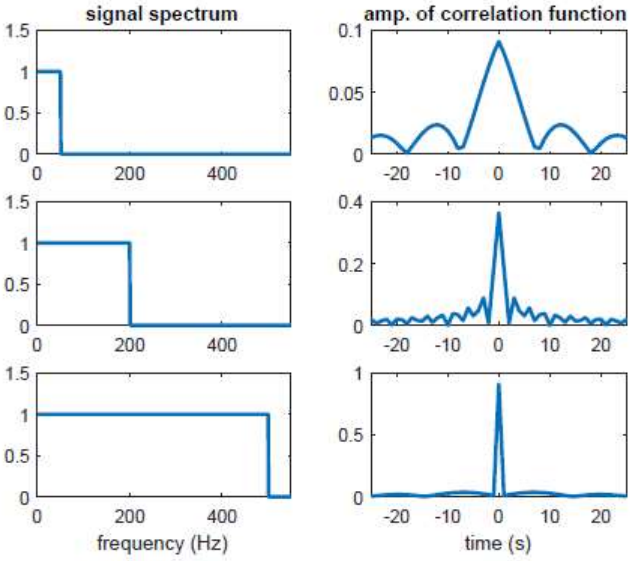
https://ohwr.org/project/white-rabbit/wikis/home



P. Moreira, J. Serrano, T. Wlostowski, P. Loschmidt and G. Gaderer,
"White rabbit: Sub-nanosecond timing distribution over Ethernet,“
2009 Intl Symp on Precision Clock Synchronization for Measurement, Control and Communication,
Brescia, 2009, pp. 1-5, doi: 10.1109/ISPCS.2009.5340196.



wideband radio transmitter



ranging using radio-signal:

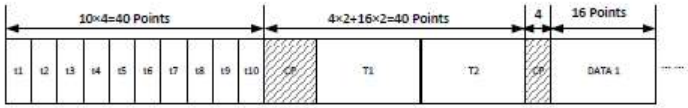
matched filter (correlate received signal with template)

→ time delay estimation

larger **signal bandwidth** → better time resolution

- **better precision**
- and **better multipath-immunity**

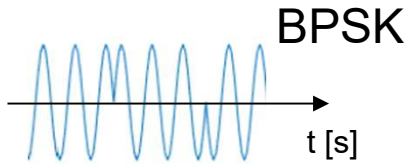
OFDM signal

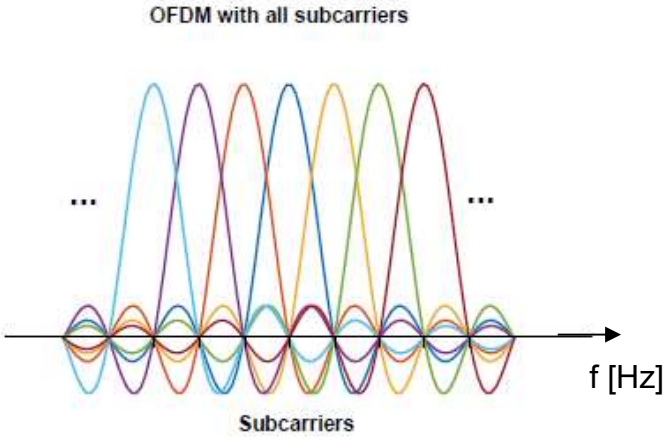


IEEE 802.11p OFDM frame structure

N = 64 sub-carriers (per band, e.g. 10 MHz)

known training symbol for ranging
(64 bits as 0/1 BPSK on subcarriers)



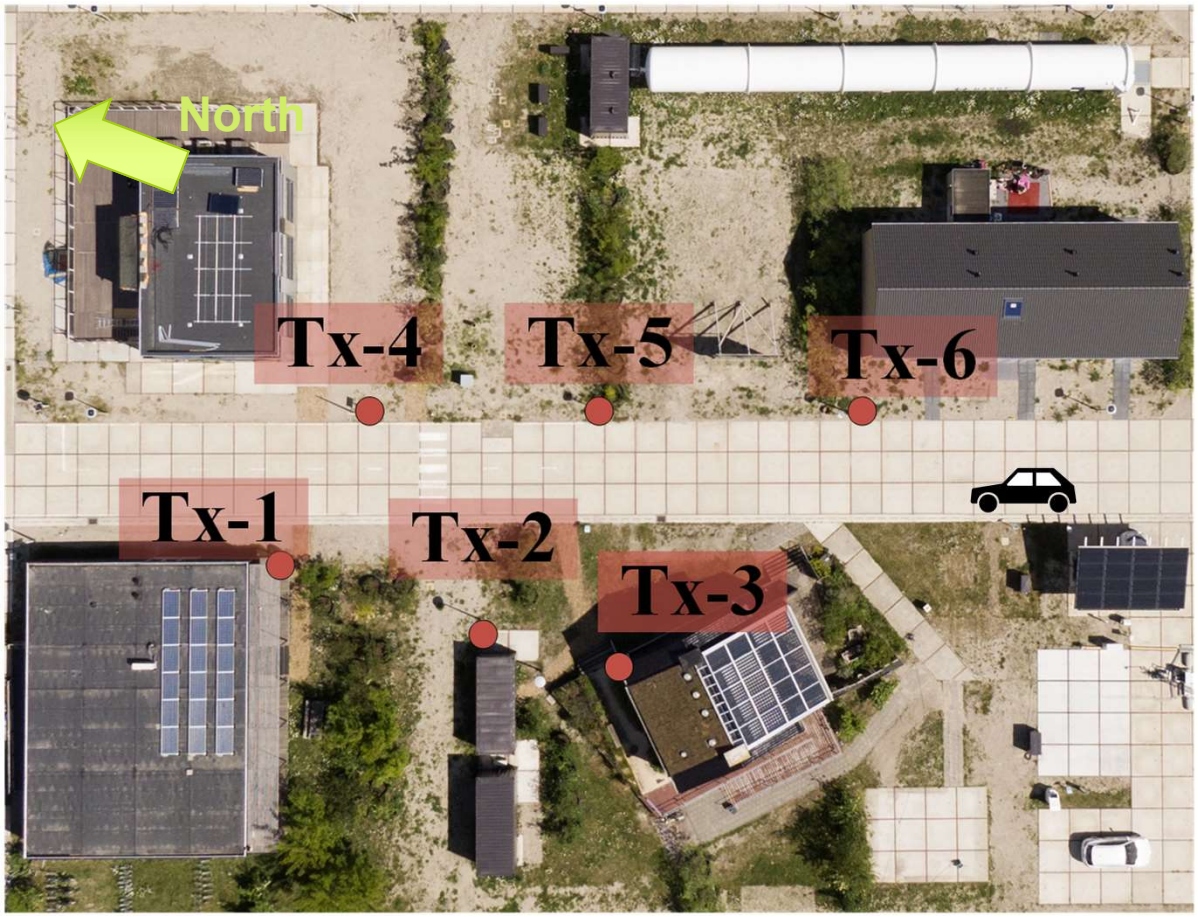


‘in each band actually 64 parallel GPS-like signals’

<u>SuperGPS-prototype:</u>
f_c = 3960 MHz
BW = 160 MHz

16 bands of 10 MHz each

experiment set-up



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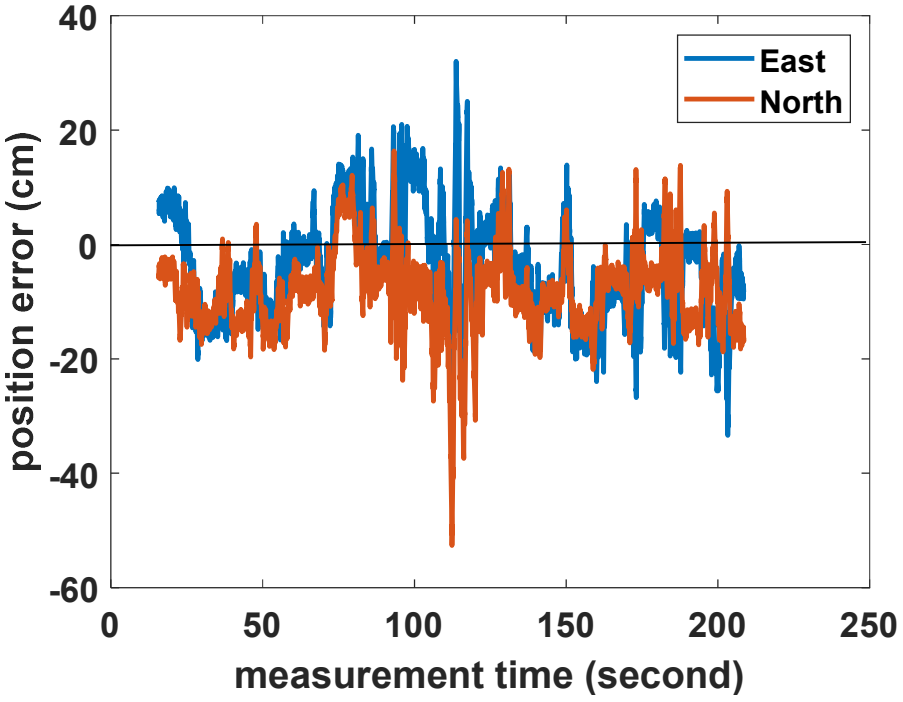
experiment set-up

experimental results: trolley

position error of Rx trajectory

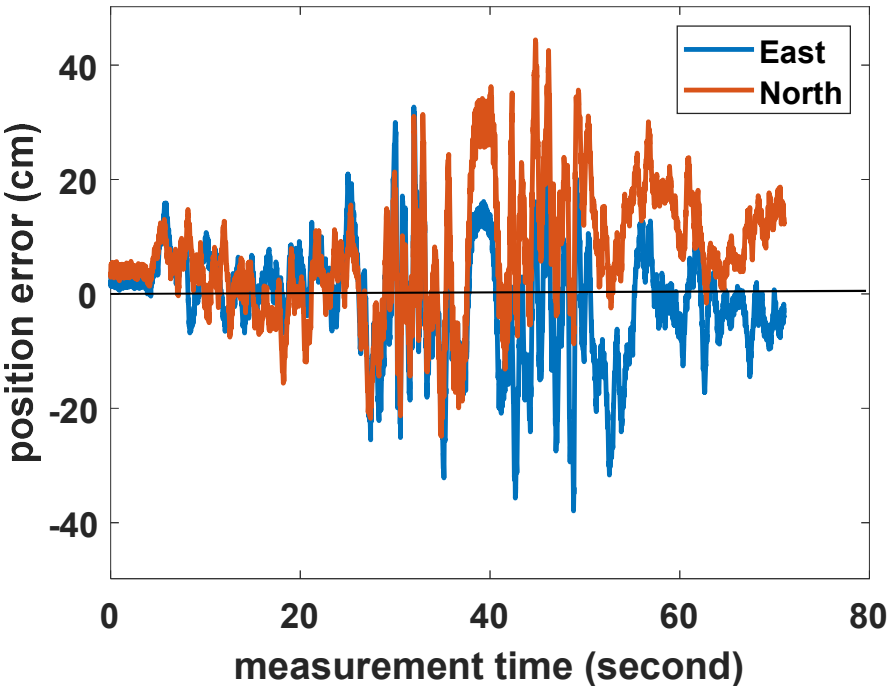


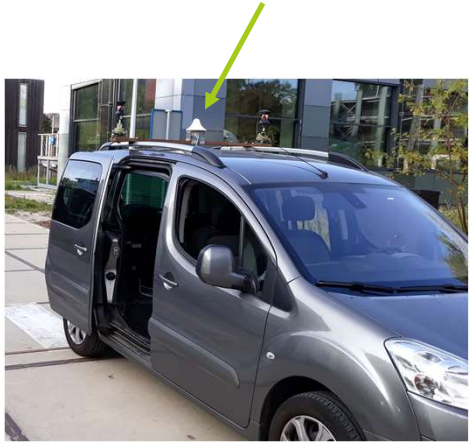
RMS

- East: 0.10 m
- North: 0.11 m

experimental results: car

position error of Rx trajectory





RMS

- East: 0.10 m
- North: 0.13 m

SuperGPS - team

Christian Tiberius received his PhD degree in 1998 from the Delft University of Technology (TU Delft), Delft, The Netherlands, on recursive data processing for kinematic GPS surveying. He is currently an Associate Professor with the Geoscience and Remote Sensing (GRS) department, Delft University of Technology. His research interest lies in navigation, primarily with GNSS and indoor radio positioning. He is, and has been responsible, for more than 15 years, for many projects in the area of navigation with national and international agencies, like ESA, and industry, as well.

Christian Tiberius

Gerard Janssen received an MSc degree from Eindhoven University of Technology in 1986, and a PhD degree from Delft University of Technology in 1998. In 1986, he joined FEL-TNO where he was involved in radar cross-section modeling, radio direction finding, interference cancellation and wideband propagation measurements. In 1992, he moved to TU Delft where he currently is an Associate Professor with the Circuits and Systems group. His research interests are in wireless communications, especially narrowband multiuser detection, digital modulation techniques, channel modeling, diversity techniques and Ultra-wideband communications and positioning.

Gerard Janssen

Cherif Diouf received a PhD degree in non-linear system modeling applied to VLSI electronic circuits in 2014 from the Université de Bretagne Occidentale (France). He then worked at the Ecole Nationale d'Ingénieurs of Brest on DSP techniques to optimize the performance of optical OFDM communication systems. In 2015, he joined the French Oceanographic institute (Ifremer). As a postdoctoral researcher, he worked on the development of a power-over-fiber prototype to allow extensions of a sea-bed observatory. Recently, he was working as an embedded systems engineer on autonomous floats. In 2018, he joined the SuperGPS research team as a postdoctoral researcher. He is interested in blackbox modeling and DSP techniques, HW/SW implementation and prototyping novel electro-optical systems.

Cherif Diouf

Tarik Kazaz received his MSc degree with honors in Electrical Engineering from the University of Sarajevo, in 2012. In 2013 he joined BH Mobile, where he was working as a Radio Access Network Engineer, while at the same time he was a part-time teaching assistant at the Faculty of Electrical Engineering, University of Sarajevo. Before joining the SuperGPS-project and his PhD studies at TUDelft, he was researcher at the department of Information Technology (INTEC) at Ghent University from January 2015 until March 2017. Within this department, he was also appointed at the iMinds and afterwards IMEC research institutes, where he was actively involved and contributed to the H2020 research projects WISHFUL and ORCA. His main research interests include signal processing for communications, wireless communications, software defined radio, cognitive radio and hardware-software co-design for wireless communications and future networks.

Tarik Kazaz

Han Dun received his BSc degree in Communication Engineering and MSc degree in Communication and Information Engineering from Shanghai University, China, in 2013 and 2016, respectively. From 2013 to 2016, he was also a member of the key laboratory of specialty fiber optics and optical access network at Shanghai University, where he has contributed to the real-time optical OFDM-PON. He is currently pursuing his PhD degree in the department of Geoscience and Remote Sensing, Delft University of Technology. His research interests include digital communication theory, wireless localization, and statistical signal processing.

Han Dun

Farnaz Chaman-Zadeh got her bachelor degree in Electrical Engineering from Shahid Chamran University in Iran. Having developed a passion for Telecommunication systems and Signal Processing, she pursued her education in Wireless communications and received her Master's degree from Lund University in Sweden. Before joining SuperGPS, she spent some time working in mobile industry as a RF Planner and Radio Access Network Engineer, where she was involved in a project on UMTS and LTE-FDD network re-design and modernization. She also contributed to LTE-TDD rollout projects. With a background in wireless systems, Farnaz conducts her research in SuperGPS on ranging and positioning exploiting already available radio signals. Her research interests include statistical signal processing, multi-carrier systems and radio based positioning.

Farnaz ChamanZadeh

Jeroen Koelemeij received his PhD in physics in 2004. He pursued a career in the measurement and distribution of time and frequency using lasers, atomic clocks and fiber-optic networks. After Postdoc positions at leading institutes in Europe and the USA, he returned to the LaserLaB institute of VU Amsterdam where he initiated the SuperGPS project, in close collaboration with Delft University of Technology. In 2014 Jeroen co-founded OPNT BV, a fast-growing provider of end-to-end synchronization solutions for fiber-optic network operators. In 2019, Jeroen returned to full-time academic research at VU Amsterdam, and remains involved in the project as a scientific advisor.

Jeroen Koelemeij

Chantal van Tour received her MSc-degree with honors in Applied Physics from Delft University of Technology in 2016. During her bachelor and master studies, she carried out several research projects under the supervision of Dr. Jeroen Koelemeij, concerning ultra-stable optical frequency transfer. In 2016 she joined the SuperGPS project as a full-time R&D engineer at OPNT BV. Her main research interest lies in increasing the accuracy and stability of time and frequency transfer over (fiber-optic) networks. In 2019 she left OPNT, and accepted a new position at De Haagse Hogeschool in Delft, as a lecturer in physics.

Chantal van Tour

Erik F. Dierikx was born in Aardenburg, The Netherlands, in 1972. He received the M.Sc. degree in electrical engineering from the University of Technology, Eindhoven, The Netherlands, in 1995, with a focus on low-frequency noise in quantum well lasers. In 1995, he joined the Electricity and Magnetism Section, VSL (Dutch metrology institute), Delft, The Netherlands, where he was specialized in low-frequency impedance measurements. Since 2006, he has been with the Time & Frequency Section, VSL, contributing to a delay calibration system for a two-way satellite time and frequency transfer station. Since 2012, he has been mainly working on time and frequency transfer through optical fibers. He is currently technically responsible for the activities at the Time & Frequency Section, VSL.

Erik Dierikx

and special thanks to Terence Theijn, Lolke Boonstra of TU Delft ICT-FM,
Rob Smets of SURF, Loek Colussi and Frank van Osselen of Agentschap Telecom,
René Tamboer and Tim Jonathan of The Green Village

SuperGPS → TNPS

- Thank you for your attention
- Questions?