Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Eidgenössisches Departement für Verteidigung,
Bevölkerungsschutz und Sport VBS
Bundesamt für Landestopografie swisstopo
Geodäsie und Eidgenössische Vermessungsdirektion

wissen wohin
savoir où
sapere dove
knowing where

swisstopo

Swisstopo Kolloquium
Positioning, Navigation, Timing (PNT)

Beginnt um 10:00 Uhr
Commence à 10h00

Hören Sie die Hintergrundmusik ?
Entendez-vous la musique de fond ?

©Zero Project,
Memories of the moon

Stellen Sie Ihre Fragen zu

Gehen Sie auf www.sli.do und geben Sie den Code **#463210** ein
oder
Scannen Sie den nebenstehenden **QR-Code**

1. Beantworten Sie die Fragen, die wir Ihnen stellen
2. Stellen Sie Ihre eigene Frage
3. Stimmen Sie für die interessantesten Fragen ab

slido

Posez vos questions sur

Allez sur www.sli.do et entrez le code **#463210**
ou
Scannez le QR-Code ci-contre

1. Répondez aux questions que nous vous posons
2. Posez votre propre question
3. Votez pour les questions les plus intéressantes

Umfrage / Sondage

Wie ist Ihre Beziehung zu PNT?

Quel est votre rapport au PNT?

Aller sur www.sli.do et
entrer le code **#463210**

Multiple-choice poll (Multiple answers)

Quel est votre rapport au PNT ? / Welche Beziehung haben Sie zu PNT ?

103

Utilisateur | Benutzer

88 %

Opérateur | Betreiber

12 %

Fabricant | Hersteller

3 %

Positioning, Navigation and Timing (PNT)

Equipe swisstopo: U. Wild, R. Rollier, R. Pott, S. Kaloustian

Invités: D. Staub et F. Gunnarsson (Swisscom/Ericsson)

M. Troller (Skyguide)

Stavros Melachroinos (Orolia)

Inhalt | Contenu

Einführung Introduction	Stéphane Kaloustian *swisstopo*
Positionning : Cellular Network enabled positioning – 5G, GNSS	Daniel Staub / Fredrik Gunnarsson (EN) *Swisscom/Ericsson*
Navigation : Navigation in aviation	Marc Troller (DE) *Skyguide*
Timing : Time we can trust	Stavros Melachroinos (FR) *Orolia*
Fazit - Was tut swisstopo? Conclusion – Que fait swisstopo?	Raphaël Rollier *swisstopo*
Fragen Questions	Alle

Begriffe
Concepts

Positionierung
Bestimmung einer Position und allenfalls Orientierung in einem räumlichen Bezugsrahmen mit einer bekannten Genauigkeit

Navigation
Bestimmung von aktueller und gewünschter Position und Orientierung, Anbringen von Korrekturen an Kurs und Geschwindigkeit zur Erreichung einer Destination

Timing
Synchronisation von Uhren bezüglich einer Standardzeit (zum Beispiel UTC) mit einer bekannten Genauigkeit

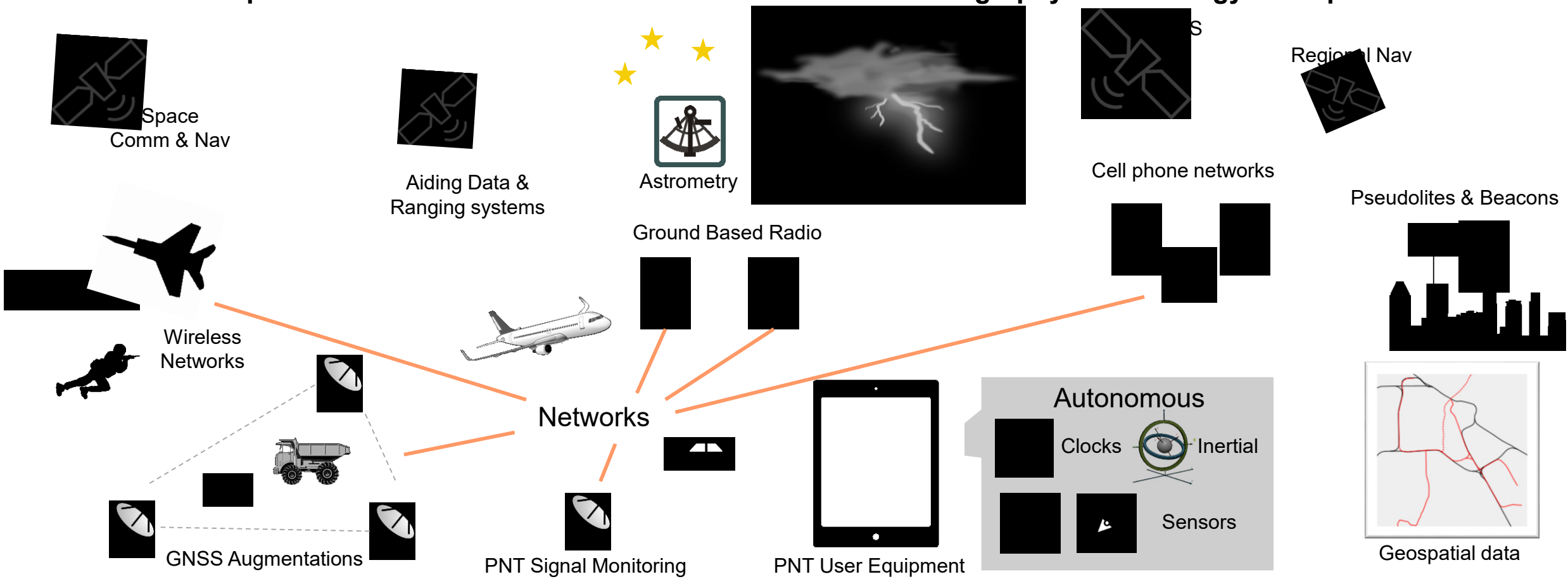
Positionnement
Détermination de sa position et, le cas échéant, de son orientation dans un référentiel spatial avec une précision connue

Navigation
Détermination de position et orientation courantes ainsi que d'une position cible. Application de corrections de cap et de vitesse pour atteindre la destination

Timing
Synchronisation d'horloges par rapport à un temps standard (par ex. UTC) avec une précision connue

PNT Landschaft | Le paysage des PNT

Spectrum – Environment – Interference – Weather – Demography – Technology – Geopolitics

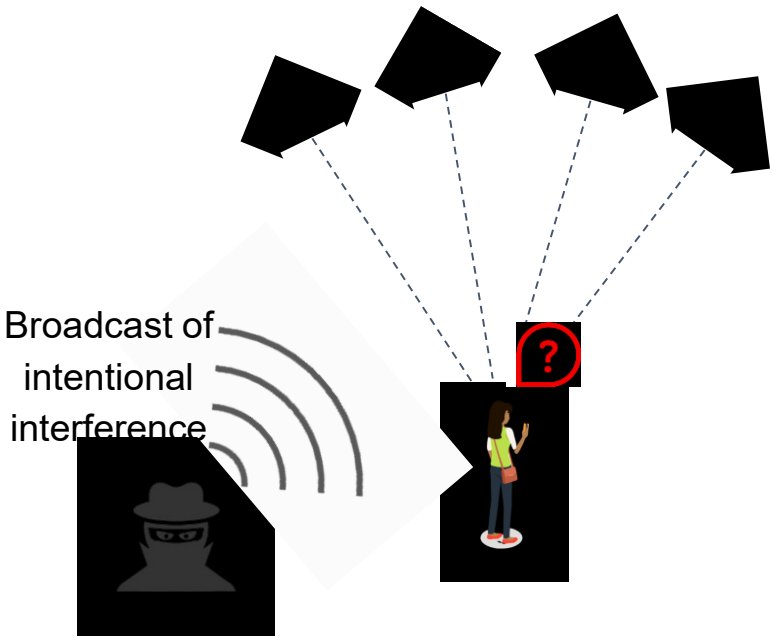


ENABLERS & INFRASTRUCTURE: Standards – Reference Frames – Crypto – Science & Tech – Star catalogs – Industry – Modeling – Mapping – Geodesy – Laser Ranging Network – Electro-optical Info – Policies – Testing

GNSS Verwundbarkeiten
Vulnérabilités des GNSS

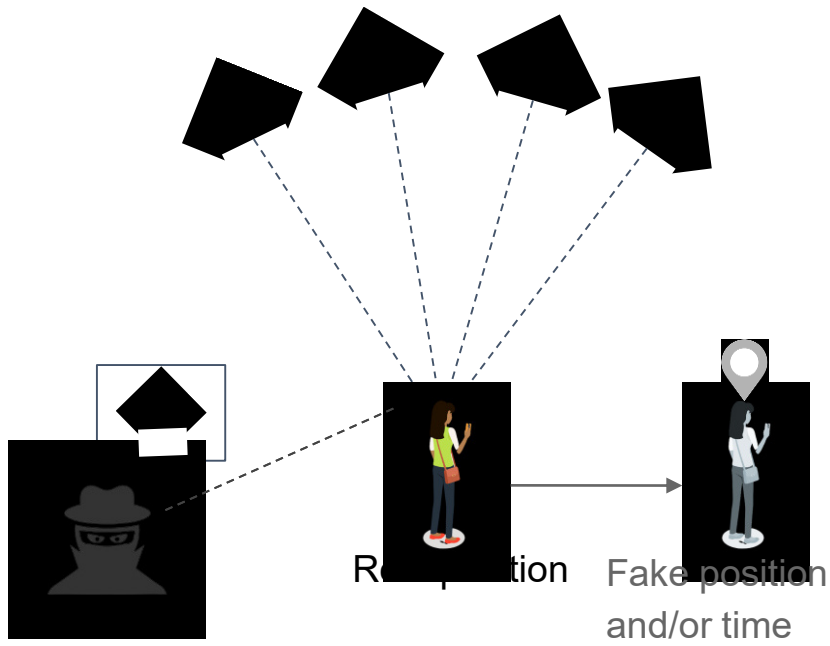
Jamming

GNSS signals' power is low...



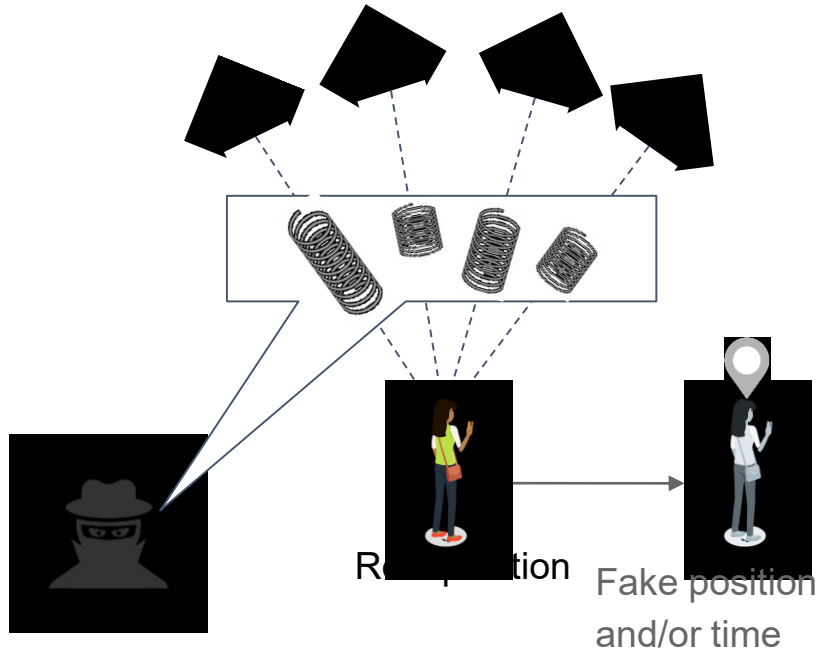
Spoofing

GNSS *civilian* signals are neither encrypted nor authenticated, and the specifications are publicly available



Meaconing

Even encrypted signals can be repeated with delay



Kritische Infrastrukturen
Infrastructures critiques

PNT services contribute to approximately 10% of the European GDP

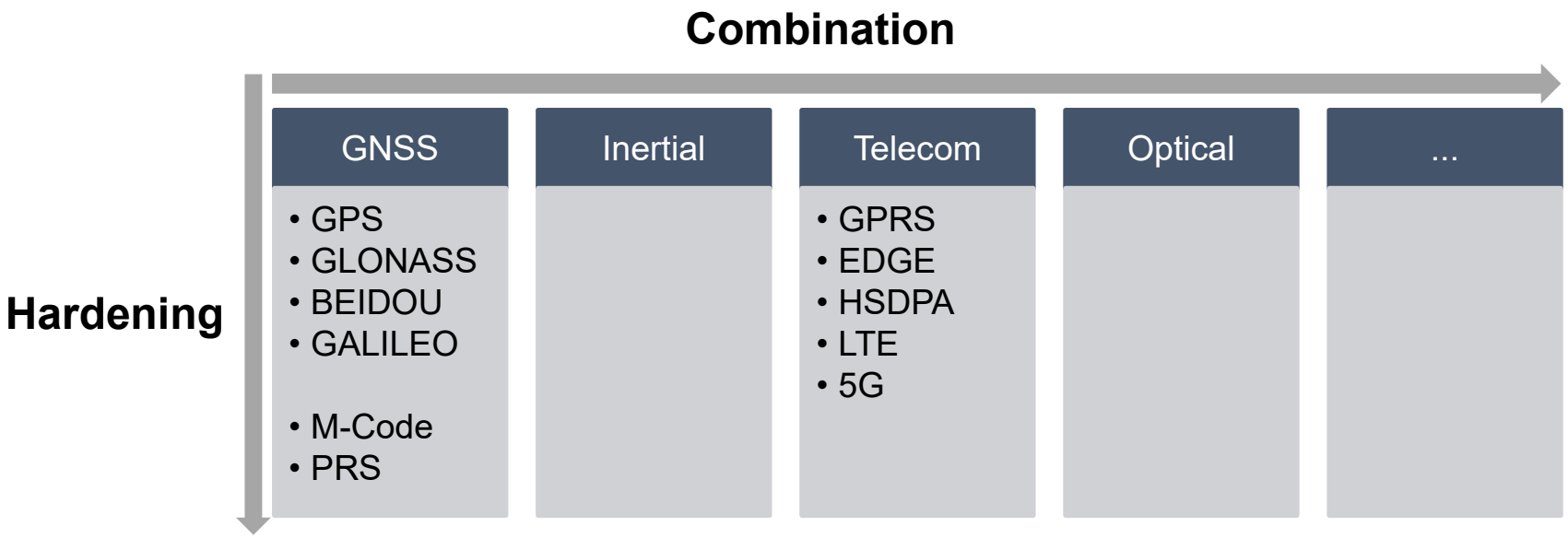
GNSS is the back-bone of PNT services as well as hidden utility in many sectors. Its central role will only increase in the future

There is a need for the alternative PNT capacity, without a common mode of failure with GNSS.

source: webinar the Alternative Position, Navigation and Timing (PNT) Services tender https://etendering.ted.europa.eu/document/document-old-versions.html?docId=79819

Resilienz
Résilience

Resilient PNT is the convergence of positioning, navigation and timing technology with non-traditional and emerging technology to improve the reliability, performance and safety of mission-critical applications in the air, on land, in the sea, and in space.



Umfrage / Sondage

Wie ist Ihre Beziehung zu PNT?

Quel est votre rapport au PNT?

Aller sur www.sli.do et
entrer le code **#463210**

Positioning

D. Staub et F. Gunnarsson (Swisscom/Ericsson)

Cellular network enabled positioning
- 5G, GNSS

Daniel Staub, Swisscom

Fredrik Gunnarsson, Ericsson Research

Swisstopo PNT Colloquium

Superior customer experience

PC Magazin Mobilfunk-Netztest TESTSIEGER Ausgabe 11/2018

connect TESTSIEGER Swisscom Mobilfunknetztest Heft 3/2019 www.connect.de/netztest

SWITZERLAND'S BEST NETWORK

CHIP Test Winner

SPEEDTEST AWARDS by OOKLA 2018

connect ÜBERRAGEND Swisscom Mobilfunknetztest Heft 3/2019 www.connect.de/netztest

cnlab

BESTES NETZ SYSTEMICS PAB Network Quality Experts NOVEMBER 2017

SWISSCOM PLATZ 1 SERVICE TELEKOM PCtipp

OpenSignal

2021: Swisscom became the world leader in best mobile network

Swisscom-Ericsson strategic partnership

Bringing 5G Driven co-creation to Swiss enterprise

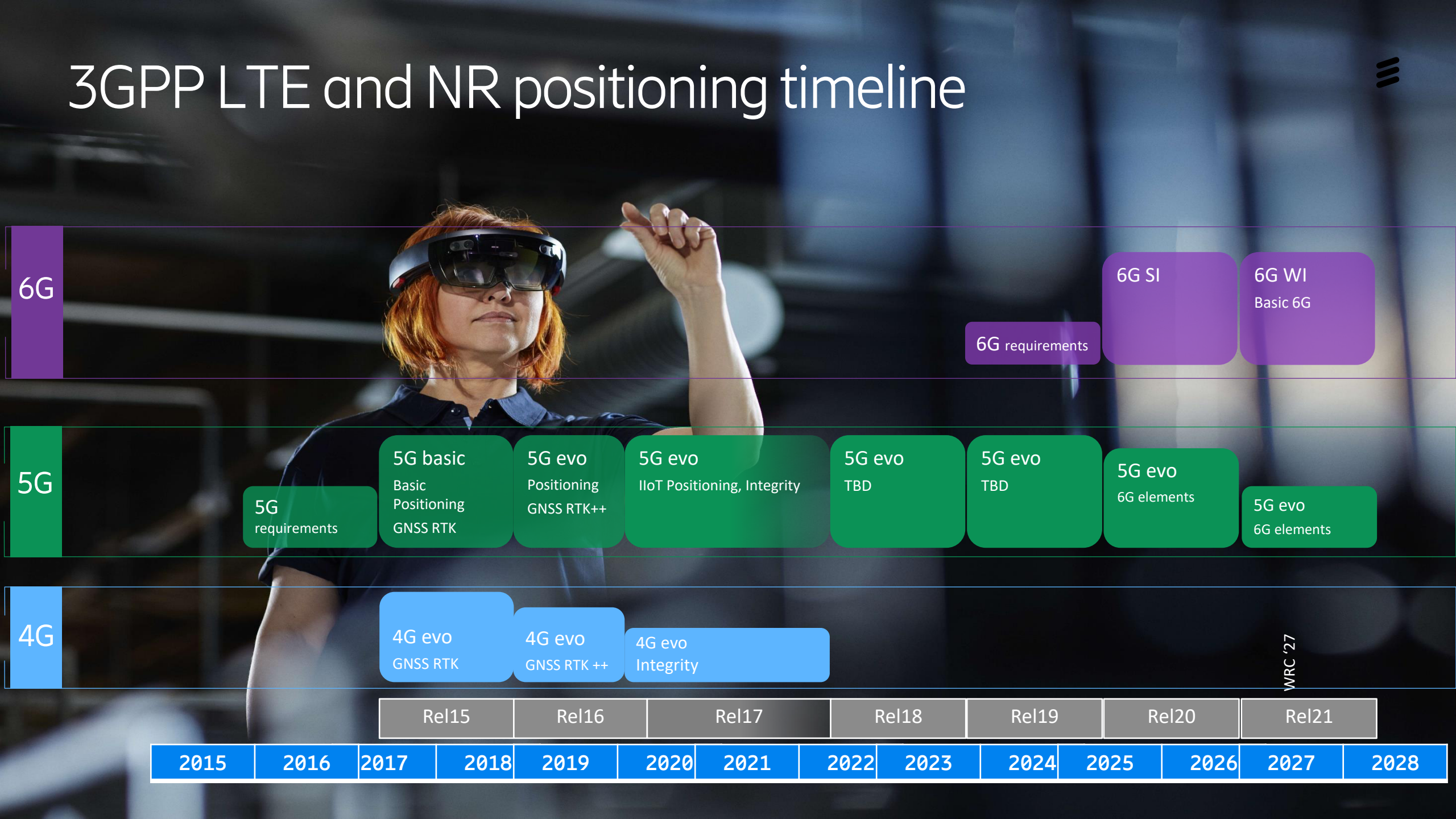
Digitalization of the physical world

- Storage & Representation
- Platform, (inter-)system management
- Trustworthiness, Identifiers
- AI, predictions, insights, planning

- Orchestration
- Actuation
- (Re)programming

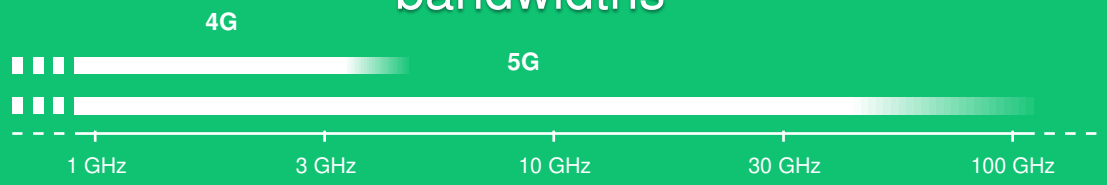
- Sensing
- Position, Time
- Learnings

3GPP LTE and NR positioning timeline

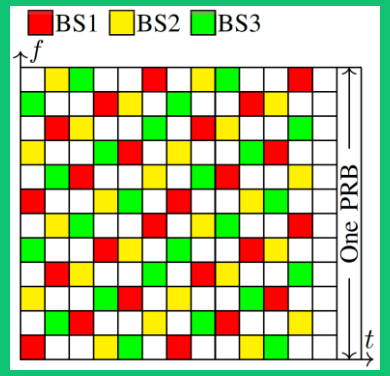


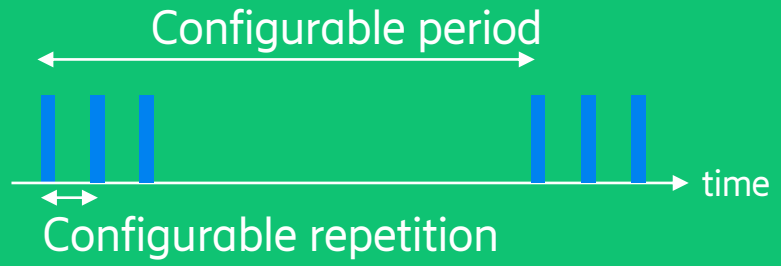
3GPP 5G positioning toolbox

Extension to higher frequencies & wider bandwidths



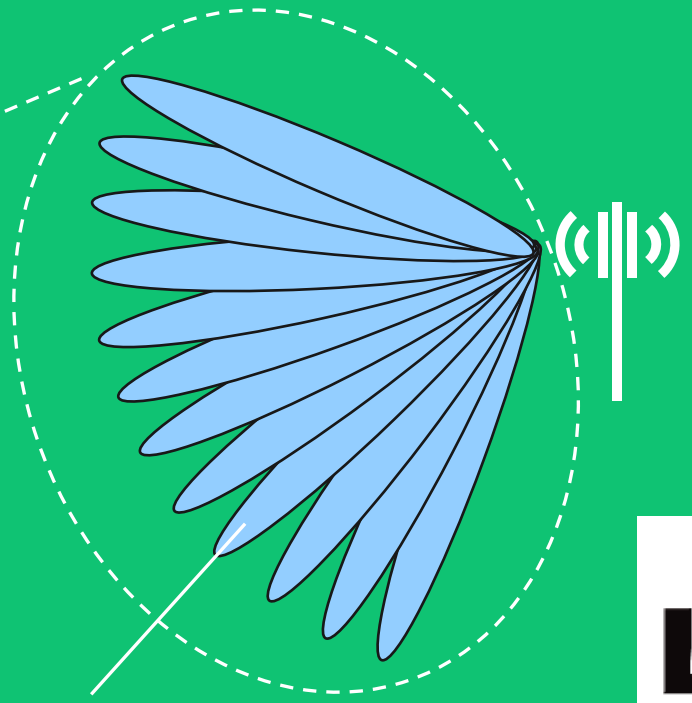
DL/UL signals designed for accurate measurements and low latency





Multiple antennas and advanced beamforming

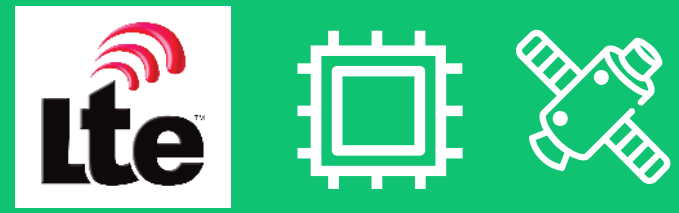
Resource Set



Resource

Flexible Network Architecture

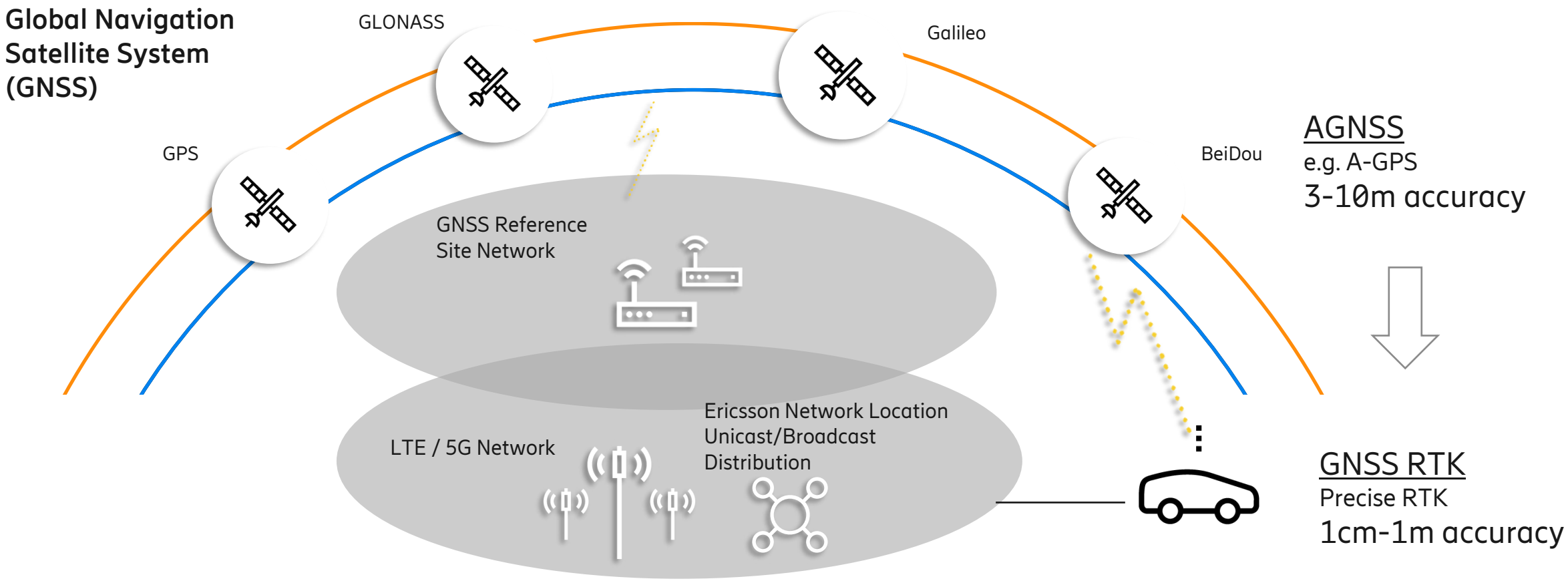
Hybridization and hardware



Satellite: Outdoor Precise Positioning

Affordable sub-meter localization accuracy for vehicles, IoT devices and next gen smartphones

GNSS RTK precise corrections + 3GPP LPP distribution + Device sensor fusion = Massive scale sub-meter positioning



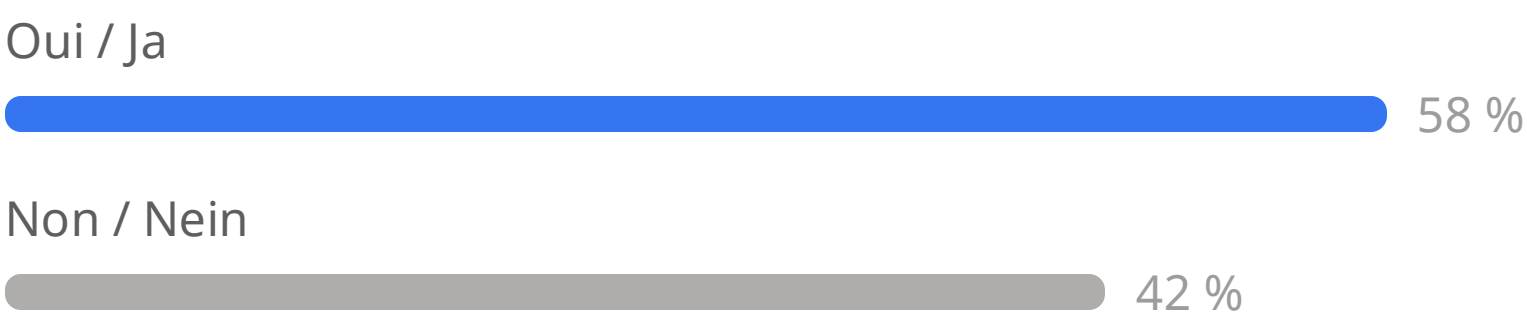
Ericsson Network Location

Full stack technology ambition

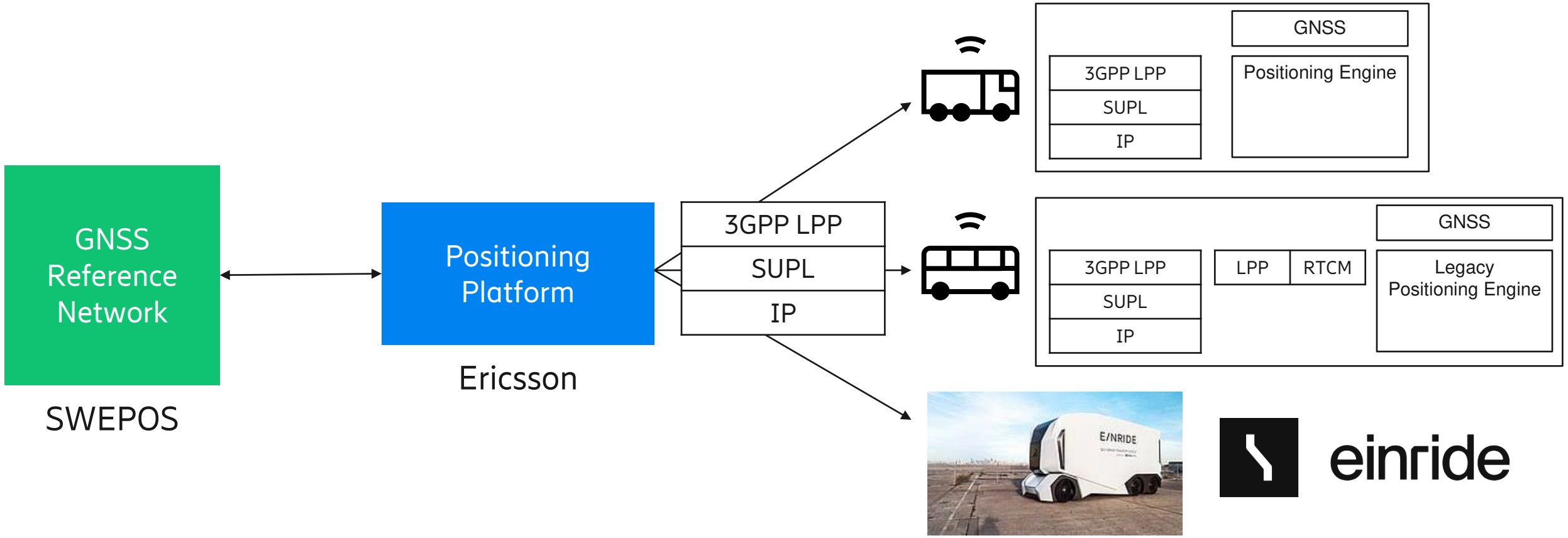
slido www.sli.do #463210.

Saviez-vous qu'avec la technologie 5G, un service de positionnement sera possible ? / Wussten Sie, dass mit dem 5G-Technologie ein Ortungsdienst möglich sein könnte?

103



Network-RTK Positioning for Autonomous Driving
Swedish national research/evaluation project



SWEPOS – GNSS RTK service from Swedish Geodesy Authorities, similar to SWIPOS

Example use case of hybrid positioning

- 3GPP-based GNSS RTK with integrity for drone navigation and UTM
- 5G positioning to provide network validation of provided drone positions
- 5G positioning in street canyons and obstructed sky environments
- Crowd sourced information for 3D coverage and population location for mission planning

Navigation

M. Troller (Skyguide)

Marc Troller
PNT colloquium swisstopo 14.01.2022

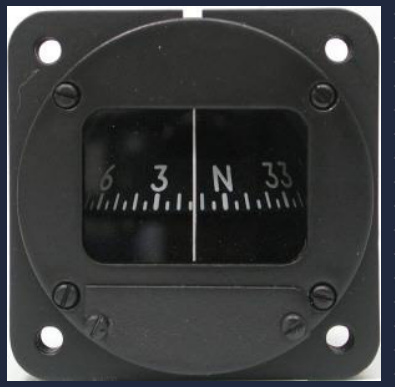
skyguide

Navigation (in aviation)

Historical Navigation

skyguide

VFR
Visual Flight Rules

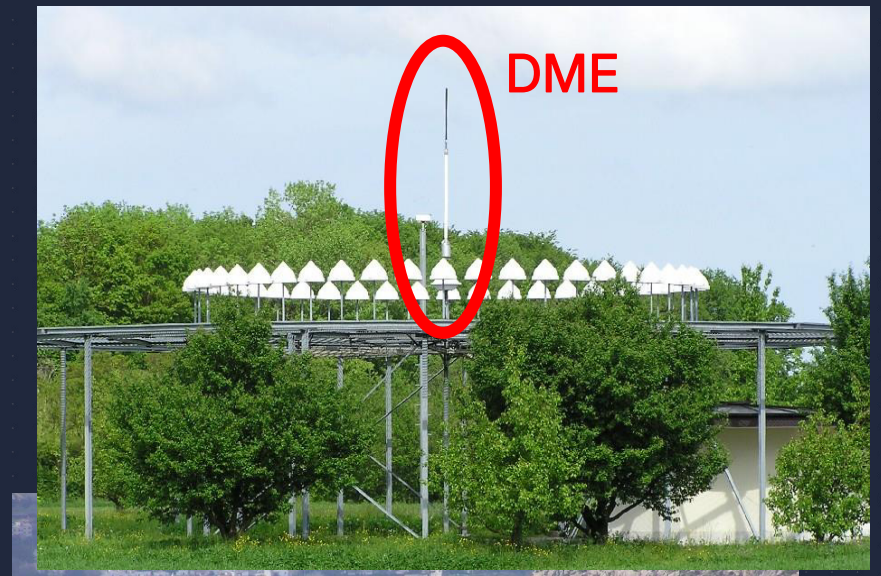


IFR
Instrument Flight Rules

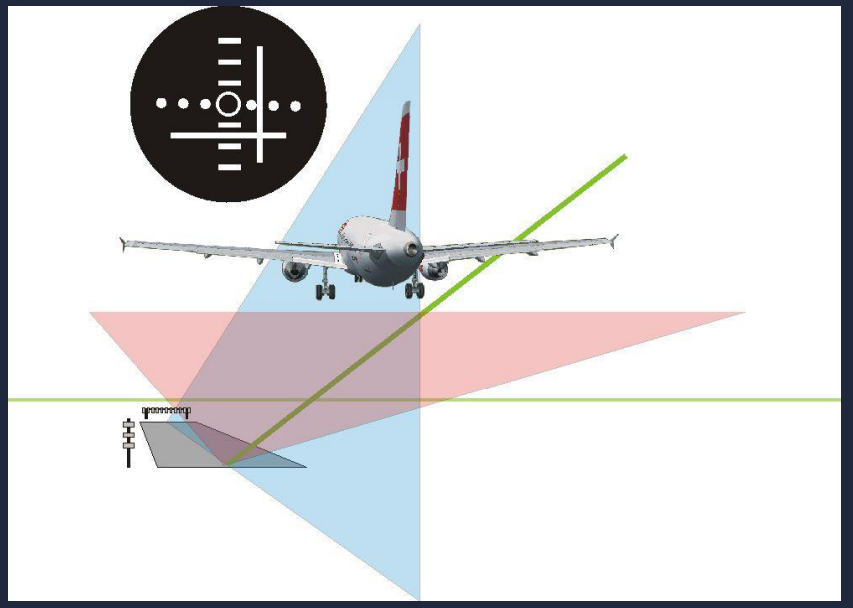
Radio Navigation – partly being decommissioned

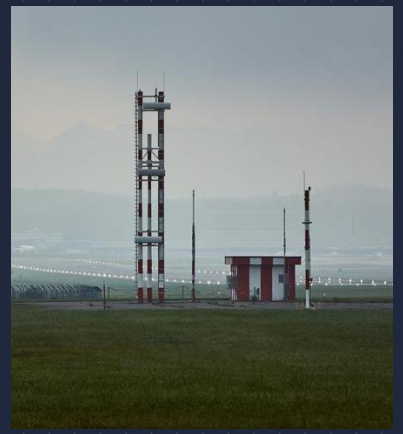
skyguide

NDB
non directional
beacon



VOR/DME
VHF omnidirectional range
distance measuring equipment





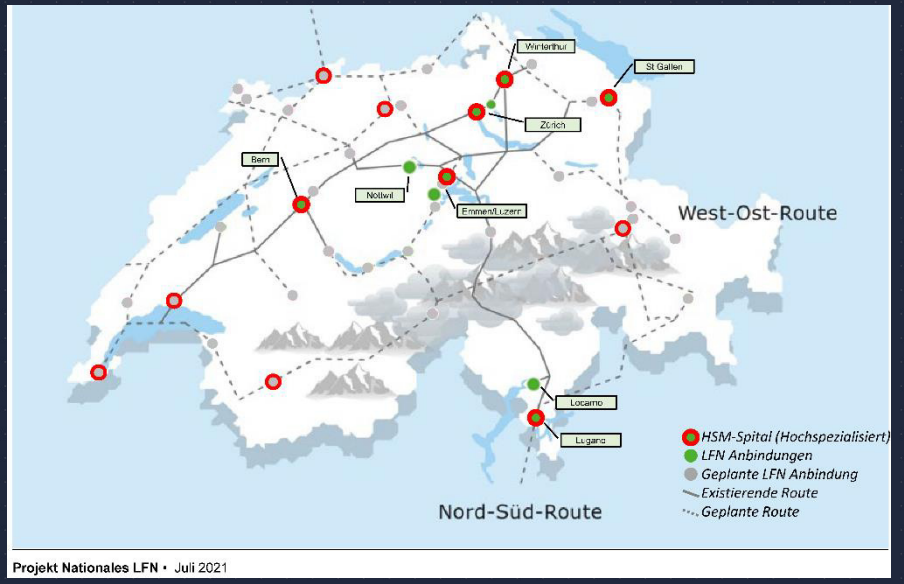
ILS
instrument landing system

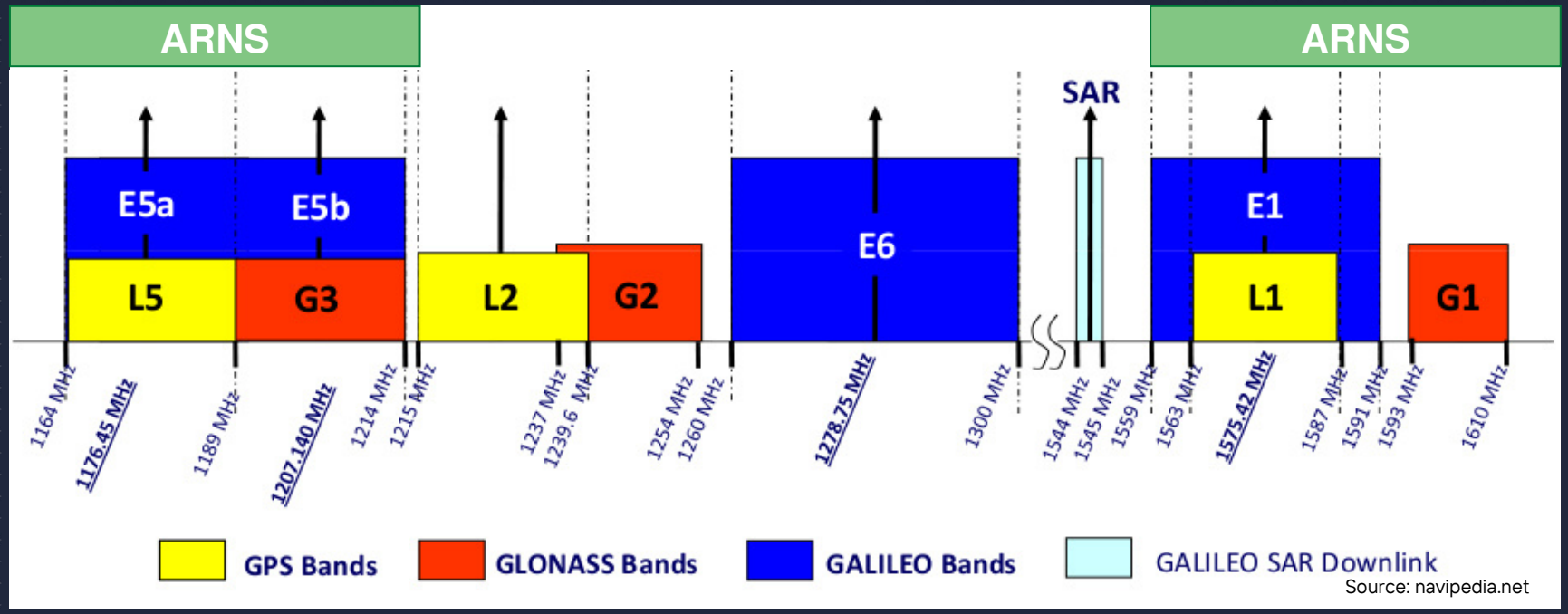
Questions/comments? Go to www.sli.do and enter the code #463210

Satellite-Based Navigation

Advantages

- One system for all phases of flight
- Worldwide availability
- High accuracy
- Globally interoperable
- More direct / environmental-friendly routes
- New developments possible(e.g. Swiss helicopter low flight network)





ARNS: Aeronautical Radio Navigation Services

according the International Telecommunication Union´s (ITU) defined as «*A radio navigation service intended for the benefit and for the safe operation of aircraft*»

Today: Limited to GPS L1 C/A according GPS Standard Position Service Performance Standard

Disadvantages Satellite-Based Navigation

What do you consider as the biggest issue / disadvantage using GNSS for navigation ?

Please answer through www.sli.do

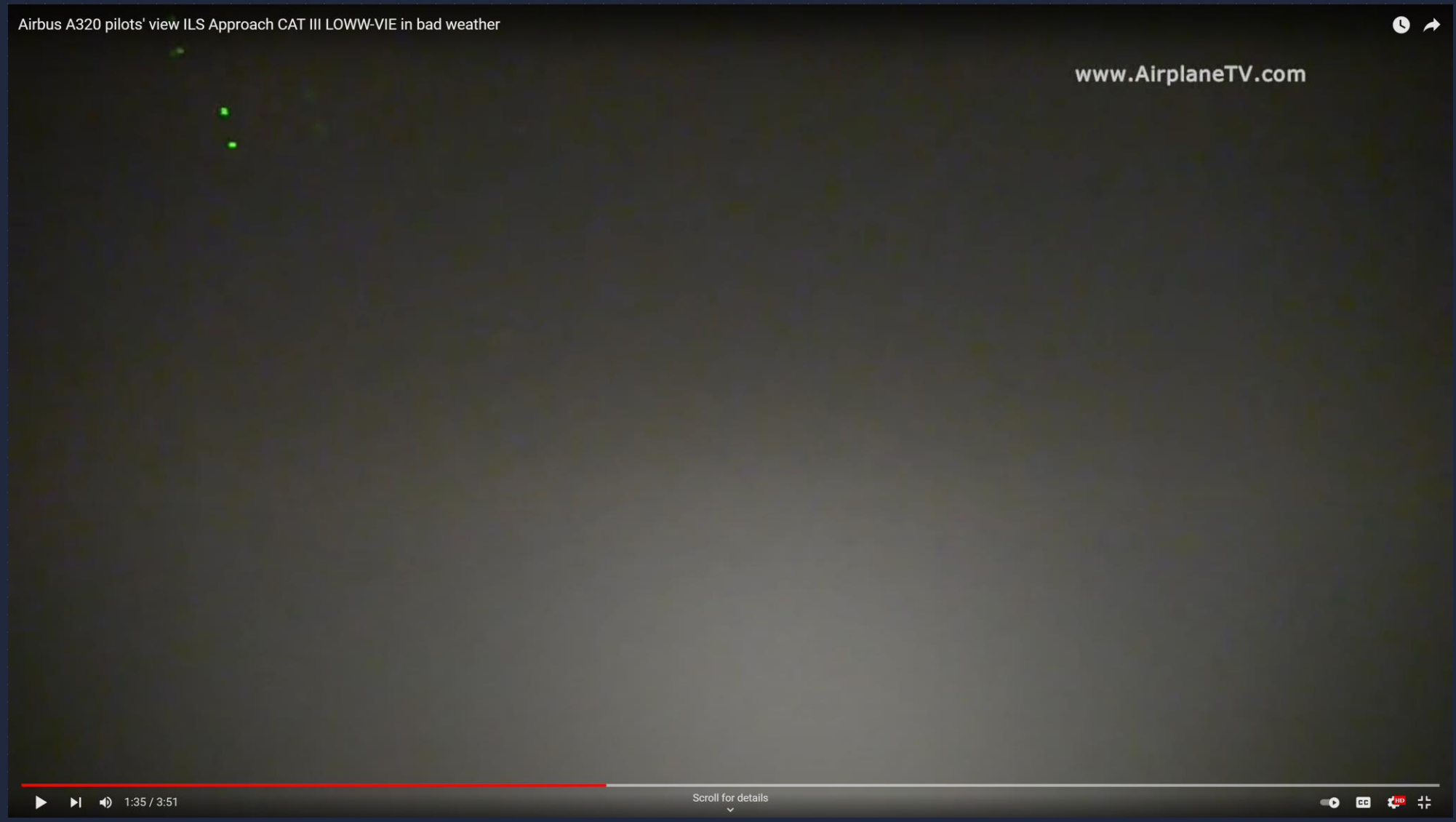
entering the code #463210 or use the QR code

Wordcloud poll

Quel est, selon vous, le principal problème ou inconvénient de l'utilisation du GNSS pour la navigation ? / Was ist Ihrer Meinung nach das größte Problem bzw. der größte Nachteil bei der Verwendung von GNSS für die Navigation?

056

Example: Approach in Clouds



Airbus A320 pilots' view ILS Approach CAT III LOWW-VIE in bad weather - YouTube

Satellite-Based Navigation

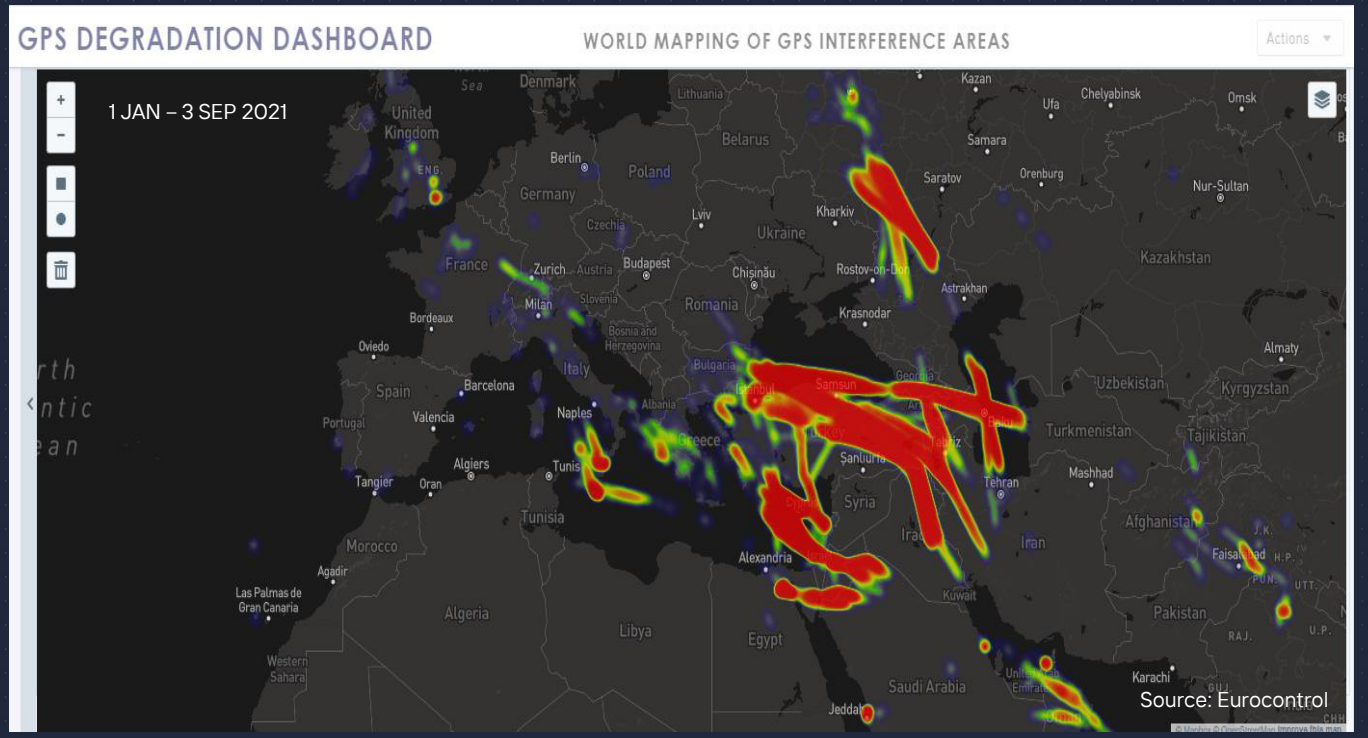
skyguide

Disadvantages

Robustness

- Risk of GPS constellation issue
- Risk of GPS satellite issue
- Risk of ionospheric issue
- Risk of RFI (radio frequency interference)
  - Unintentional interference
  - Intentional interference (jamming, spoofing)

- GNSS not only used for navigation but also for other applications such as surveillance, timing systems



Aviation Requirements

Example for approaches (standardized by the International Civil Aviation Organisation):

- Accuracy
  - horizontal 95 % (2σ): 16 m
  - vertical 95 % (2σ): 4 m
- Service availability: 99 % - 99.999 % (0.9 seconds of service interruption per day)
- Integrity (correctness of information): $1 - 2 \times 10^{-7}$ (1 event per 5 Mio. approaches)

Satellite-Based Augmentation Systems

skyguide

Receiver autonomous integrity monitoring (RAIM)

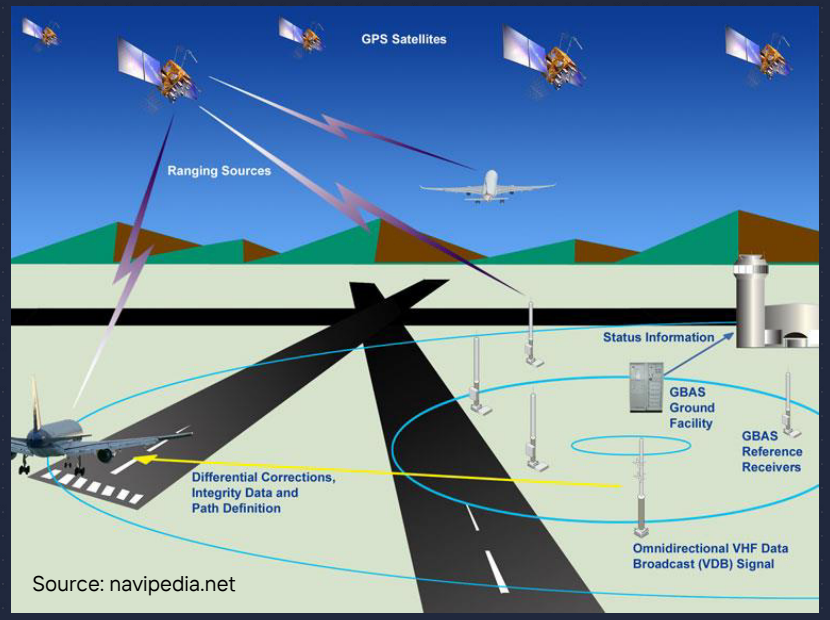
- Use of > 4 GPS satellite information (over-determined system)
- Estimation of performance
- Only lateral navigation (not for vertical navigation)

Satellite-based augmentation system (SBAS)

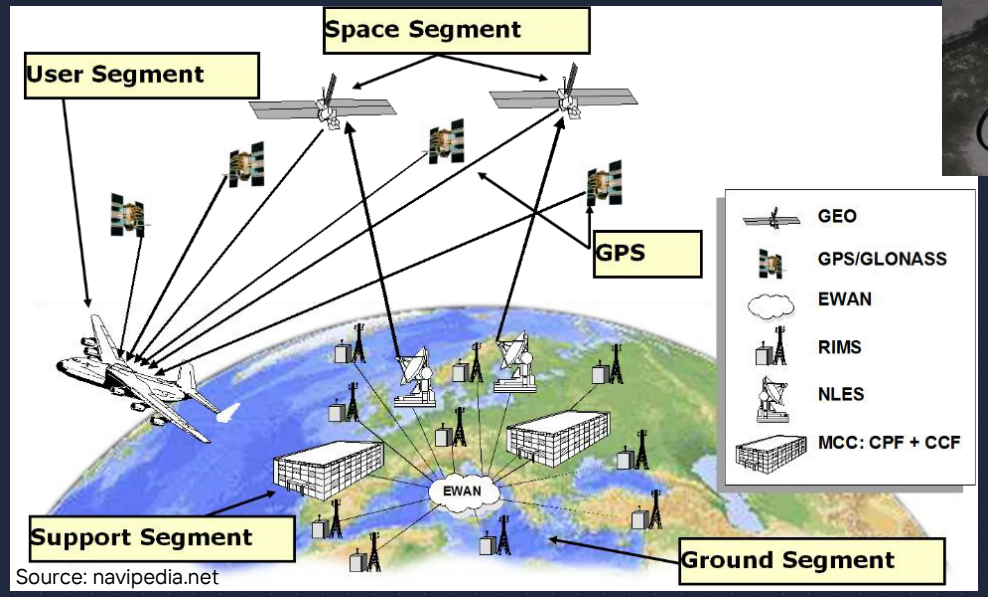
- DGPS principle (GPS L1 C/A)
- EGNOS (European Geostationary navigation overlay service)
- Upgrade to include GPS L5 and GALILEO in progress
- Skyguide is operating one RIMS (ranging and integrity monitoring station)

Ground-based augmentation system (GBAS)

- DGPS principle (GPS L1 C/A)



Source: navipedia.net



Source: navipedia.net

Questions/comments? Go to www.sli.do and enter the code #463210

Requirements for Using Satellite-Based Navigation

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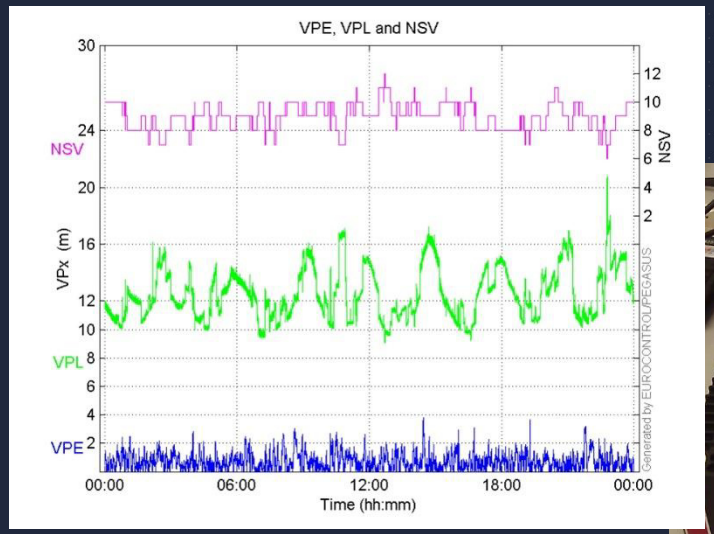
GNSS Performance Monitoring

- Operation of aviation receivers
- Continuous monitoring GPS, EGNOS and GBAS performance
- Detection of performance degradation



GNSS Unavailability Prediction

- Operational service with DFS (Deutsche Flugsicherung) and ESSP (European Satellite Service Provider)
- Daily forecast of GNSS performance
- Information distribution to pilots via NOTAM (notice to airmen)

(A0328/21 NOTAMN
Q) LSAS/QGAAU/I/NBO/A/000/999/4727N00833E005
A) LSZH B) 2106120738 C) 2106140735
D) 12 0738-0743 13 0734-0739 14 0729-0735
E) GPS RAIM IS NOT AVAILABLE FOR LNAV AND LNAV/VNAV.)

RF (radio frequency) Assessments

- Monitoring of spectrum to detect intentional / unintentional jamming

GNSS Legal Recording

- Realized through the AGNES network (swisstopo)
- To carry out post-incident/accident assessments

Future Navigation Setup in Aviation

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Primary means of navigation: GNSS

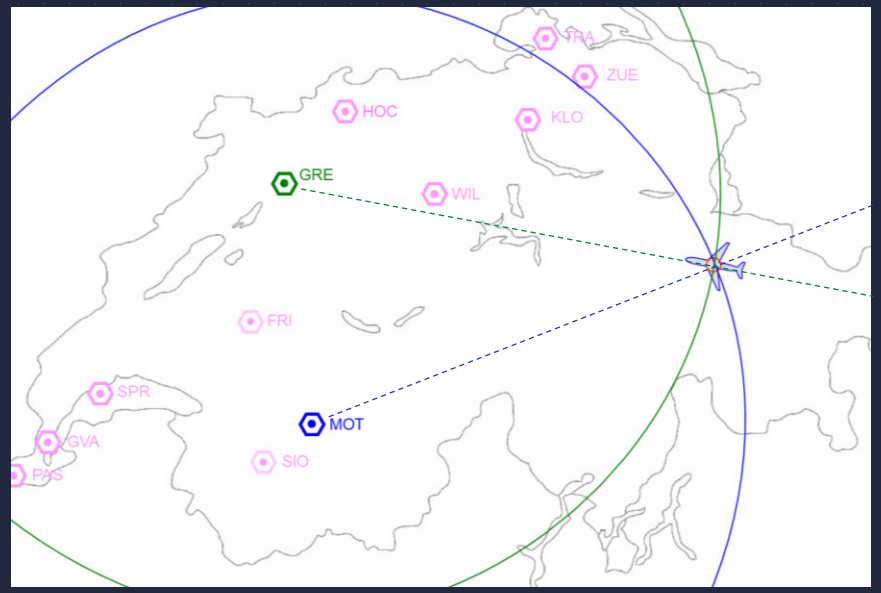
- Augmented with RAIM, EGNOS or GBAS
- Use of GPS L5 and GALILEO

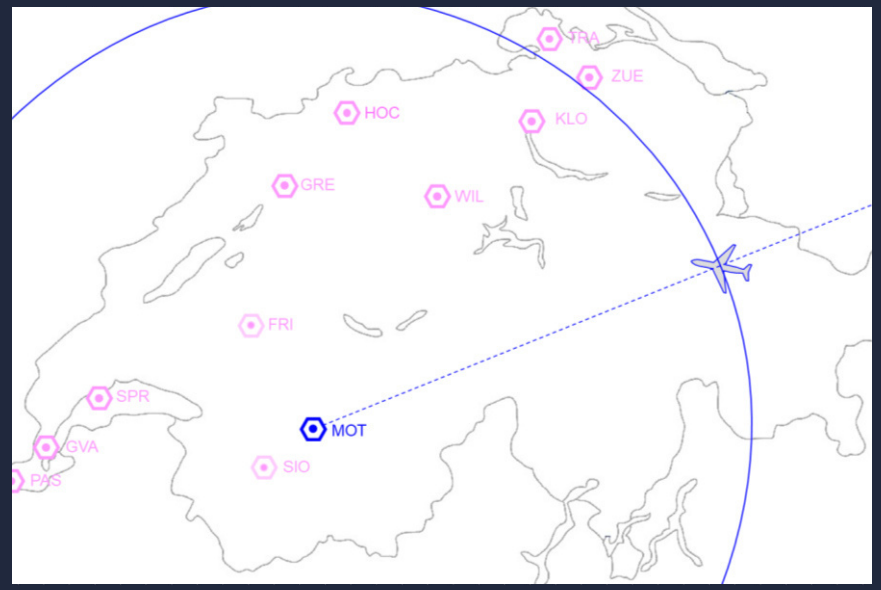
Secondary means of navigation: DME/DME and ILS

- Same operational performance for most aircraft

Alternate means of navigation: VOR/DME

- Limited coverage, for aircraft not equipped with DME/DME





Expectation towards the Federal State

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(to continue) cooperation with European Union space programme (FEDRO / SERI)

- allows the use of EGNOS and in the future GALILEO

(to continue) operation of automated GNSS network AGNES (swisstopo)

- allows to have data recordings for incident / accident assessment in all regions of Switzerland
- provides access to the international coordinate system

(to continue) safeguarding of aviation spectrum (OFCOM)

- allow the safe provision of air navigation services using primary and alternate means of navigation

monitoring and troubleshooting of RFI (radio frequency interferences), e.g. jamming (OFCOM / swisstopo?)

- troubleshooting managed by OFCOM
- no continuous spectrum monitoring so far

skyguide

Thank you for your attention

Timing

Stavros Melachroinos (Orolia)

TIME YOU CAN TRUST

DR. STAVROS MELACHROINOS
PNT COLLOQUIUM SWISSTOPO

LEADERSHIP POSITIONS IN RESILIENT PNT

In today's world, GNSS signals are not always available or accurate. Orolia makes these signals virtually fail-safe for critical applications in defense and commercial industries worldwide.

With robust, accurate GNSS-based systems and proven technologies, Orolia is the world leader in Resilient Positioning, Navigation and Timing (PNT) solutions.

#1 for Space
Atomic Clocks

#2 for Timing and
Synchronization

#2 for PNT
Test & Simulation

#2 for Emergency Location
Beacons

Time and Location You Can Trust™

orolia

PRESENCE IN 100 COUNTRIES
9 CORE FACILITIES +

PNT vulnerabilities

ABOUT GNSS

GPS

- Since 1980s
- 31 sats
- GPS III Launch Dec 2018

GLONASS

- Refurb 2012
- Operating well with 24 sats

Galileo

- 18 of 24 sats operational since 2016
- Full capability 2020

Beidou

- Regional initially building out to full global coverage by 2020

Regional Systems

Japan - QZSS

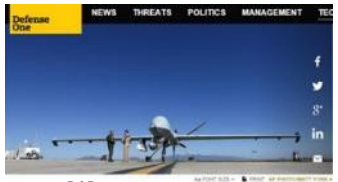
India - NAVIC

GNSS are great as they provide the necessary PNT accuracy and coverage but…

Les GNSS sont excellents car ils fournissent la précision et la couverture PNT nécessaires, mais…

SPECIFIC THREATS IMPACT GNSS

DEC 2015 - USA-MEXICO

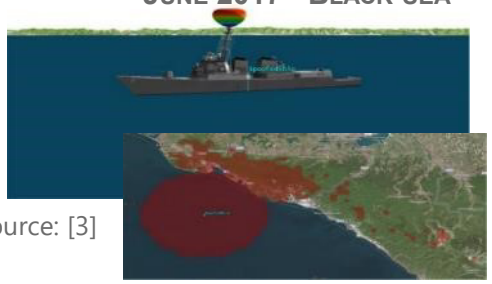


Source: [1] DHS: Drug Traffickers Are Spoofing Border Drones

DEC 2019 - CHINA

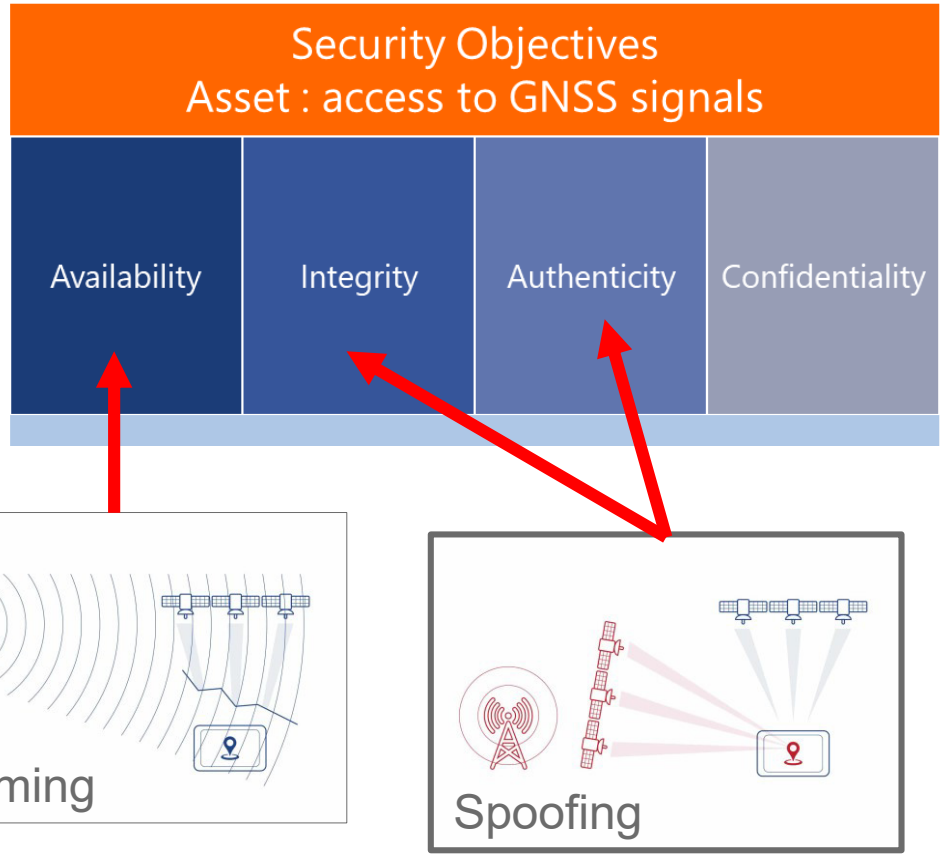
Source: [2]

JUNE 2017 - BLACK SEA



Source: [3]

APR 2019 – GENEVA MOTOR SHOW [4]



GEARS

Aiming to increase robustness and resilience of timing and synchronization (T&S) services for energy, finance and communication networks but also for transport and other governmental applications [5]

European Global Navigation Satellite Systems Agency

STRIKE3

HORIZON 2020

RF Interference (RFI) events are growing [6]

- About **73.000 interferences** have been identified and classified in **23 countries** around the globe
- Vast majority is **unintentional**

[1] https://www.defenseone.com/technology/2015/12/ DHS-Drug-Traffickers-Spoofing-Border-Drones/124613/
[2] GPS World Chinese GPS spoofing circles could hide Iran oil shipments
[3] https://www.gpsworld.com/spoofing-in-the-black-sea-what-really-happened/
[4] https://gpspatron.com/gps-spoofing-on-cars/
[5] https://www.orolia.com/document/gears-project/
[6] http://gnss-strike3.eu/

orolia

GPS SPOOFING AND JAMMING ATTACKS: A RISING THREAT WORLDWIDE

June 2017: Spoofing Attack in Black Sea

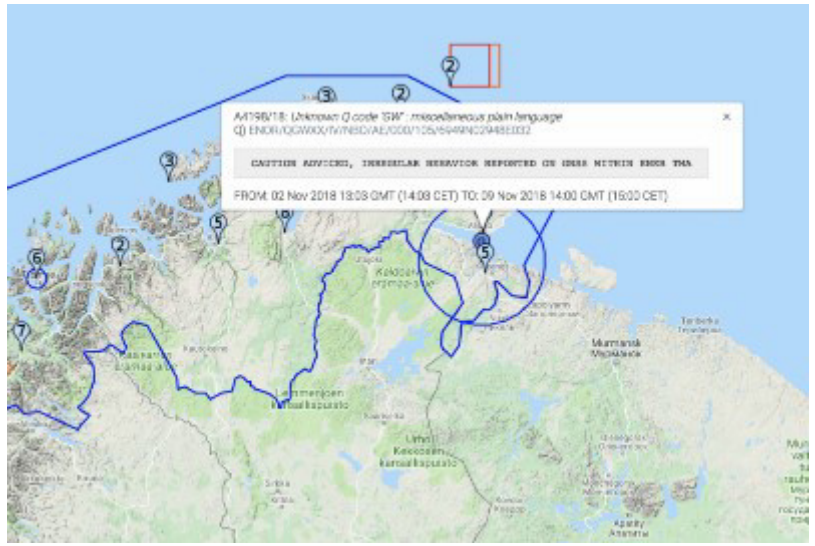
Nov 2018: Northern Finland Jamming in the Artic Sea

June 2019: Israeli Airports GPS Signal Loss

July 2019: NASA reports passenger aircraft nearly crashes due to GPS disruption

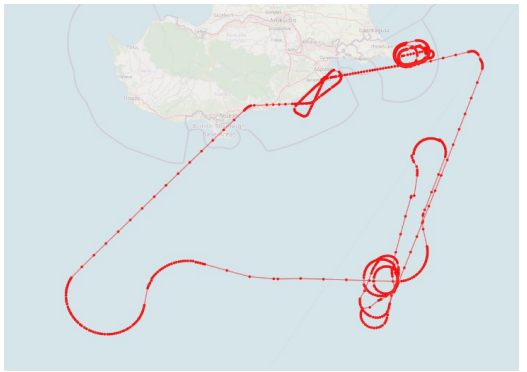
Feb 2020: US President Trump signs an Executive Order directing critical infrastructure operators to address the vulnerabilities of their PNT services to disruption and manipulation

More GNSS Jamming and Spoofing events on Orolia Resilient PNT Industry News

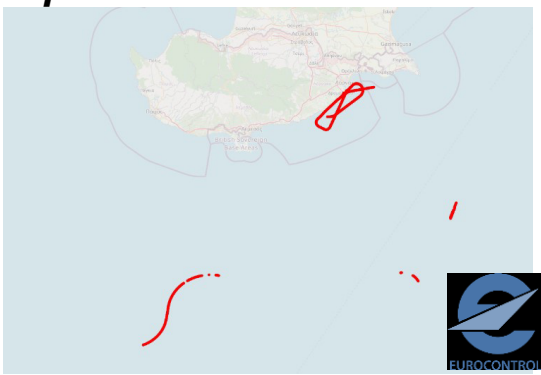


Airbus A320 Test Flight
in Cyprus Airspace (ATRA)

13 FEB 2020 Flight Track



Parts of track where GPS position was available !



DLR: German Aerospace Research Center

HOW MUCH WILL A GPS OUTAGE COST ?

2018 NIST research study : https://www.nist.gov/system/files/documents/2020/02/06/gps_finalreport618.pdf

WHY IS TIMING IMPORTANT ?

Though generally hardly visible, time and/or frequency synchronization is a key enabler of most distributed applications, which require to share a common timescale (generally UTC), with various levels of accuracy

Radiowave-based systems
5G, Terrestrial TV / radio
Satcom
Military communications
Radars / sensors
Electronic warfare

Required accuracy : 100 ns to 100 µs
- coherent signal demodulation (low phase noise required)
- Plot / Track / Measurement timestamping
- Cell / Transmitter synchronization
- Measurement synchronization

Transaction-based systems
Datacenters
Finance / banking
Process Control / SCADA
Air Traffic Control
Transport System signaling
Security systems

Required accuracy : 1 µs to 1 ms
- Transaction timestamp
- Event / security log entry timestamp
- Time-based authentication

Audio-video signal processing
Multimedia content management
Broadcast

Required accuracy : 1 µs to 100 µs
- Audio/video stream alignment
- Event / security log entry timestamp

THE OROLIA PNT RESILIENCE & SECURITY APPROACH

Prevent

Avoid being interfered

"Spatial filtering" of interferences : Anti-jam antenna, GPS-Dome

Multi-band GNSS reception

Use protected GNSS signals

- GPS SAASM / M-Code (military only),
- Galileo OS-NMA,
- PRS (military only)

Respond

Manage the impact of successful interferences

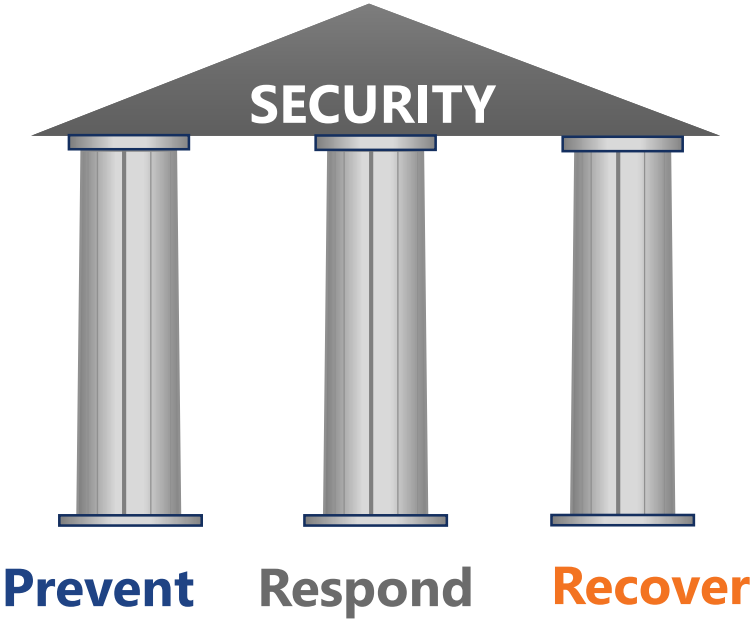
Interference detection

Switch to alternative / **backup time source** when available

Switch to **Holdover mode** (internal timescale keeping)

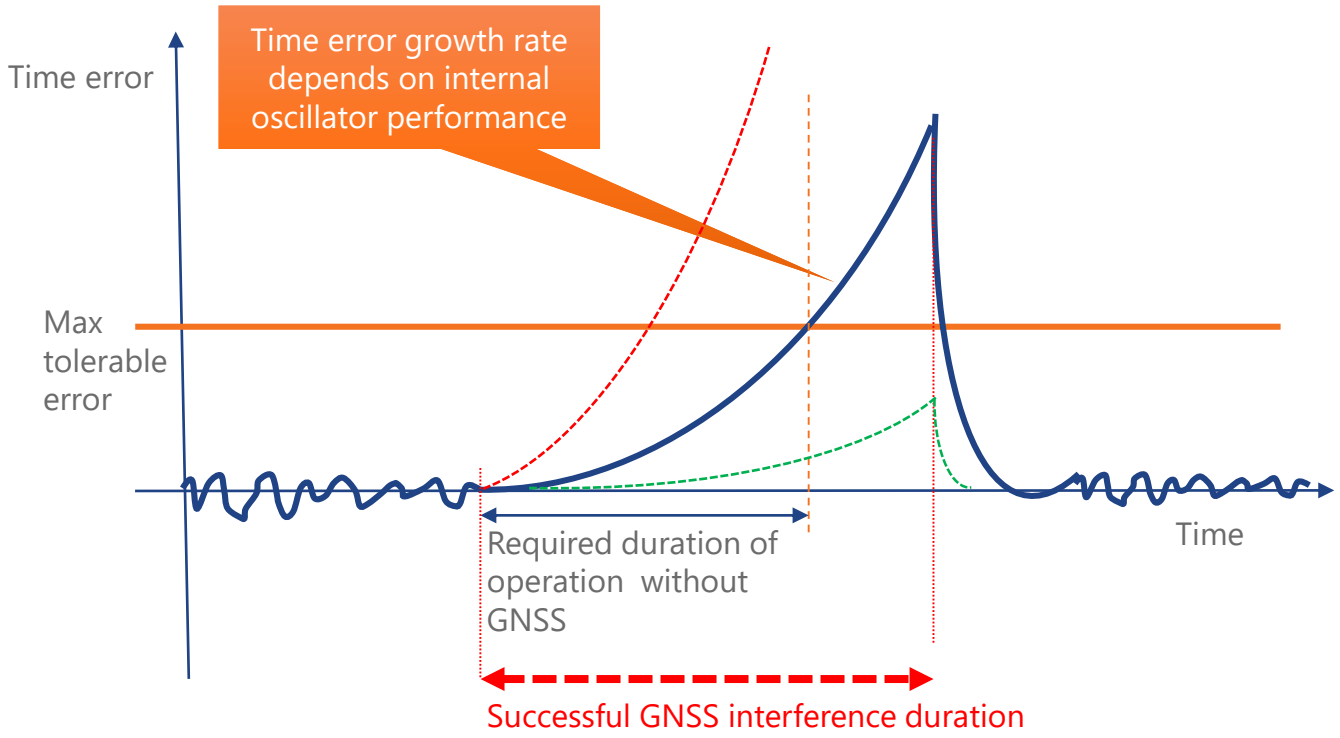
Recover

Automatic internal timescale re-alignment to UTC



GNSS resilience is part of overall system cybersecurity considerations

UNDERSTANDING HOLDOVER CAPABILITY



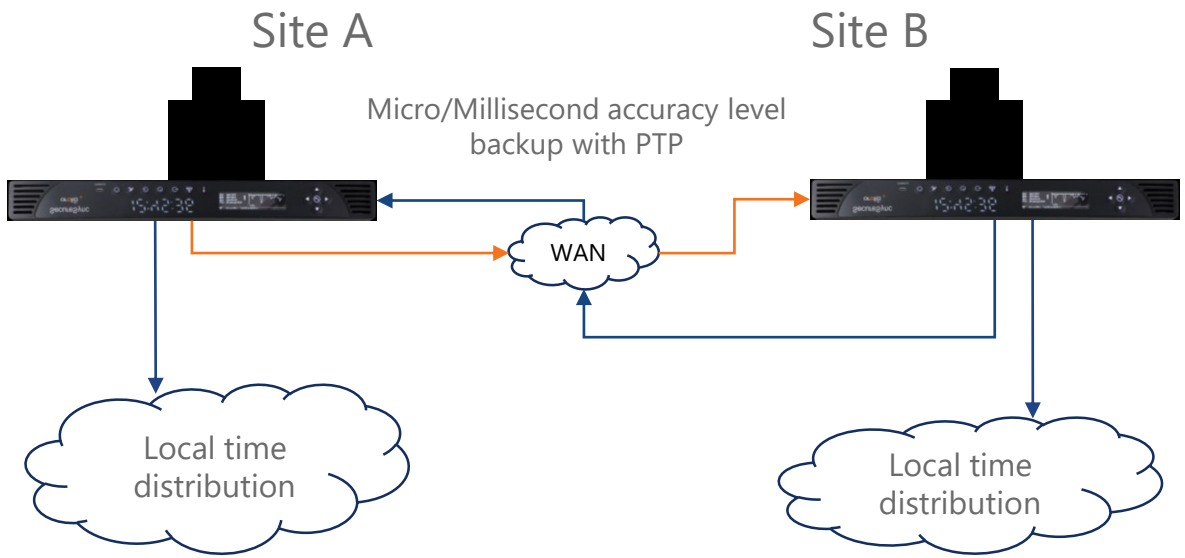
Orolia offers a range of oscillators allowing to maintain a millisecond accuracy up to 3 months (atomic clock)

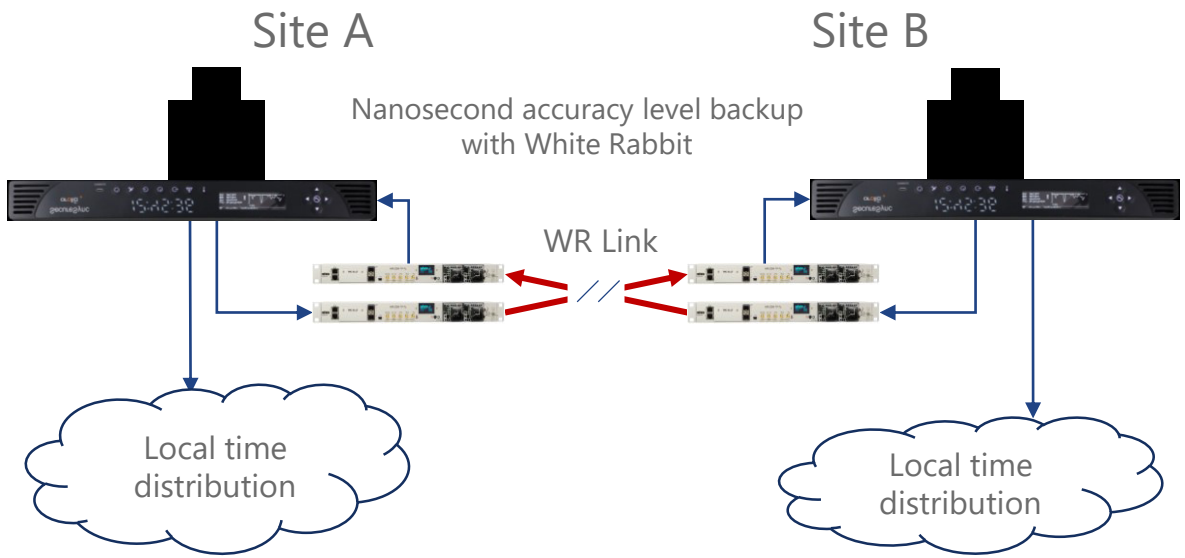
Oscillator	4 hours	1 day	1 week	1 month
TCXO	12 µs	450 µs	20 ms	400 ms
OCXO	1 µs	25 µs	1 ms	20 ms
High Perf OCXO	0.5 µs	10 µs	440 µs	8 ms
Rubidium	0.2 µs	1.5 µs	20 µs	240 µs

1. **Holdover mode** allows to maintain time delivery with some time error which grows with the duration of GNSS outage
2. **Time error growth** rate depends on the internal oscillator performance (and other factors)
3. **The internal oscillator** should be selected based on :
   - ✓ The maximum acceptable time error (system-based requirement)
   - ✓ The minimum duration during which the system shall operate properly (within acceptable time error) without GNSS

TIMING & SYNCHRONIZATION

CREATING RESILIENT ARCHITECTURES



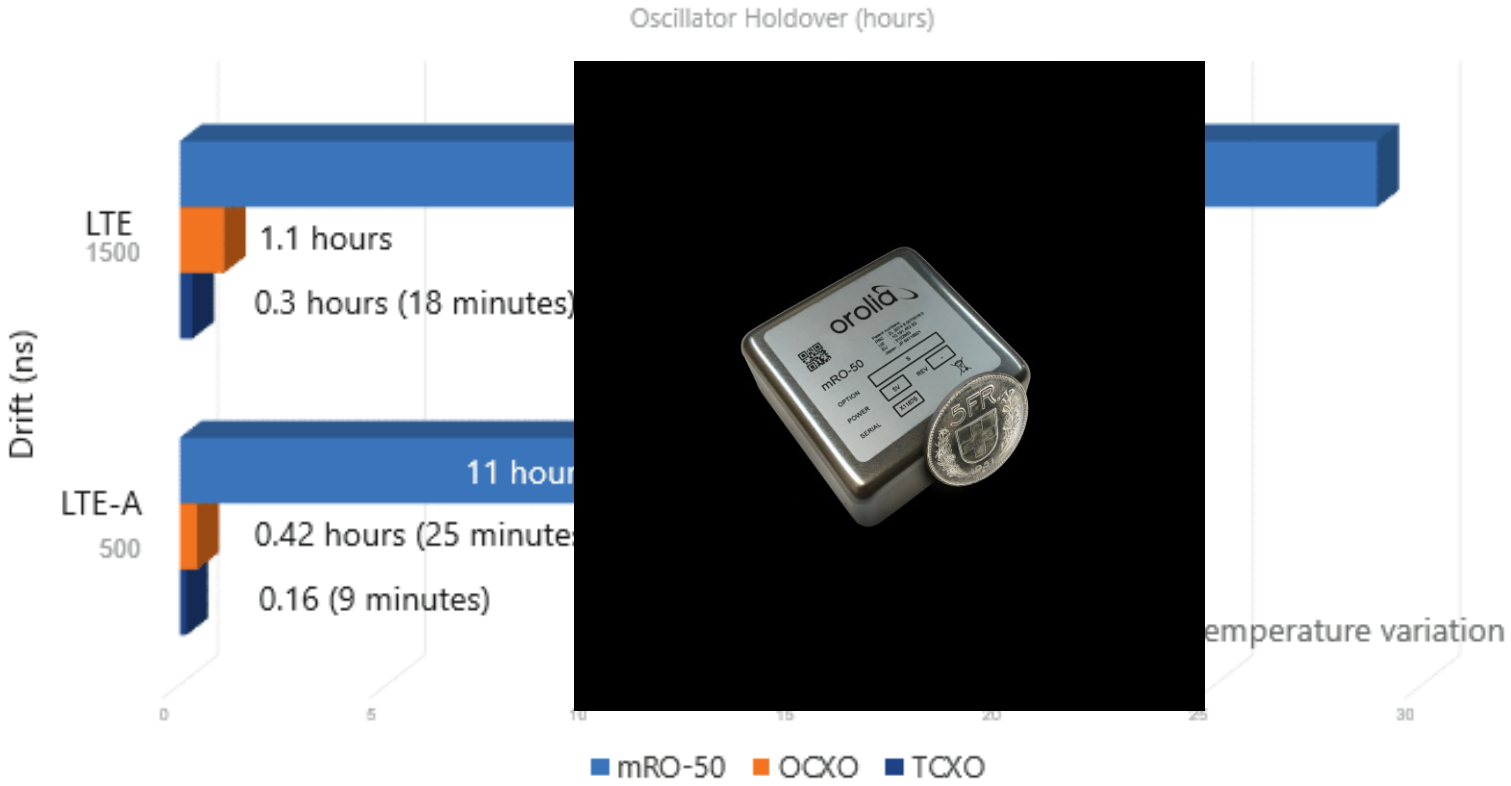


- In case of GNSS outage on site A, site B provides timing backup through NTP, PTP or White Rabbit, depending on required accuracy during GNSS outage
- Alternative architecture involves an approved time source (eg national metrology lab) as Primary Reference Clock, with single direction time feed as a backup to site A.

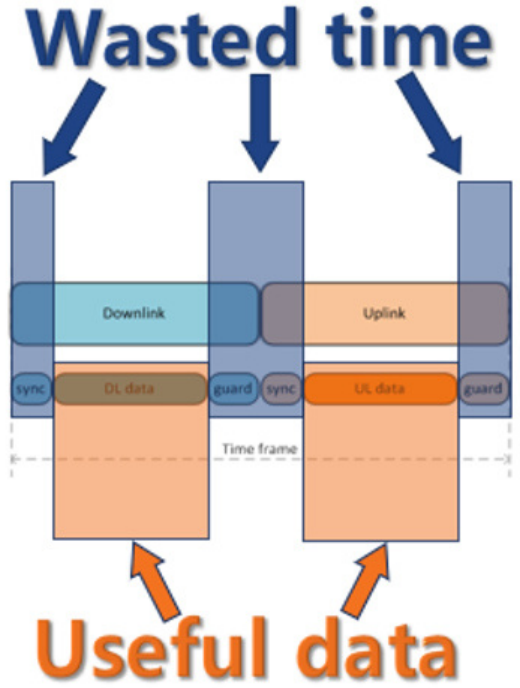
DEFENSE

RESILIENT PNT IN MOTION

AN ATOMIC CLOCK IN TACTICAL COMMS



Why does sync matter?



Radio TDMA systems :

- free running synchronization over hours
- Need for **long term holdover** and **low power** in radio silent sleep mode- known as **EMCON** - used to prevent soldiers from being detected,

Guard Bands

modern military radios operate by :

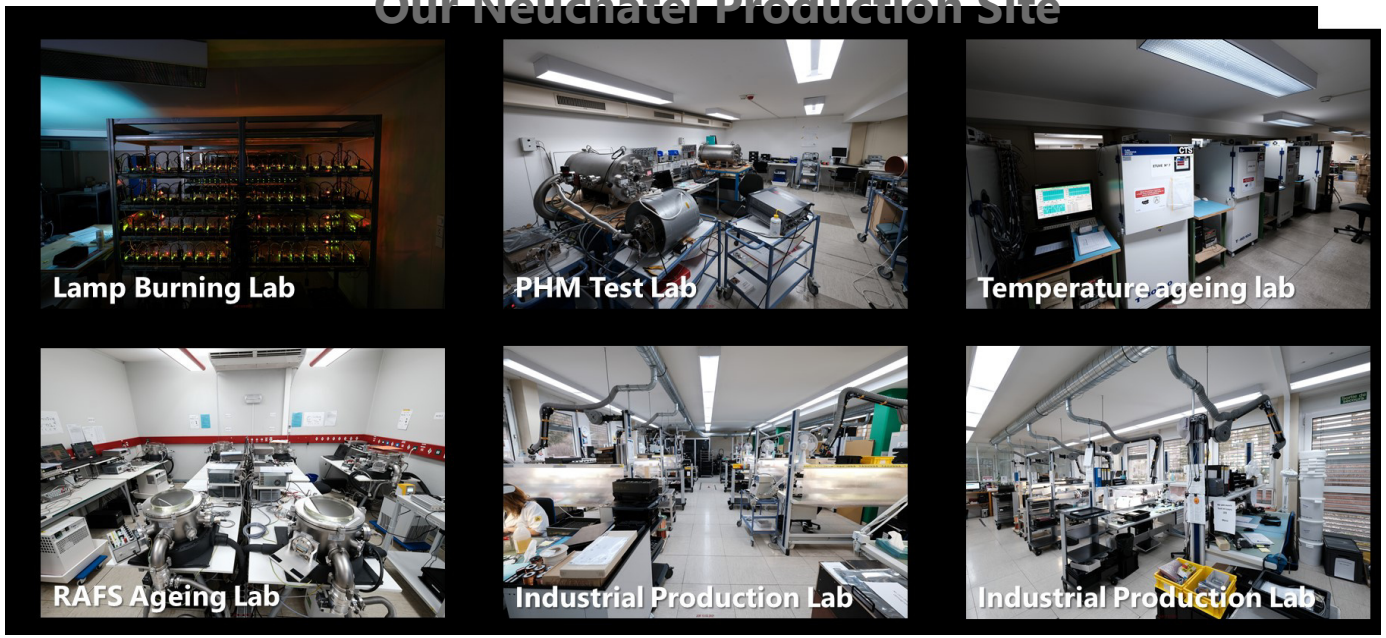
- assigning time slots to users
- preventing the radios from “talking over each other”
- each time slot, requires “guard bands”

➢Need for **perfect synchronisation**

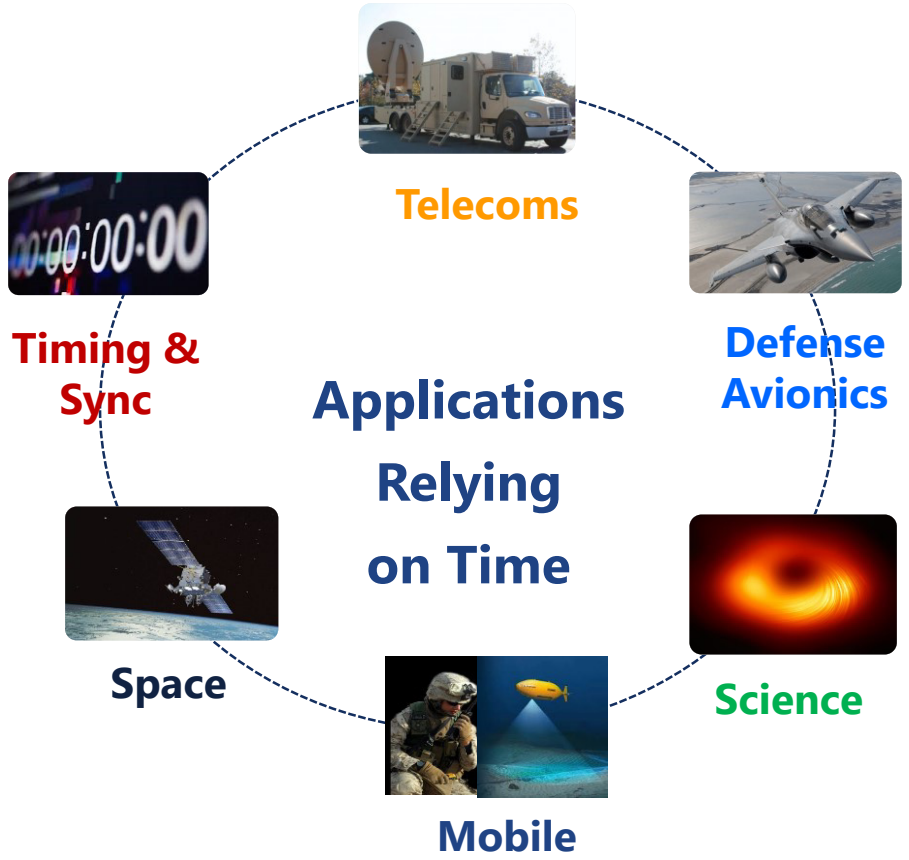
ABOUT OROLIA CH TIMING SOLUTIONS

OROLIA CH (SPECTRATIME)

Our Neuchâtel Production Site



Niche Market Segments



OUR PNT EXPECTATIONS TOWARDS THE STATE

- Consider actions taken by other states ex. Feb 2020 US Presidential Executive Order on PNT giving a mandate to the American administrations to guard against such hazards and risks
- Identifiy dependencies of critical national infrastructure on GNSS signals
- Map the vulnerability of such systems to GNSS disruption or denial together with effective mitigation
- Must raise awareness and define the rules so that infrastructures are equipped with alternative PNT sources to be resilient to denial of GNSS services:
  - the use of improved holdover technologies for timing
  - the use of additional terrestrial or space-based positioning & timing services
- Actively support the PNT industry in Switzerland, including atomic clocks technology development

QUESTIONS ?

Fazit - Was tut swisstopo?

Conclusion – Que fait swisstopo?

R. Rollier

Aktivitäten

- Abhängigkeitsanalyse Weltraum (GS-VBS, 2019)
  - *Starke Abhängigkeit von GNSS für PNT*

- Grundlagenpapier Weltraum (ASTAB, 2020)
  - *AGNES für nationales Monitoring der GNSS-Signale*
  - *Galileo PRS*
  - *Geostation Zimmerwald (Zusammenarbeit mit AIUB)*

- Strategie 2025 swisstopo:
  - *«Swisstopo betreibt einen krisenresistenten Positionierungsdienst»*

- Leistungsvereinbarung swisstopo 2022
  - Ein Konzept für Einführung des Kompetenzzentrum Positionierung, Navigation und Timing (CCPNT) ist erarbeitet

Objectifs d’un centre de compétences PNT
Ziele eines Kompetenzzentrums PNT

Le Centre de Compétences PNT est la centrale nationale de surveillance et d’alarme en cas d’incidents des services PNT. Il a également pour but d’améliorer la résilience des services PNT.

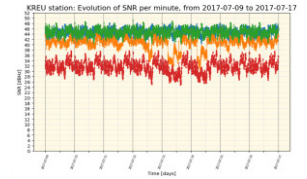
Das Kompetenzzentrum PNT ist das nationale Überwachungs- und Alarmzentrum bei Problemen oder Ausfällen von PNT-Diensten. Es hat ausserdem das Ziel, die Resilienz von PNT-Diensten zu verbessern.

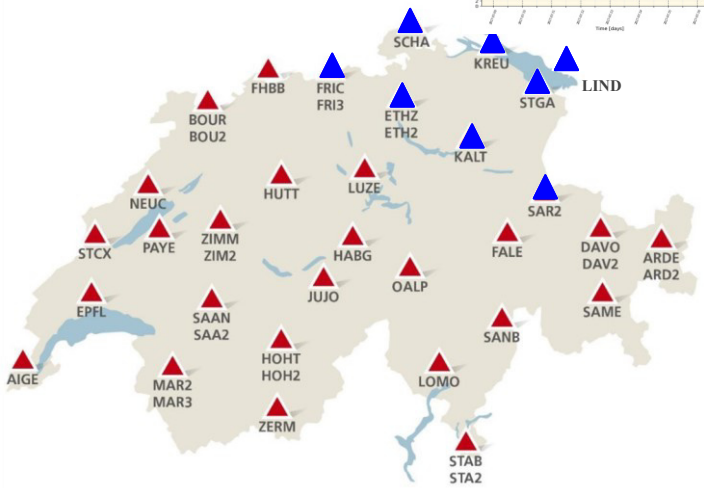
Mesures envisagées, 2 exemples
Geplante Massnahmen, 2 Beispiele

Surveiller et alarmer

Überwachen und Alarmieren

- Surveiller les signaux GNSS et diffuser des alertes en temps réel en cas d'incidents/anomalies des signaux GNSS sur le territoire Suisse.
- Überwachen von GNSS-Signalen und Alarmierung in Echtzeit bei Ausfällen/Anomalien in der Schweiz





Opérer un service GNSS crypté

Betrieb eines verschlüsselten GNSS-Dienstes

- Fournir l'accès au service européen Galileo PRS aux acteurs suisses.
- Zugang zum europäischen Galileo PRS Dienst für Akteure in der Schweiz sicherstellen

GALILEO PRS Public Regulated Service

N’hésitez pas à nous contacter pour des questions ou pour être impliqué dans cette initiative

Haben Sie Fragen oder möchten Sie aktiv zu dieser Initiative beitragen?

mensuration@swisstopo.ch