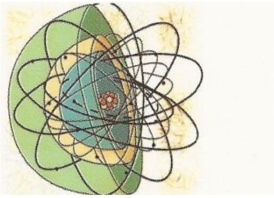
AubryConseil White paper

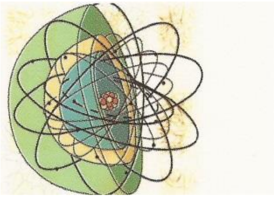
MITIGATION OF GNSS VULNERABILITIES



Agenda

- Time – *more generally P N T* - is everywhere in our lives and systems
- As key contributor to Critical Infrastructure, Time is a very sensitive asset
- GNSS-based timing: the most commonly used, ***but HIGHLY VULNERABLE***
- GNSS-BACK UP strategies
  - Improved resilience GNSS receiver (HW, SW, network)
  - GNSS augmentation data (EGNOS, WAAS…)
  - PNT Alternative
    - Fiber (AM; protocol,…) , RF (pseudolite network, LW, …) LEO,
  - Towards hybridation of PNT sources for better operation ability:

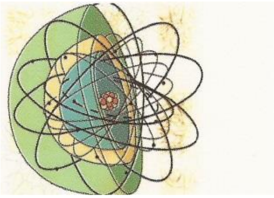
availability, thrustability,



GNSS Vulnerabilities mitigation

- The user point of view
  - When we make use of GNSS signal, for any of the P,N,T feature (Positionning, Navigation, Timing) for a given system (including our daily life), key words are:
    - ***accuracy*** (defined by the user system objectives and operation)**,** ***availability***, ***thrustability***, ***traceability*** and ***cyber-criminality resistant***
- Since the well known "GNSS vulnerability VOLPE report" released in 2001 [1], and from many GNSS-receivers jamming and spoofing reports, nobody can ignore that GNSS signal, at the receiver level , is **DEEPLY vulnerable**. 50 US$ jammer are offered on the net, and the original "customer" (back in the 90's) of such devices were taxi drivers, truck drivers who do not want their "boss" to know where they are and what they are doing….
- Since those good old time, unfortunately, cyber-criminal learned how to play with such devices,….
- In parallel, the digitalization of our world bring IP and telecom in all and every system, either for a proper time-based or location-based operation, or through its remote management access

[1] *Vulnerability Assessment of the Transportation Infrastructure relying on the Global Positioning System, Final Report* @ Draft Final Report (uscg.gov)

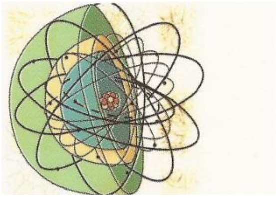


Where do we need good time

(good means accurate, traceable, thrustable, available ….)

- Fintech
- Telecom (fix line, wireless)
- Data Center, IaaS, Cloud computing
- smart Grid, energy distribution,
- security : time stamped data flow,
- critical infrastructure timing,
- airport, rail transportation (GNSS back up or stand alone synchronization solution)
- timing in encryption
- time stamping (documents, paper free,…)
- potential new application (autonomous cars, synchronized pseudolite, secure data time stamping, raw data time stamping…)
- Timing in time-sensitive critical Infrastructure
- Timing in security technologies
- Timing in IoT
- TaaS concept
- ,,,,

[1]www.rime.inrim.it/H2020-Demetra/project-overview
[2] www.clonets.eu; CLONETS report and deliverable
[3] Time-Aware Applications, Computers, and Communication Systems (TAACCS), NIST et al. M;Weiss et al., Time-Aware Applications, Computers, and Communication Systems (TAACCS) (nist.gov)
[4] www.gsa.europa.eu/market/market-report



Critical Infrastructures

Since the early 2000's , the need to identify and protect the so-called « Critical Infrastucture » was identified, and pave the way towards protective action request,

« Critical Infrastructure » are defined as

« SYSTEMS AND ASSETS, WHETHER PHYSICAL OR VIRTUAL, SO VITAL THAT THE INCAPACITY OR THE DESTRUCTION OF SUCH SYSTEMS AND ASSETS WOULD HAVE A DEBILITATING IMPACT ON SECURITY, NATIONAL ECONOMY SECURITY, NATIONAL PUBLIC HEALTH OR SAFETY, OR ANY COMBINATION"

Or

"INFRASTRUCTURE WHOSE MALFUNCTION MAY AFFECT SERIOUSLY THE ECONOMY, SECURITY, THE WELL BEHAVE OF PEOPLE'

Critical Infrastructures

CI infrastructure involve all domain of private, public and social daily life:

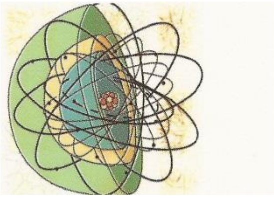
- *General administration (public offices, official and Governmental offices and infrastructure),…Telecommunication (voice, data, intenet, video, information emergency channels) ; Electricity generation, transport and interconnection ; Power plants (gas, oil, coal, nuclear power, DER ; Security services (police, military, justice, fire brigade, amblances); Water supply (drinking water, waste management)); Transportation systems (energy supply, air transportation,, airports, harbours, railway network, inland shipping, road traffic management…); Public health (hospitals, medical care and services, ambulances); Agriculture, food production and distribution; Economic sector; Goods and services (logistic,) and financial services (banking, HFT,…); and all the IT related to them*

[1] *https://ec.europa.eu/home-affairs/what-we-do/policies/crisis-and-terrorism/critical-infrastructure_en*
[2] Protecting Time-Sensitive Critical Infrastructure Systems, webinar, November 15, 2018, Orolia, NIST & Dana Goward, President, Resilient Navigation and Timing Foundation
[3] DHS Department of Homeland Security, Improving the Operation and Development of Global Positioning System (GPS) Equipment Used by Critical Infrastructure www.navcen.uscg.gov/pdf/gps/Best%20Practices%20for%20Improving%20the%20Operation%20and%20Development%20of%20GPS%20Equipment.pdf

Critical Infrastructure domain

- ***Electricity & energy production center, interconnection, pipeline transport***
- ***Chemical industries (Seveso_plants)_hazardous_waste , nuclear plant, nuclear waste management, solid_waste***
- ***Hospitals, rescue services operation***
- ***Telecommunication buildings, networks connection, Base station, microwave links…***
- ***Utilities***
- ***Airports, ports, train station, rail interconnection; roads; lighthouses; mass transit***
- ***Underground transportation, Parks***
- ***Public housing state schools public spaces***
- ***Water supply, reservoirs, water towers, dams, levees, irrigation channels, sluices weirs wastewater, sewage***
- ***CI operating center***

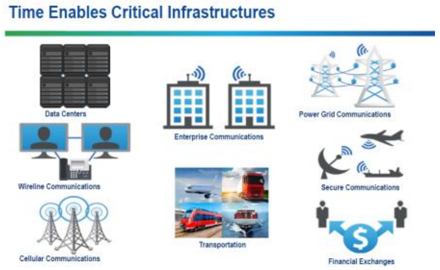
[1] https://ec.europa.eu/home-affairs/what-we-do/policies/crisis-and-terrorism/critical-infrastructure_en
[2] www.gsa.europa.eu/european-gnss/gnss-market/gnss-user-technology-report
[3] www.gsa.europa.eu/market/market-report



Time-sensitive critical infrastructure
some littérature (short extract…)

Data Center specific

*[1] **Exploiting a Natural Network Effect for Scalable, Fine-grained Clock Synchronization;** Y. Geng, S. Liu, et al. Proceedings of the 15th USENIX Symposium on Networked Systems Design and Implementation (NSDI '18). April 9–11, 2018 • Renton, WA, USA ; ISBN 978-1-939133-01-4; https://www.usenix.org/conference/nsdi18/presentation/geng*
*[2] **Globally synchronized time via datacenter networks,** LEE, K. S., et al. Proceedings of the 2016 conference on ACM SIGCOMM 2016 Conference (2016), ACM, pp. 454–467.*
[3]. Time, clocks, and the ordering of events in a distributed system, LAMPORT, L ; Communications of the ACM 21, 7 (1978), 558– 565.
[4] The Forrester Wave™: Database-As-A-Service, Q2 2019, The 12 Providers That Matter Most And How They Stack Up, Noel Yuhanna, June 2019
[5] https://www.srgresearch.com/research/datacentre infrastructure



Courtesy Microsemi

Energy & Smart Grid Specific

[1] SEREC - Swiss Electromagnetics Research and Engineering Centre – « Electromagnetics in Renewable Energies », ETH Zürich, 9th November 2012, in ESC Energy Science Center(Homepage - ESC – Energy Science Center (ESC) | ETH Zurich
[2] www.epfl.ch/research/domains/sccer-furies/
[3] NASPI
www.naspi.org/sites/default/files/reference_documents/naspi_distt_synchrophasor_monitoring_distribution_20180109.pdf

Timing in PMU

[1] "IEEE standard for synchrophasor measurements for power systems," IEEE Std C37.118.1-2011 (Revision of IEEE Std C37.118-2005), pp.1–61, Dec 2011.
[2] Time synchronization in the electric power system," NASPI Time Synchronization Task Force, 2017

Transport : Air, rail road, sea, radar,
IT infrastructure in CI
Time stamping, legal signature
Encryption,
Event time stamping, neutral data time stamping..

Telecom mobile & fix 'transport' specific

[1] Ericsson white paper : S;Ruffini, 5G synchronization requirements and solutions (ericsson.com)
[1] GSM XE.pdf (ahti.fr) & (Microsoft PowerPoint - La gen\350se de la norme GSM) (ahti.fr)
[3] Mobile Bakhaul, an overview, June 19, 2019 , GSMA Future Networks
*[3] Precision Time transfer using IEEE 1588 over OTN through a commercial optical Telecommunication Network, M.Weiss et al;, NIST T&F division, Microsemi et USNO, IEEE instrumentation and Measurement Society, 2016, **DOI:** 10.1109/ISPCS.2016.7579503, ,*
[4] Ethernet Time Transfer through a U.S. Commercial Optical Telecommunications Network, ; M. Weiss, L. Cosart, and J. Hanssen Proc. 2014 PTTI Mtg., 214-220, (2014)
[5] Synchronization as a Service; How to provide phase and time of day information using PTP over a transport network; challenges and solutions, NOKIA white paper
[6] OTN networks: ITU G-709 (interface for OTN), G-798 (hierarchy and functional blocks in OTN) , G-872 (OTN architecture), VIAVI white paper, www.viavisolutions.com/en-us/literature/next-generation-optical-transport-networks-white-paper-en.pdf; G-709, The Optical Transport Network (OTN), VIAVI White paper, www.viavisolutions.com/en-us/literature/g709-optical-transport-network-otn-white-paper-en.pdf

Fintech Specific

[1] https://www.fca.org.uk/mifid-ii/1-overview
[2] www.orolia.com/mifid-white-paper
[3]: www.npl.co.uk/npltime
[7] https://www.nist.gov/pml/time-and-frequency-division/time-services/nist-authenticated-ntp-service
[8] www.deutsche-boerse.com/exchange-en/resources/initiatives/technical-changes/high-precision-time-white-rabbit-pilot

GNSS Vulnerabilities impact

- Global economic cost, evaluation by London Economic [6]
  - Takes into account all and every impact
  - Assumes total vanish of GNSS signal, assumes no back-up, no holdover capability
  - ***Conclude to a global economical cost of 5 b£ (5 Billions!) per week of GNSS disruption for UK …***

[4] DHS Department of Homeland Security, Improving the Operation and Development of Global Positioning System (GPS) Equipment Used by Critical Infrastructure *www.navcen.uscg.gov/pdf/gps/Best%20Practices%20for%20Improving%20the%20Operation%20and%20Development%20of%20GPS%20Equipment.pdf*

[5] Protecting Time-Sensitive Critical Infrastructure Systems - GPS World Webinar on Demand | RNTF (rntfnd.org), *Orolia, NIST & Dana Goward, President, Resilient Navigation and Timing Foundation*

[6] The economic impact on the UK of a disruption to GNSS - GOV.UK (www.gov.uk)

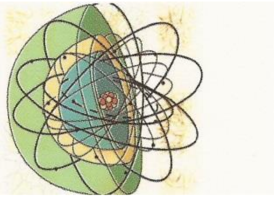
P N T improvement Strategies

GNSS vulnerabilities apply at the level of the receiver and mainly at the antenna because of the GNSS signal low power

- fake signals, multipath,.. To be rejected by HW or SW
- Message authentication and recognition, anti spoofing SW, to be available to allow to « unuse » fake signal not rejected
- Augmentation data real time availability to improve accuracy and partially thrustability
- Intercomparison with a mesh receiver network to improve thrustability
- GNSS-independent third party timing signal might be used as back-up / counter measure

Back up GNSS means back-up timing-source (alternative channel/GNSS independant) and/or improved resilience against cyber attempt of P N T corruption

RNT, Resilient Navigation and Timing fundation maintain pression over Gvt institutions and provides guide and tools to improve P N T resilience : . GPS/GNSS Security, Backup and GPS Timing Alternatives | RNTF (rntfnd.org)



GNSS-receivers back up strategies

Sat-based RF

-multi-frequencies (L1, L5,..)
-mulit-constellation
-MEO GEO augmentation (WAAS, EGNOS, …)
-**LEO**

Ground-based RF

-Pseudolite network
(LOCATA, SuperGPS-type network
-mobile 5G TDMA TDD signals
-WWF **DCF77** in Europe
-**eLORAN**

Signal/code message

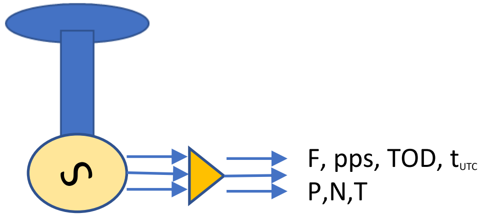
-Navigation message
-OS-NMA
-CS authentication
-FLAG status

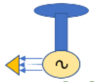
Intelligent antennas

-beam forming
-rotating antenna

Fiber-based optional

-NTP PTP PTP-HA (WR)
-dedicated timing signal





Ground-based

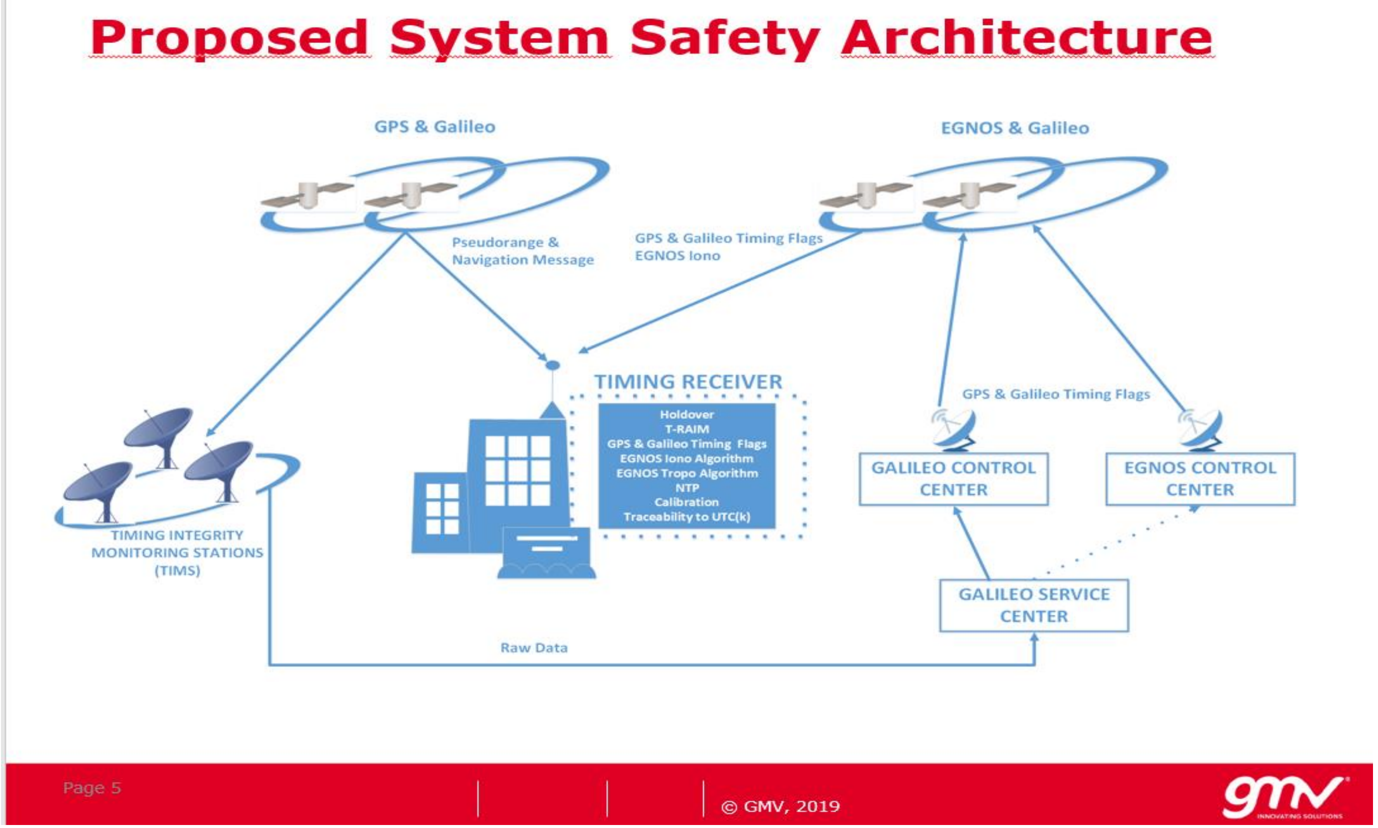
Reference receivers
Network

Intelligent receiver

Anti–jam anti–spoof algorithms
Anti-scintillation, multipath
Iono/tropo correction
Signal Quality monitoring
-RAIM, T.RAIM
-High performance LO

PPP
RTK
Common view TT

GNSS augmentation : EGNOS



Identify biases in GNSS P N T information

Transmit correction data (generally post processing)

Correction data might be used in « real-time » by registered users

[4] egnos_timing_and_synchronisation_web.pdf (europa.eu)

Ground-based GNSS back up

- RF-based
  - PNT awared Pseudolite network
  - Modulated RF (long range), ie DCF 77

- Fiber-based
  - AM –based technologies
  - Protocol-based technologies : NTP / IEEE-1588 PTP / White Rabbit – 1588 HA
  - Media support
    - Telecom Network
    - Data Center centric
    - OTN
    - Dark fiber

[1] IEEE 1588 working group / current draft / IEEE 1588-2019 Draft Standard D1.6 20190906.doc

[2] IEEE 1588 sub committee, , Securing Precision Time Protocol Networks Against Insider Threats, C. DeCusatis, ITU-T SG 15 Q13 contribution to IEEE 1588 security SC

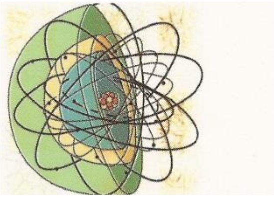
[3] IEEE-1588 release 2019, intégre l'option HA "high accuract", issue du White Rabbit et un $ spécifique aux aspects sécurité *IEEE 1588-2019 - IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems*

GNSS alternative technologies

[4] LOCATA web site and white papers on www.locata.com

[5] www.tudelft.nl/en/ceg/about-faculty/departments/geoscience-remote-sensing/research/projects/supergps/

[6] https://white-rabbit.web.cern.ch/



LEO-based GNSS back-up

- LEO constellation under deployment
  - SpaceX-Starlink, Amazon-Kuiper, OneWeb, Telestar, CubeSat, NanoSat, constellation are under tremendous deployment
  - Some constellation aim to provide complete ground and sea coverage, with multiple application: communication, data exchange, with low power (distances are in the range 700-1000 km, vs GEO (36000 km) and GNSS (# 25000km)
- LEO main target
  - Earth observation, Satellite-based communications , localization and rescue services
  - Internet access
    - *We will note that Bharti, one of the major key Internet acces provider and telecom operator in India is controlling 45% of the shares of OneWeb, and note the UK Gvt is controlling another 45 %.... ()*
- LEO PNT contribution
  - PNT on board LEO
    - Anti collision avoidance
    - Real time position and navigation / POD precise orbit determination

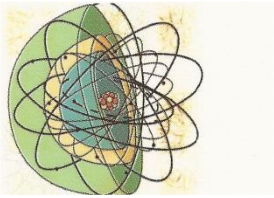
[1] www.oneweb.world/investors "In 2020, OneWeb was acquired by the UK Govt. and the Bharti Group. The Government invested $500m as did Bharti Global. In Jan, 2021, SoftBank and Hughes returned as equity investors with an additional $400m. This took equity to $1.4bn with no debt finance"

LEO in vision

- LEO-based Communication and PNT functionnalities operates through a constellation of LEO satellites; global coverage requires a large number of spacecraft.
- SpaceX is the most relevant example of a LEO Constellation. It is currently deploying an operational system call Starlink. For Starlink, 422 satellites were in orbit as of late April 2020, and the company claims that it can begin offering commercial service this year 2021.
- Telesat, with a proposed initial constellation of 117 spacecraft and the potential to deploy more than 500,,,,,.
- Amazon, has filed to launch 3,236 spacecraft in its Kuiper constellation, FCC approved : Amazon receives FCC approval for Project Kuiper satellite constellation (aboutamazon.com)
- OneWeb aims to deploy a constellation of # 500 units and claim to offer services in Communication, internet Access, and PNT

Road map GNSS back-up in US

- VOLPE report : 2001 : first formal definition of GPS vulnerabilities and call for back up
  - Draft Final Report (uscg.gov)
- GPS malfunction impact identification
- Critical Infrastructure (CI) identification, multiple contributions (NIST, Industry, agencies and department, …)
  - > Time critical infrastructure, PNT integrity identified as a critical issue
- DHS & DOT GNSS-back-up investigations
- Gvt decision on back-up GPS implementation
- DOT operation: 2018-2020
  - call for technologies, technologies identification, vendor selection
  - Selection of 11 vendors and technologies to be tested, based on multiple technologies (RF & microwave, LEO, fiber, RF area recognition
  - January 2021: release of first evaluation report (accuracy, disponibility, indoor/outdoor, fix/mobile?....: U.S. DOT releases "Complementary Positioning, Navigation, and Timing (PNT) and GPS Backup Technologies Demonstration" Report to Congress | US Department of Transportation



Road map GNSS back-up in US

11 companies / various technologies selected for performance evaluation

- **Echo Ridge LLC** develops a way to determine position from **radio signals**.
- **Hellen Systems LLC** develop and deploy enhanced LORAN **(eLORAN). !!** (despite that LORAN-C infrastructure was dismounted 5//6 years ago in the US…)
- **NextNav LLC** provides encrypted signals and accurate positioning in three dimensions using **licensed spectrum and terrestrial transmitters**. (**LOCATA pseudolite-based type of solution**)
- **OPNT BV** distributes synchronized timing over existing fiber networks based on the **White Rabbit** protocol developed by the European Organization for Nuclear Research (CERN).
- **PhasorLab Inc.,** offers **high-precision carrier synchronization** technology that can be used to do time and frequency synchronization. determining position and centimeter-level target tracking. (***RF based)***
- **Satelles Inc**., uses the Iridium satellite constellation to provide strong, encrypted navigation signals that the firm said in 2016 would enable 20- to 50-meter unaided position accuracy and **microsecond timing**.
- **Serco, Inc.** is a global provider of air navigation services. focuses **on eLoran**.
- **Seven Solutions Sociedad Limitada** provides **time as a service**, remote timing monitoring, GPS jamming protection and solutions for **intra- and inter-datacenter** synchronization. (***fiber based solution, White Rabbit***)
- **Skyhook Holding Inc.**, uses Wi-Fi, GNSS and cell signals to locate devices, even if they are offline. ***RF based solution***
- **TRX Systems** uses ***sensor fusion and mapping algorithms*** to provide real-time 3-D location and mapping within buildings and underground where GPS is not always available. (***RF based***)
- **Ursa Navigation Solutions Inc. (UrsaNav)** has developed an eLoran transmission system in cooperation with the Canadian firm Nautel. offers ***eLoran equipment***.

Road map GNSS back-up in US

Vendor	PNT Technology	Demo Site	Timing Scenarios: 72-Hr Bench Static Timing	Timing Scenarios: Static Outdoor Timing	Timing Scenarios: Static Indoor Timing	Timing Scenarios: Static Basement Timing	Timing Scenarios: Reference Station Offset (eLORAN Timing)	Positioning Scenarios: Dynamic Outdoor Positioning with Holds	Positioning Scenarios: Static Outdoor Positioning	Positioning Scenarios: Static Indoor Positioning	Positioning Scenarios: Airborne 3D Positioning
Echo Ridge	LEO commercial S-band (2483.5 - 2500 MHz)	LaRC					N/A		X		
Hellen Sys	eLORAN terrestrial RF (90-110 kHz)	JBCC	X			X	X				
NextNav	UHF terrestrial RF (920 - 928 MHz)	LaRC	X	X	X	X	N/A	X	X	X	X
OPNT	fiber optic time service (white rabbit PTP)	LaRC	X				N/A				
PhasorLab	802.11 terrestrial RF (2.4 GHz)	JBCC	X	X	X		N/A	X	X		X
Satelles	LEO commercial L-band (1616 - 1626.5 MHz)	JBCC	X	X	X	X	N/A		X		
Serco	R-mode terrestrial RF (283.5 - 325 KHz)	JBCC					N/A	X	X		
Seven Solns	fiber optic time transfer (white rabbit PTP)	LaRC	X				N/A				
Skyhook	802.11 terrestrial RF (900 MHz, 2.4 & 5 GHz)	LaRC					N/A	X	X	X	X
TRX	UWB & IMU map matching (3.1 - 5 GHz)	LaRC					N/A	X*	X	X	
UrsaNav	eLORAN terrestrial RF (90 - 110 kHz)	JBCC	X		X	X	X				
GPS (SPS PS)	MEO government L-band (1575, 1227, 1176 MHz)	All	X	X			X	X	X		X

*static holds only

Key: N/A Technology incompatible with scenario definition

Tableau 1: Scenarios de tests P.N.T. menés par DoT

Initial conclusion after 1 year test of these various technologies, published in Hanuary 2021:[]

« *The report called for an architecture that include signals from space in L-band, terrestrial broadcast in the ultra high frequency (UHF) and low frequency (LF) spectra, and a fiber backbone to synchronise and feed precise time to terrestrial transmitters”* .

- []

Road map GNSS back-up in US : P N T options & main results

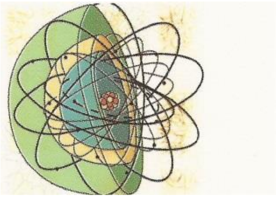


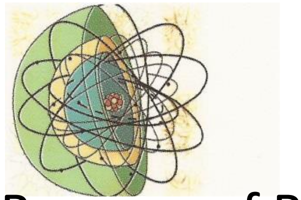
Table 58. Scenario 1: 72-Hour Bench Static Timing Statistical Results

Vendor UE	Slope (ns/hr)	Median (ns)	SD (ns)	Max Deviation (ns)	95th Percentile (|.|) (ns)
Hellen §	0.095	82.08	38.24	215.12	114.47
NextNav §	0.16	6.88	9.52	63.45	22.03
OPNT1	0.014	0.053	0.99	4.07	1.88
OPNT2	0.0045	0.087	0.062	1.43	0.15
PhasorLab	0.0072	1.35	4.46	23.33	9.40
Satelles SecureSync1-Rb (Ch2A) §	0.34	-39.72	118.85	698.25	243.57
Satelles EVK2-Rb (Ch3A) §	-0.42	25.44	30.89	91.63	75.47
Satelles EVK2-OCXO (Ch4A) §	0.00020	34.25	40.87	208.72	107.38
Seven Solutions	0.00030	0.014	0.052	0.55	0.10
UrsaNav §	0.57	-35.48	37.81	171.46	94.93

§ Indicates that detrending was necessary and performed.

Tableau 1: comparaison 72H timing statique LORAN, RF, LEO, Fibre

- Basic/initial P N T performances characterization
  - Sub-ns level time synchronisation obtained through fiber
  - Sub-µs time synchronisation obtained from LEO
    - Onboard POD accuracy limitations?
    - Doppler limitations ?
  - Results on P and N comparison are also available. Please Consult full report t



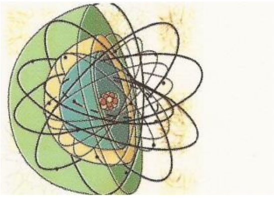
GNSS back-up actions in UK

- Because of Brexit, UK Gvt commit on « independant PNT »
- UK Gvt does not want to « lease » PNT capacity from a foreign vendor for critical applications (military, defense, infrastructures,…)
- UK Gvt engage two main actions related to PNT « world-wide autonomy »
  - The SBPP, **S**pace **B**aced **P**NT **P**rogram: Space Based PNT Programme – GOV.UK (www.gov.uk)

    Aiming to combine Up to date technologies, MEO/GEO,.. to perform:
    - feasability, demonstration,…under scope of National Timing Centre programme, include application sectors telecommunications, energy, autonomy, finance, smart factories, sensors, the Internet of Things (IoT), broadcast, health, space, and transport including rail, road, aviation, maritime.
    - **Support and enable industry-led innovation** for resilient time, frequency and synchronisation (TFS) including, products, services and end user applications
    - Develop a TFS ecosystem and capability for all relevant industries and **critical national infrastructure**
  - **UK Gvt took partial control of OneWeb** (45% UK Gvt, 45% Bharti) – target telecom & PNT services:

    Network | OneWeb \ Position Navigation & Timing

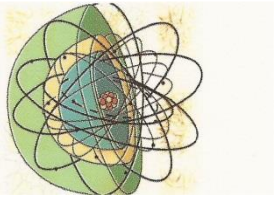
“ OneWeb’s first generation system is being used to develop an innovative and accurate timing capability in a project with the UK-based space hub Satellite Applications Catapult that requires no satellite changes and minimal ground network modification. OneWeb intends to introduce PNT capabilities on subsequent generations of satellites, to complement existing services, and to provide additional global resilience for this critical infrastructure *www.oneweb.world/investors*



What's in Europe and France

- Europe still hasn't learned its lesson.
  - ***Despite its definition of Critical Infrastructure and care recommendations, Europe is still blinded by the Galileo Program, and hide any action on GNSS-back up, either fiber-based or LEO-based, aside preliminary feasibility program such as Clonets , Demetra, …, all "Galileo-only centric"***
- France still hasn't learned its lesson.
  - ***Despite the activities of major laboratories devoted to Time & Frequency, such as Syrte and Femto-ST, despite efforts on information and the sensibilization about time criticality, France has dismantled LORAN infrastructure, is still blinded by the Galileo Program, and has no action on secure time transfer, aside the attempt made by private sector SCPTime, delivering only, so far, mainly secured NTP, even if some people, like Thierry Breton, start asking for deployment of an independent LEO constellation devoted to Internet link:*** Pour Thierry Breton, l'UE doit avoir sa propre constellation de satellites pour l'internet haut débit (usine-digitale.fr)
- ***When can we expect a real acknowledgement of the risks encountered by most of our systems, including highly sensitive and potentially highly impacting, of time criticality in Critical Infrastructure…***
- ***Technologies are available (fiber, LEO,…) we just need and wait for vision and decisions…***

[1]www.rime.inrim.it/H2020-Demetra/project-overview
[2] www.clonets.eu; CLONETS report and deliverable

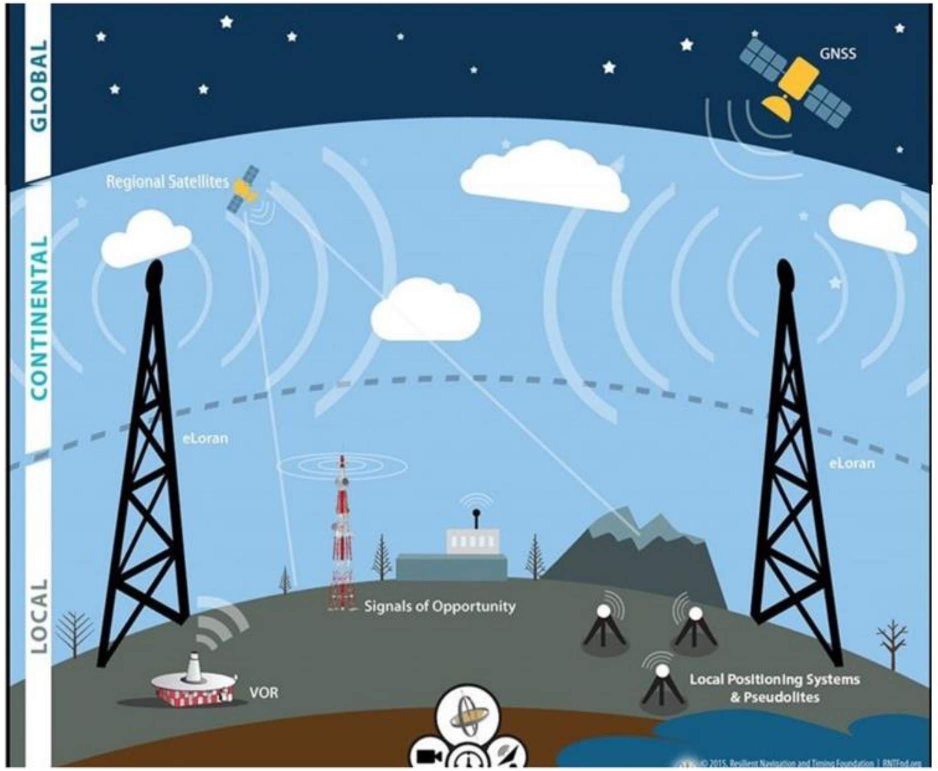


Mitigation of GNSS vulnerabilities

conclusion and propositions

- GNSS vulnerabilities must be acknowledged, Critical Infrastructure to be protected. Time thrustability and availability is Key. ***GNSS-back need to be implemented***
- Back-up should be fully technology independent
- ***More resilient receivers***: GNSS receivers manufacturer should implement anti-spoofing tool (HW, SW, NMA, T-RAIM, intelligent antennas, …) and alternative time source:
  - NMA to be available, GNSS augmentation data to be available
  - fiber-based (PTP, PTP.HA) , through network of synchronized offices (DC, Telecom, …)
  - local area Pseudolite network (LOCATA type), LW (ie DCF 77) regional area coverage (#3000km)
  - Ground reference GNSS receivers network “sensors” should be deployed, paving a meshed timing network
- ***Hybridation of time reference link à receiver level : fiber, RF, LEO:***
- ***PNT awared LEO constellation to be deployed*** : world wide, nation wide
  - Augmentation data (ie EGNOS) should be available in real time, to feed LEO, through GEM MEO sat or internet link from ground
  - LEO sat must be equipped with on board high accuracy real time PNT intelligence
- ***TaaS concept should be deployed***

PNT hybridation



Do not hesitate to consult AubryConseil to buid your GNSS back-up strategy

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  - https://www.transportation.gov/sites/dot.gov/files/2021-01/FY%2718 NDAA Section 1606 DOT Report to Congress_Combinedv2_January 2021.pdf
- TaaS "Time as a Service" and time dissemination
  - *[1] JP Aubry, Precise time generation and dissemination in power networks: available technologies and trends to address Smart Grid needs, in Electromagnetics in Renewable Energies, Serec-ETHZ, November 2012 , in SEREC - Swiss Electromagnetics Research and Engineering Centre – « Electromagnetics in Renewable Energies », ETH Zürich, November 9th 2012*, in ESC Energy Science Center(Homepage - ESC – Energy Science Center (ESC) | ETH Zurich
  - *[2] **Globally synchronized time via datacenter networks,** LEE, K. S., WANG, H., SHRIVASTAV, V., AND WEATHERSPOON, H. Proceedings of the 2016 conference on ACM SIGCOMM 2016 Conference (2016), ACM, pp. 454–467.*
  - *[1] www.nist.gov/pml/time-and-frequency-division/services/internet-time-service-its*

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