VIAVI Solutions

Retrofitting At-Risk Legacy GPS/GNSS Equipment with a Resilient and Cost-Effective PNT Solution

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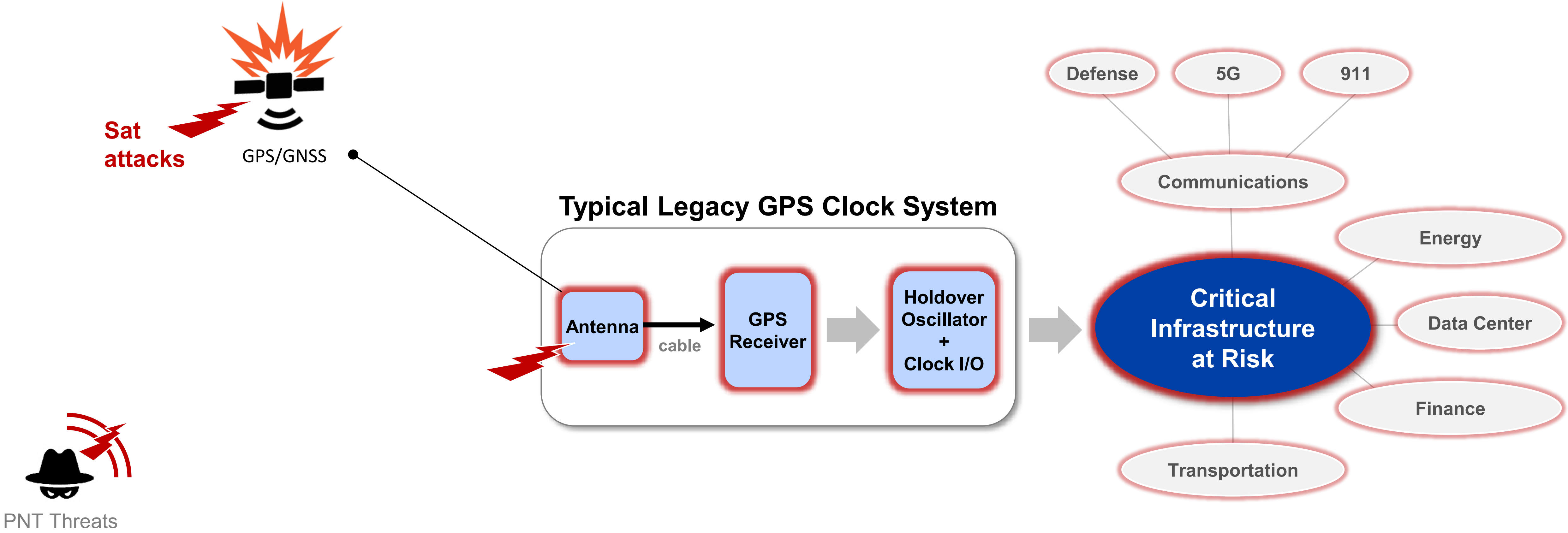
| 9/16/24 | CGSIC @ ION GNSS+ | 11:10-11:30a ET | Baltimore, MD

Problem: Current At-Risk Legacy GPS/GNSS Clocks from Jamming/Spoofing Attacks



Are GPS/GNSS Jamming/Spoofing Threats Real & Increasing in Frequency?

NEWS UKRAINE WAR Oct 27, 2022

Russia threatens to shoot down Western satellites for helping Ukraine

GPS GNSS POSITIONING NAVIGATION TIMING WORLD

Jan 21, 2022

What happened to GPS in Denver?

Disruption *"lasted for 33.5 hours. Wireline and cellular providers had timing backup systems and were unaffected. A radio system with no backups suffered, as did a simulcast radio system that used rubidium backup clocks"*

ET Satcom.com From ETTelecom March 19, 2022

Ukraine war disrupts GPS in Finland, Mediterranean

DAILY HONKER Oct 19, 2022

Mysterious GPS Disruptions Spread Across Texas; FAA Issues Warning to Pilots (Dallas airport)

Industrial Cyber

April 3, 2023

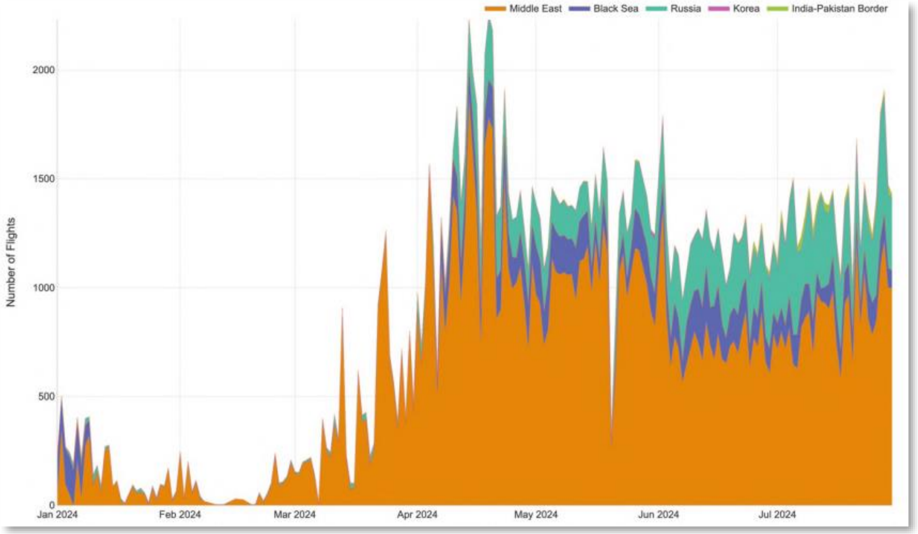
GhostSec hackers target satellite receivers, as threats toward satellite communication networks gradually rise

WAR IN SPACE

THE NEXT BATTLEFIELD

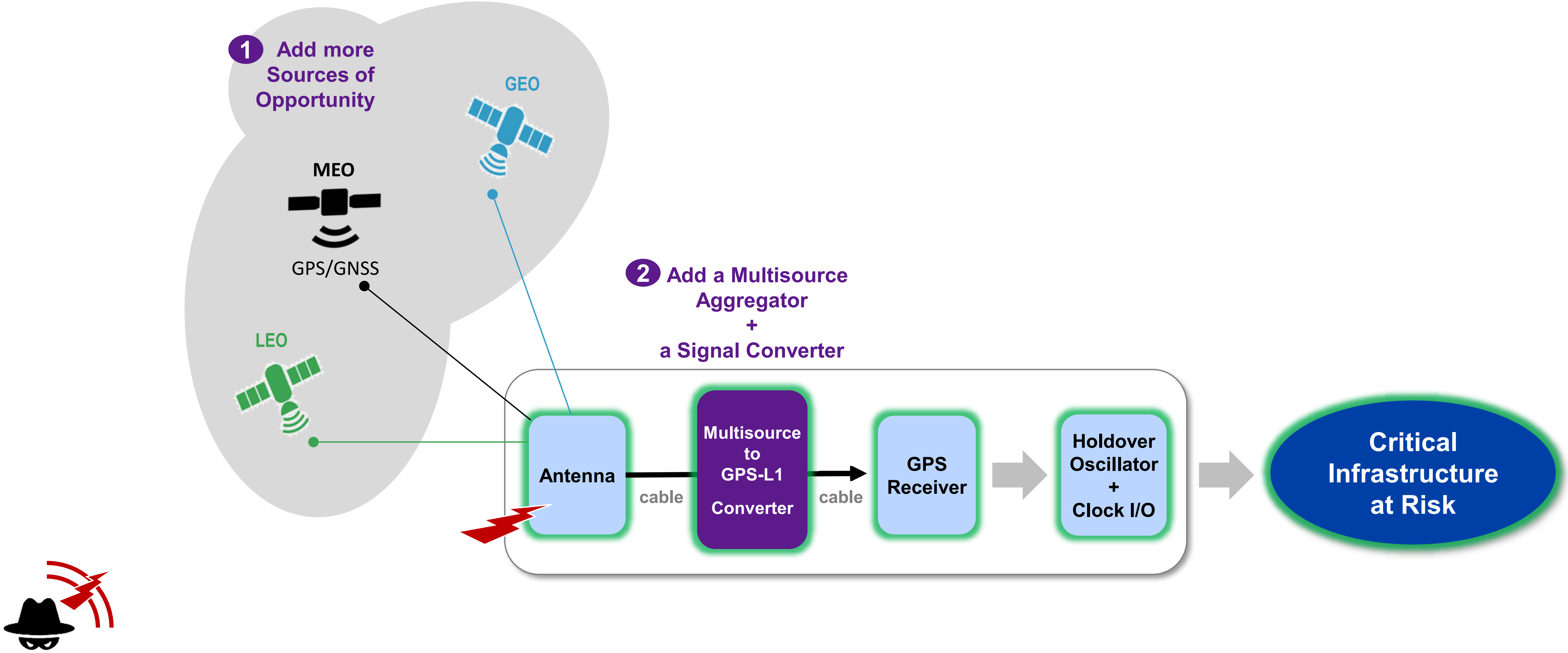
What would happen to America if GPS was attacked? Feb 1, 2017

GPS Spoofing Report by the OPSGROUP



Daily flights affected by GPS spoofing by region in 2024 Sep 6, 2024

Solution: Concept of Retrofitting At-Risk Legacy GPS/GNSS Clocks with Multisource Resiliency



1 Add more Sources of Opportunity
GEO
MEO
GPS/GNSS
LEO
2 Add a Multisource Aggregator + a Signal Converter
Antenna
cable
Multisource to GPS-L1 Converter
cable
GPS Receiver
Holdover Oscillator + Clock I/O
Critical Infrastructure at Risk

Integrating AI Sensor Fusion Function into the Multisource-to-GPS-L1 Converter

1. **Multisource Sensor Fusion Attributes**
   - ✓ **Inputting** constellation Almanacs & Ephemerides (GNSS, LEO, GEO)
   - ✓ **Fusing** all internal and external PNT sources
   - ✓ **Weighing** the quality of all the sources
   - ✓ **Predicting** optimal estimation of current PNT state

2. **Zero-Trust AI-based Jamming/Spoofing Detection & Mitigation**
   - ✓ **Authenticating** select sources that support NMA like Galileo OSNMA
   - ✓ **Verifying** all the sources thru the analytics of Almanacs/Ephemerides' observables
   - ✓ **Qualifying** and selecting the best source
   - ✓ **Learning** patterns/behaviors from large datasets to apply ML/DL/neural network models
   - ✓ **Going into holdover** before switching to the best source for hitless phase switching

Analyzing the Resiliency of Multisource Services for GPS/GNSS Backup

Multisource Services	GPS/GNSS	eGNSS(2) GEO	altGNSS(4) GEO-L	altGNSS LEO-S	Future Sources
Sat operator / orbit	MEO	MEO + Inmarsat GEO	Inmarsat GEO	Iridium LEO (STL)	xEO
Sat frequency band	L	L	L	L	Others like Ku
Accuracy	<±15ns	<5ns	<100ns(5)	<80ns(5, 7)	Various
GNSS authentication	X GPS ✓ Galileo OSNMA(1) only	✓ NMA on GPS, etc.	✓coupled w eGNSS GEO	✓coupled w eGNSS GEO	tbd
↳ **Anti-spoofing detection / mitigation**	X	✓	✓	✓	
Encryption	X GPS M-Code & Galileo PRS only	✓	✓	✓	
Jamming resistance	X	X	✓✓(6)	✓(8)	
Indoor antenna	X	X	X	✓(8)	
Standard antenna	✓ Outdoor	✓ Outdoor	✓ Outdoor (parabolic - best resilience)	✓ Indoor / Outdoor	
Over-the-air 1-way key activation/upgrade	X	✓	✓	X	
Ground control source	GNSS-based	GNSS and non-GNSS(3)	Non-GNSS(3)	Non-GNSS(3)	
Current available coverage	Global	Global	Global	Region on request	
Traceability	UTC	UTC	UTC(NIST/PTB)	UTC(NIST)	UTC

(1) Thru Open Service Nav Message Authentication
(2) enhanced GNSS source
(3) Proprietary ground stations
(4) alternative GNSS-independent source
(5) Meets ITU-T PRTC-A standard
(6) If an L-band parabolic antenna is used
(7) Typical accuracy, peak-to-peak, with an outdoor antenna & a Rb oscillator
(8) X1000 stronger signals from LEO sats making STL work in indoor environments

Detecting GPS/GNSS Spoofing Attacks with the eGNSS GEO’s NMA Service

Spoofing indicators

1. Health status

2. Detection commands

   gps:spoof?

   0: no spoofing

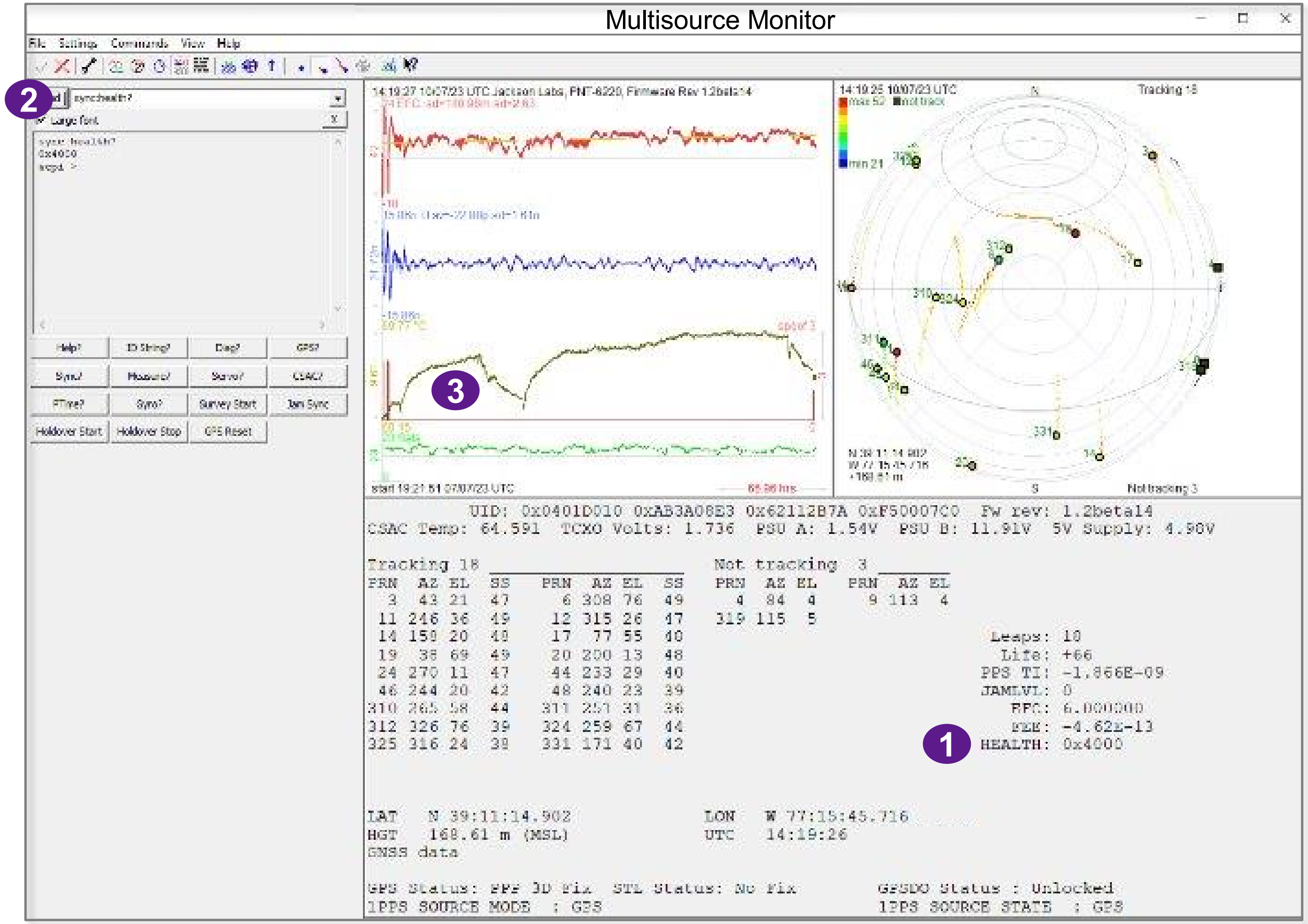
   1: spoofed detected w std algo

   2: spoofed detected w ETA* algo

   3: spoofing detected w both std & ETA* algos

   **Enhanced Timing & Authentication (AI Sensor Fusion Function)*

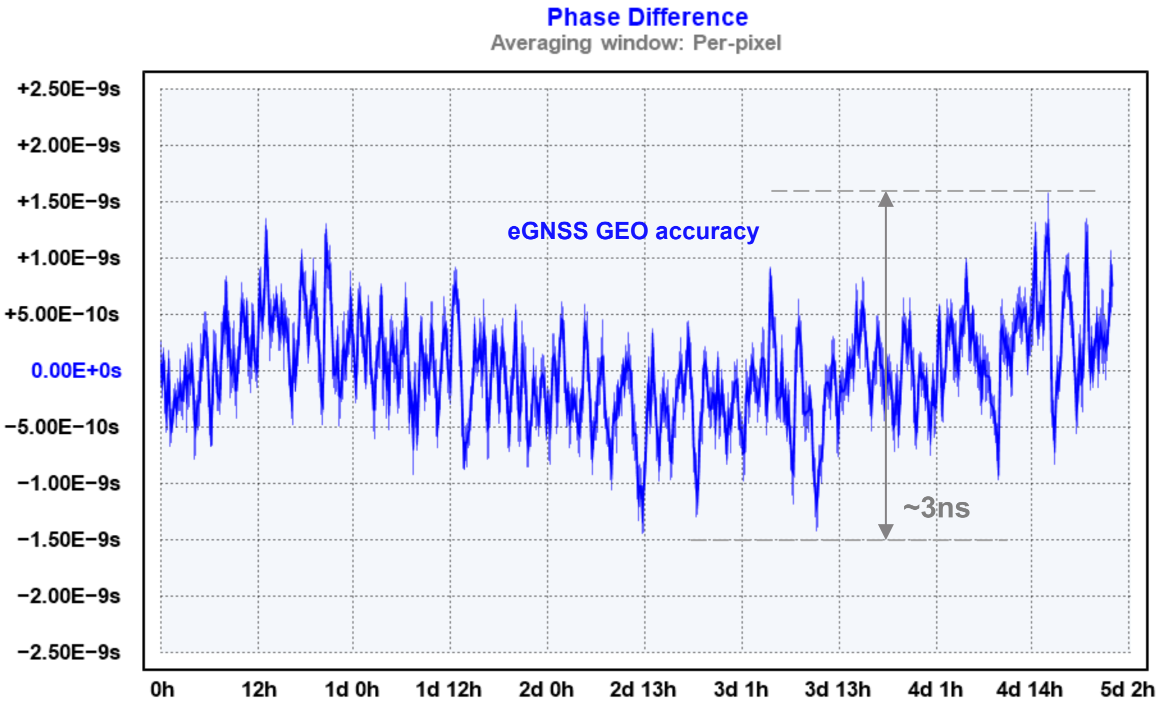
3. Detection/Mitigation graphs



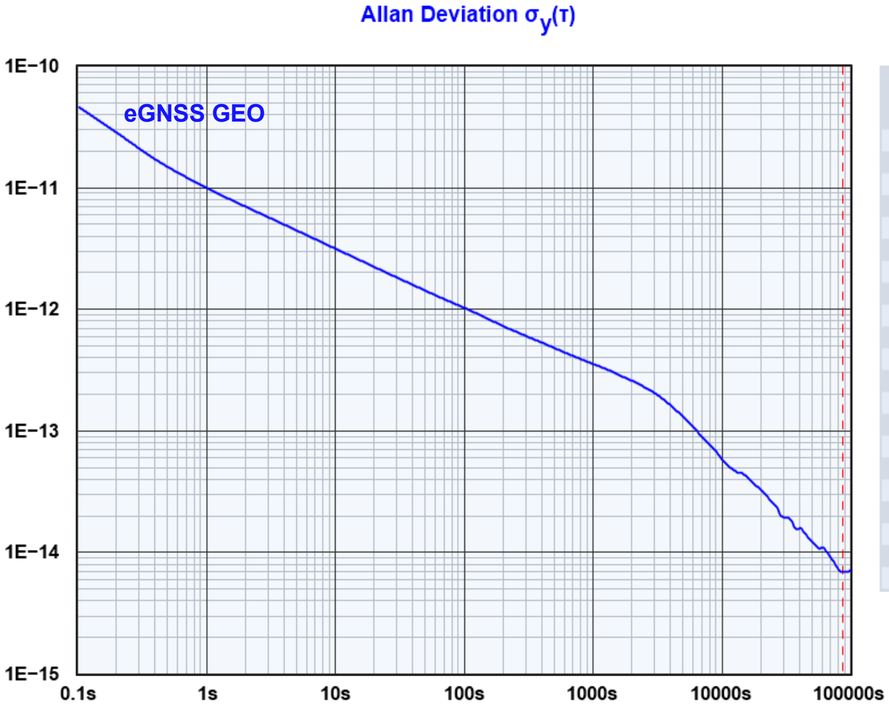
```
sync:health?
0x4000
scpi >
```

```
          UID: 0x0401D010 0xAB3A08E3 0x62112B7A 0xF50007C0  Fw rev: 1.2beta14
CSAC Temp: 64.591  TCXO Volts: 1.736  PSU A: 1.54V  PSU B: 11.91V  5V Supply: 4.90V

Tracking 18 ________________          Not tracking  3 _______
PRN  AZ  EL   SS    PRN  AZ  EL   SS  PRN  AZ  EL    PRN  AZ  EL
  3  43  21   47      6 308  76   49    4  84   4      9 113   4
 11 246  36   49     12 315  26   47  319 115   5
 14 159  20   40     17  77  55   40                             Leaps: 18
 19  38  69   49     20 200  13   48                              Life: +66
 24 270  11   47     44 233  29   40                            PPS TI: -1.866E-09
 46 244  20   42     48 240  23   39                            JAMLVL: 0
310 265  58   44    311 251  31   36                               EFC: 6.000000
312 326  76   39    324 259  67   44                               FEE: -4.62E-13
325 316  24   39    331 171  40   42                            HEALTH: 0x4000


LAT   N 39:11:14.902                  LON   W 77:15:45.716
HGT   168.61 m (MSL)                  UTC   14:19:26
GNSS data

GPS Status: PPP 3D Fix  STL Status: No Fix          GPSDO Status : Unlocked
1PPS SOURCE MODE  : GPS                             1PPS SOURCE STATE  : GPS
```

Visualizing the eGNSS GEO Service’s Accuracy/Stability Performance



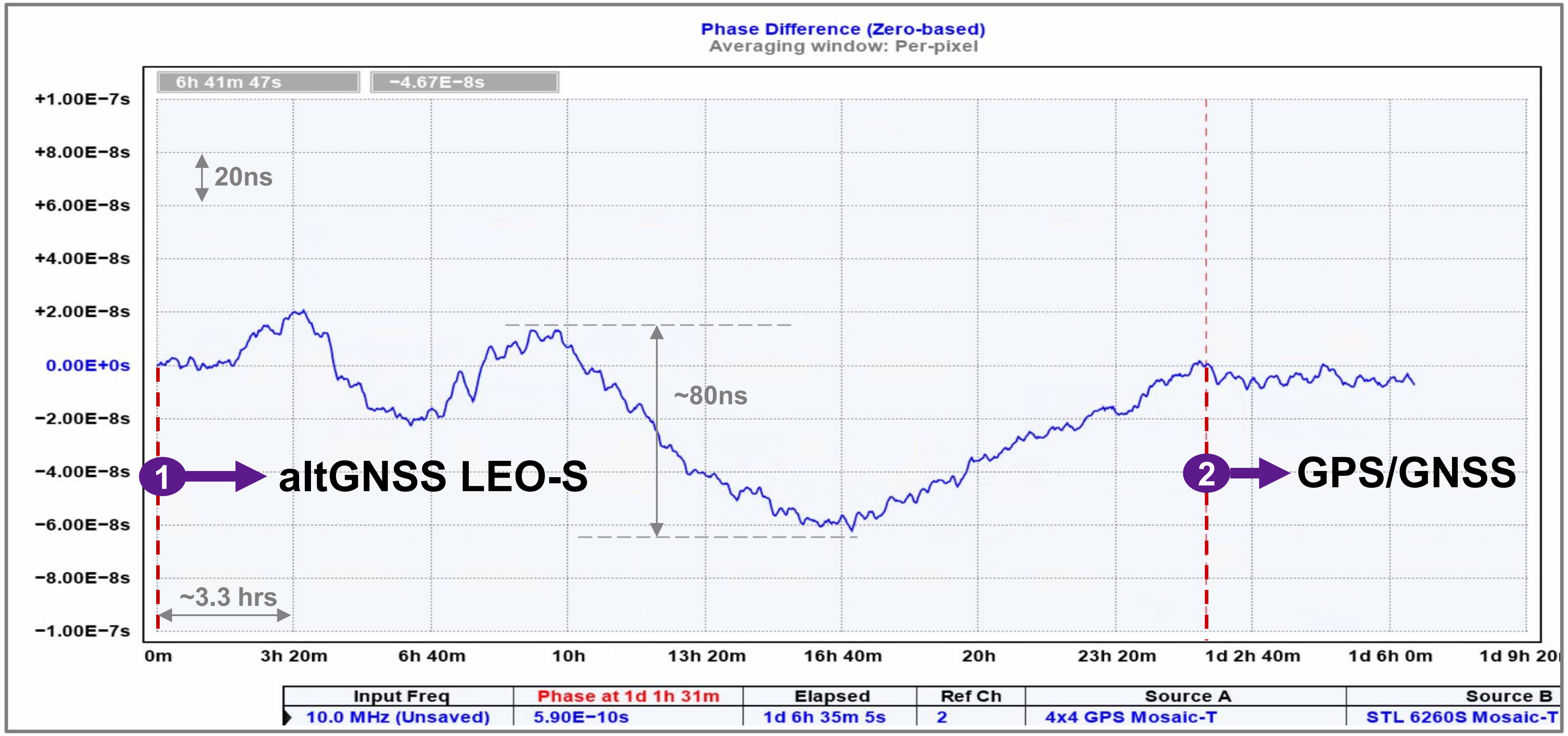
Input Freq	Elapsed	Instrument	Source A	Source B
10.0 MHz	5d 0h 0m 0s	Microchip 53100A	PNT Clock w/ETA	VCH1006 (Maser)



Tau	Sigma(Tau)
1s	1.00E−11
2s	7.03E−12
4s	5.00E−12
8s	3.54E−12
10s	3.17E−12
20s	2.24E−12
40s	1.60E−12
80s	1.14E−12
100s	1.03E−12
200s	7.32E−13
400s	5.35E−13
800s	3.92E−13
1000s	3.57E−13
2000s	2.60E−13
4000s	1.61E−13
8000s	7.61E−14
10000s	5.78E−14
20000s	3.28E−14
40000s	1.61E−14
80000s	7.15E−15
100000s	7.31E−15

Input Freq	ADEV at 86400s	Elapsed	Instrument	Source A	Source B
10.0 MHz	7.06E−15	5d 0h 0m 0s	Microchip 53100A	PNT Clock w/ETA	VCH1006 (Maser)

Multisource Switching from GPS to LEO when GPS/GNSS is Spoofed



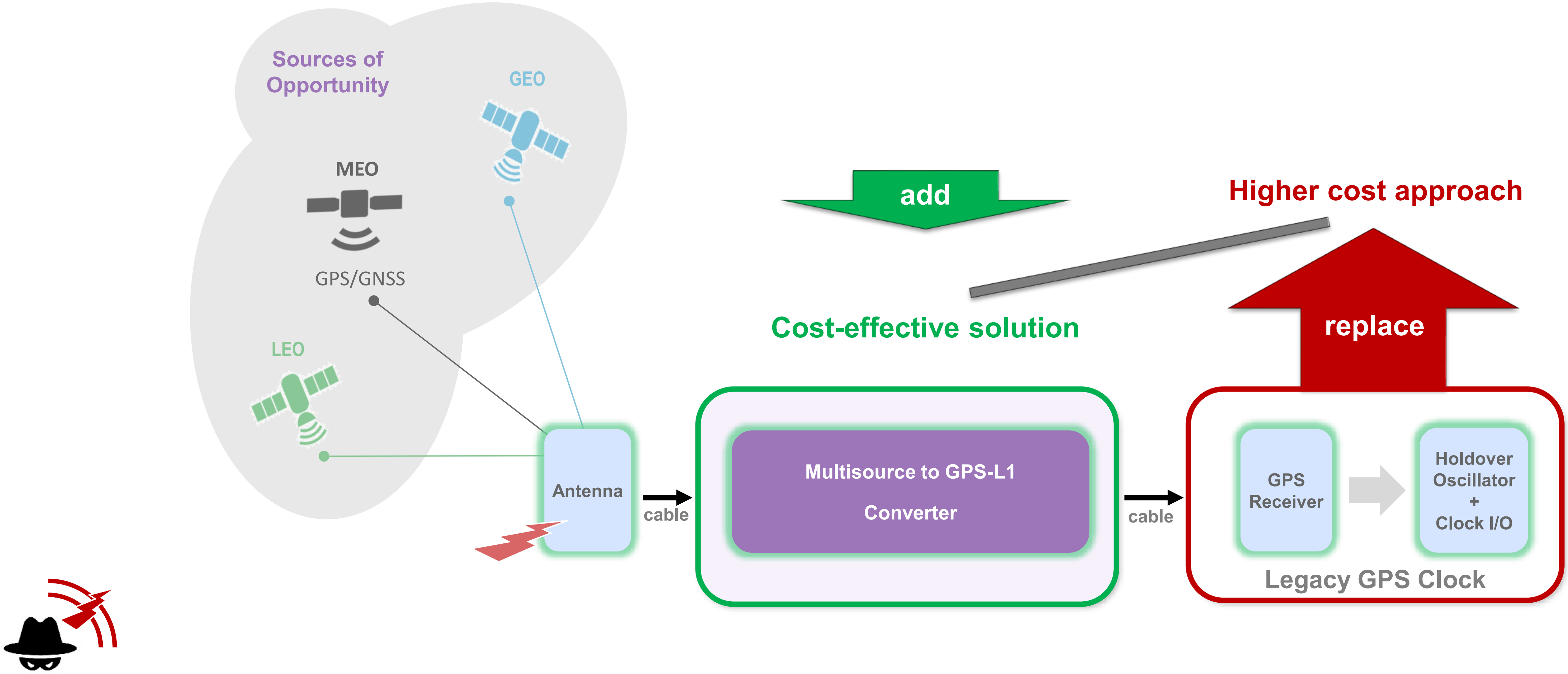
Input Freq	Phase at 1d 1h 31m	Elapsed	Ref Ch	Source A	Source B
10.0 MHz (Unsaved)	5.90E−10s	1d 6h 35m 5s	2	4x4 GPS Mosaic-T	STL 6260S Mosaic-T

GPS/GNSS

1 GPS spoofing detected from the eGNSS GEO’s NMA service, so switching to the altGNSS LEO-S (alternative Iridium LEO STL) service

2 GPS spoofing no longer detected, so switching back to the GPS/GNSS source

Weighing the Cost of Adding a Multisource Resiliency Device vs. Replacing a Legacy GPS Clock



Thank you!

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