Locata

DEFIS Alt-PNT "Demo Day"
Locata Technology Overview

Timing Tests Results

JRC Ispra Campus
18 May 2022

JRC
EUROPEAN COMMISSION

18 May 2022 – DEFIS "Demo Day": Over 100 EU execs, researchers & engineers came to the **Joint Research Centre** to see the performance of non-GNSS positioning & timing technology on display. In the morning Locata demonstrated our indoor positioning technology, followed by an indoor timing demo. After lunch, in the JRC conference centre, Locata and EU engineers also presented **the results of Locata A-PNT testing run by JRC engineers over a 3-month period**

18 May 2022 – DEFIS "Demo Day": After lunch, in the JRC conference centre, Locata and EU engineers also presented **the results of Locata A-PNT testing run by JRC engineers over a 3-month period**

What has Locata invented?

A suite of completely unique new capabilities which overcome the many limitations of space-based positioning & timing.

Locata broadcasts a proprietary signal

THAT <u>ONE</u> SIGNAL <u>SIMULTANEOUSLY</u>

1. Synchronizes our transmitters to picosecond levels
2. Enables cm-level positioning indoors and out; and
3. Enables exceptional new multipath mitigation.

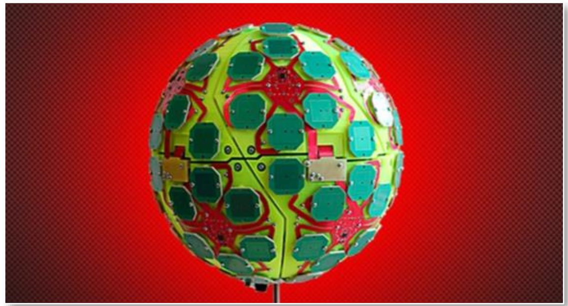
<u>Without</u> atomic clocks, satellites, external corrections…

Locata Technology Platform Components

Over 150 patented advances have made Locata the world leader for enabling new capabilities in next-generation positioning applications

NETWORK Creates the Signals

- **A LocataLite** - the heart of Locata developments
- Ground-based hardware equivalent of a $250M satellite
- World-first capabilities = unprecedented performance



ANTENNA Maximizes Mobile Use

- **VRay Antenna** is the enabler for myriad new apps
- Totally new concept – first major change in 80 years
- Delivers high-accuracy in areas where GPS just *fails*

SOFTWARE Extremely Adaptable

- **Locata IP** - the brains for Locata, with >150 patents!
- Over 3.6 million lines of code = reinvented GPS
- **Delivers new capabilities that GPS will <u>never</u> replicate**

Locata DEFIS Demonstration - Tested Scenarios

Key PNT system capabilities

- Time transfer
- Indoor and outdoor positioning
- System resilience
- System remote monitoring

Timing

- Nano second – level timing
- To static & kinematic Locata devices
- T2 scenarios
  - Over-the-air: T2B, T2C, and T2E
  - Copper/ coax: T2A
  - Fibre optic: T2D
- T3
  - Same as T2C but longer than 24 hrs

Positioning

- cm-level positioning
- Static & kinematic positioning
- T6
  - Industrial automation application
  - Shown at a Locata customer facility
- T7
  - Indoor mobile platform
  - Shown at JRC

Locata's extremely **comprehensive test plan set out to demonstrate** to the EU **our performance** for **every capability**, **in all scenarios**, **required** for a true, Alternative Positioning, Navigation & Timing system!

Test Scenario Name (System Validation T1 & T5 not shown)
Short term clock stability & time transfer performance @JRC
T2A – Copper/coax cable
T2B – Over-the-Air (OTA) indoor
T2C – OTA outdoor local area
T2D – Fibre optic
T2E – OTA outdoor wide area
Medium term clock stability & time transfer performance @JRC
T3C – OTA outdoor
Kinematic outdoor positioning @Locata customer facility
T6 – Outdoor
Static & Kinematic indoor positioning @JRC
T7 - Indoor
Resilience & network monitoring (same as T4) @JRC
T8A – Remote monitoring
T8B – Bracing
T8C – Dual Master

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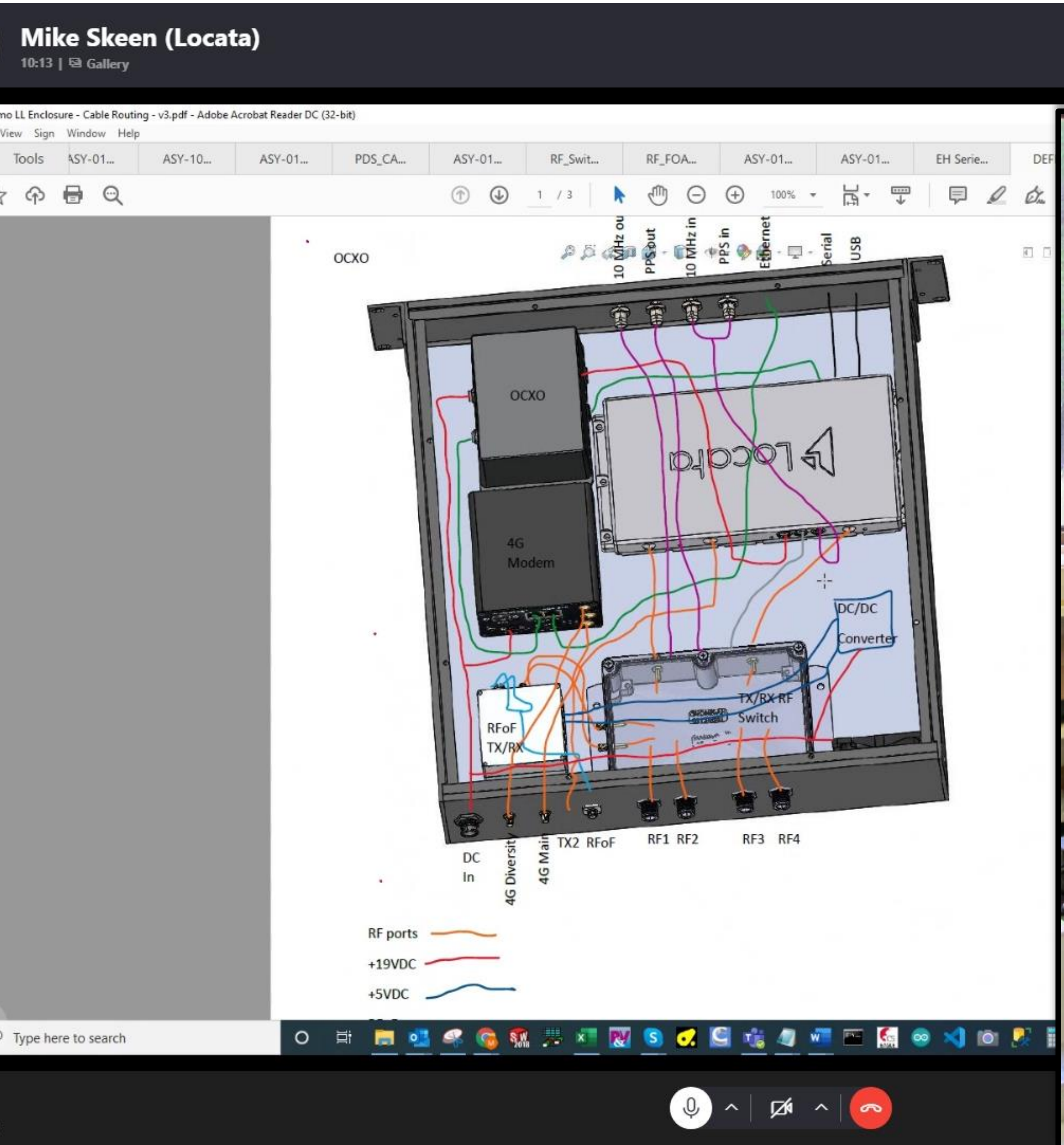
Locata DEFIS Demonstration Development



Locata DEFIS Demonstration Example Sites

Locata DEFIS Demonstration Example Sites

JRC EUROPEAN COMMISSION

Locata DEFIS Demonstration Example Sites

Another Locata transmitter 44 km away

To revolutionize PNT you first have to **reinvent** fundamental concepts of **synchronization**

TimeLoc

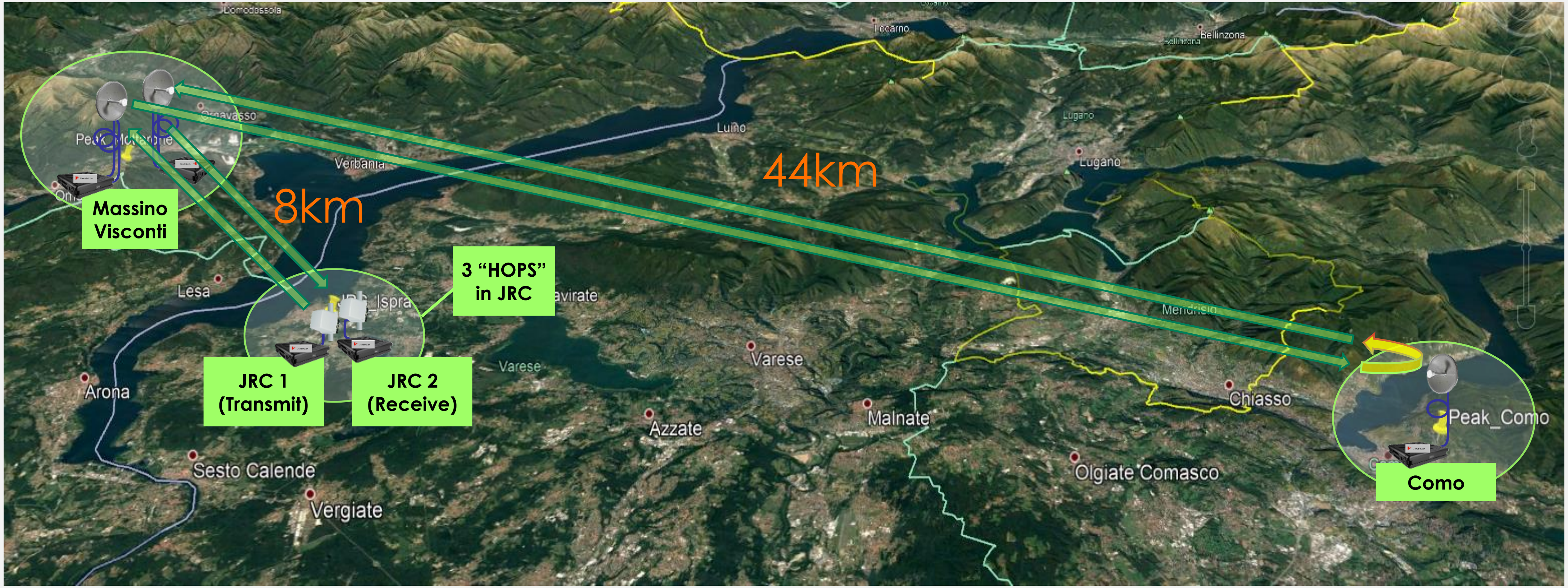
Sub-nanosecond synch

Without atomic clocks

Without GNSS satellites

Without external corrections

Frankly TimeLoc sounds…. “unbelievable”



Details of Test Configuration

105km total Time Transfer distance – JRC to Como & back

TimeLoc Cascaded through **8 “HOPS”**

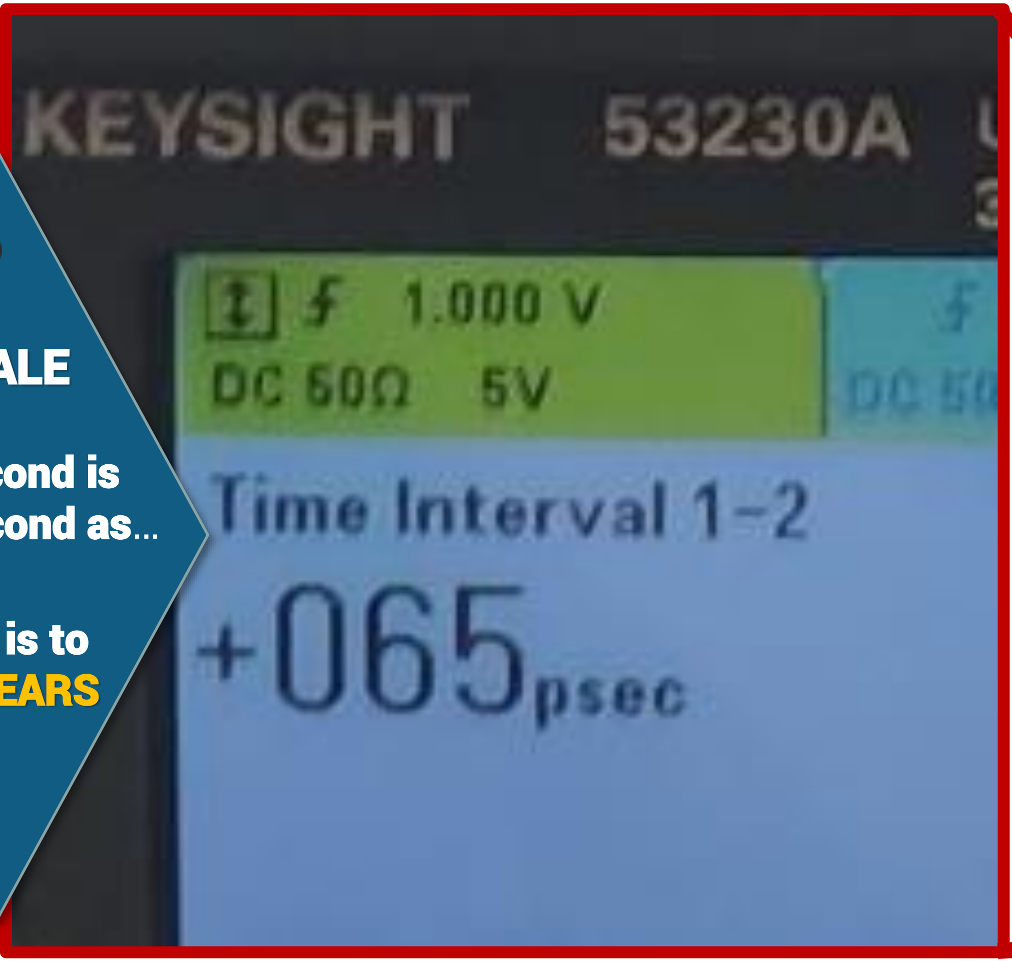
>24-hour test. Just 1 milliwatt transmission power!

Tropospheric adjustments generated and applied continuously, in real time

Locata

JRC TimeLoc testing

After 8 TimeLoc “hops” over 105km

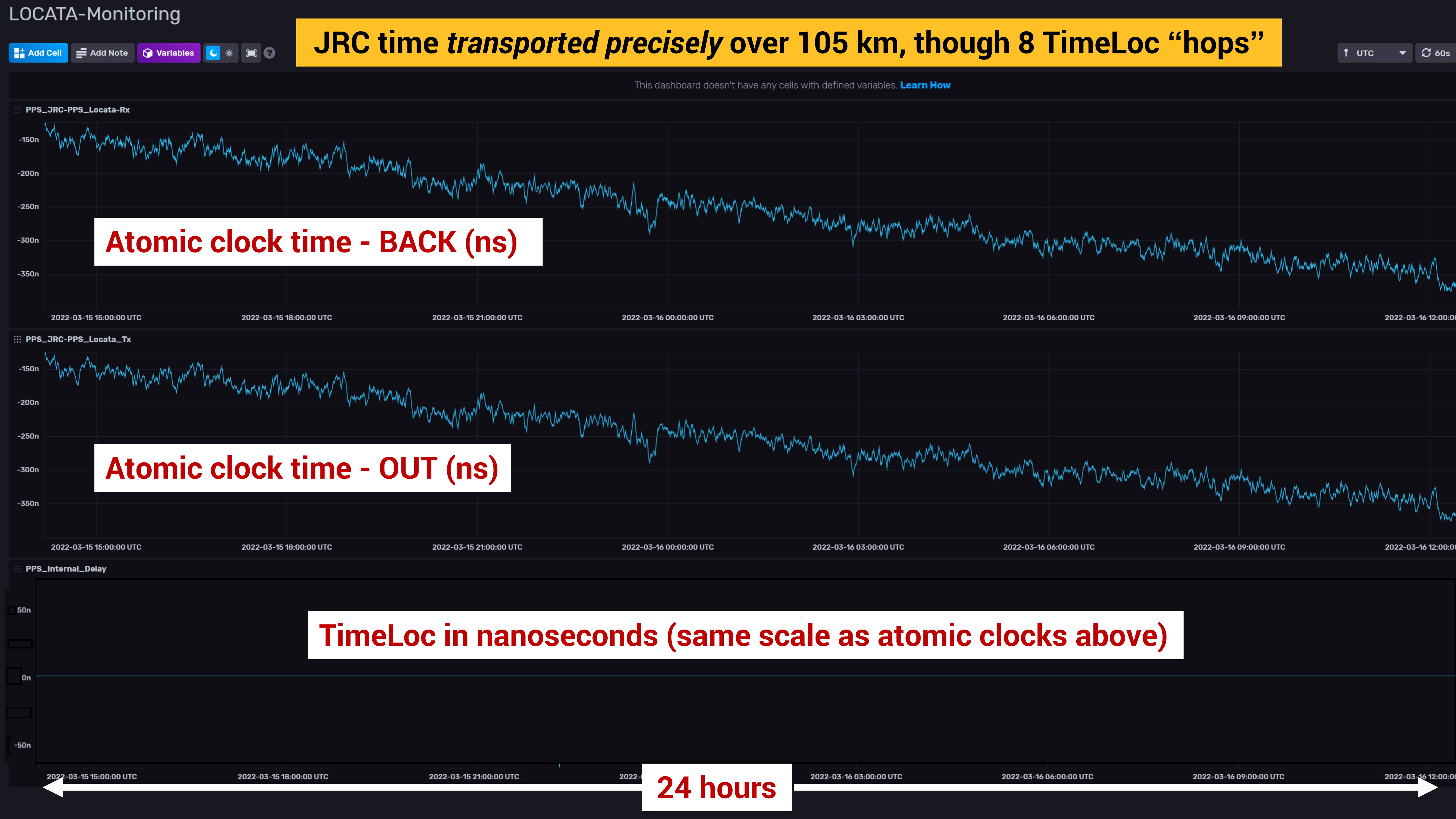


FOR SCALE

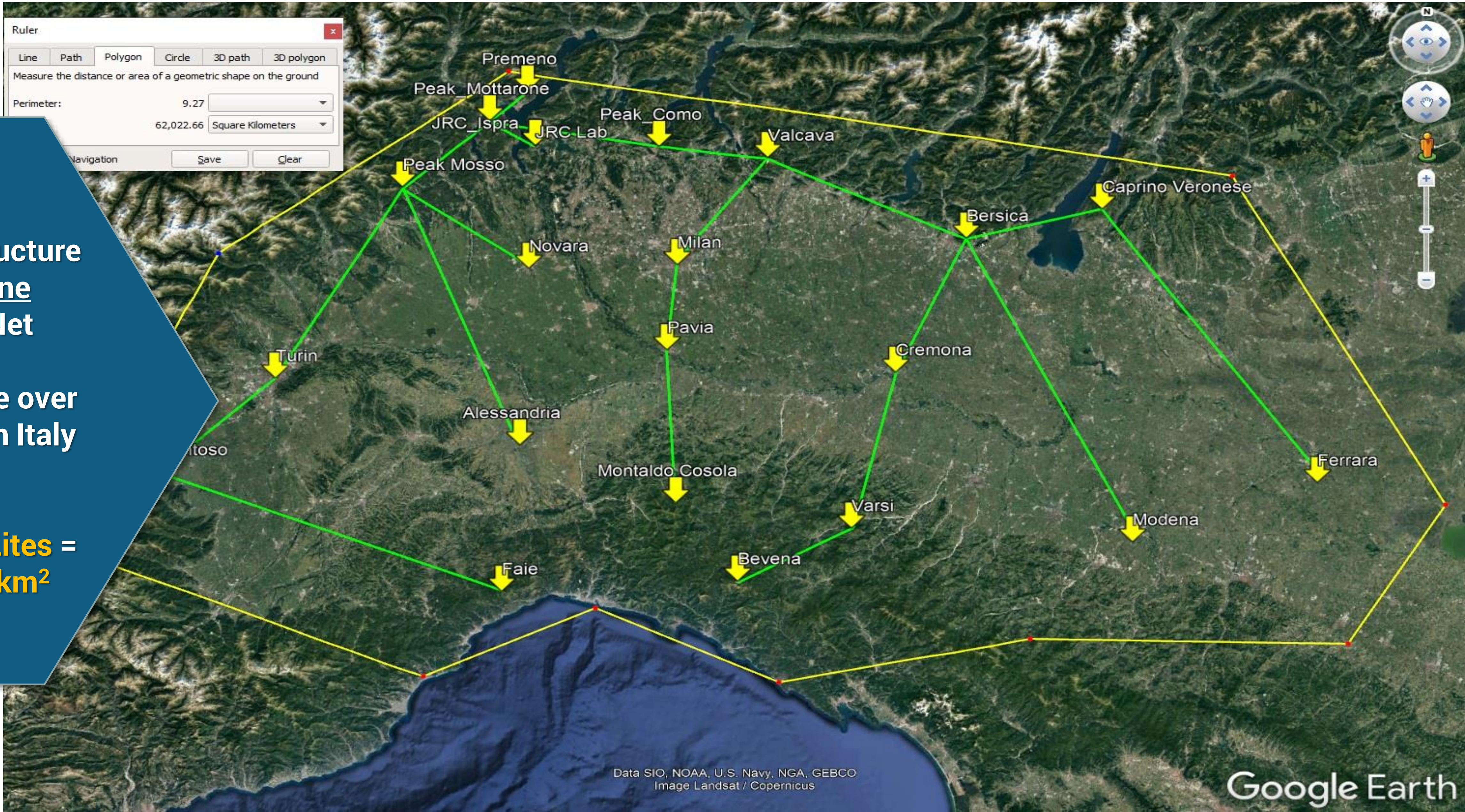
1 picosecond is to 1 second as…

1 second is to 31,700 YEARS

Picoseconds!


LOCATA-Monitoring
JRC time *transported precisely* over 105 km, though 8 TimeLoc "hops"
Add Cell
Add Note
Variables
UTC
60s
This dashboard doesn't have any cells with defined variables. Learn How
PPS_JRC-PPS_Locata-Rx
-150n
-200n
-250n
-300n
-350n
Atomic clock time - BACK (ns)
2022-03-15 15:00:00 UTC
2022-03-15 18:00:00 UTC
2022-03-15 21:00:00 UTC
2022-03-16 00:00:00 UTC
2022-03-16 03:00:00 UTC
2022-03-16 06:00:00 UTC
2022-03-16 09:00:00 UTC
PPS_JRC-PPS_Locata_Tx
Atomic clock time - OUT (ns)
PPS_Internal_Delay
50n
0n
-50n
TimeLoc in nanoseconds (same scale as atomic clocks above)
24 hours

Example Deployment – Locata as a PNT Backbone



Critical Infrastructure Backbone LocataNet

Example over northern Italy

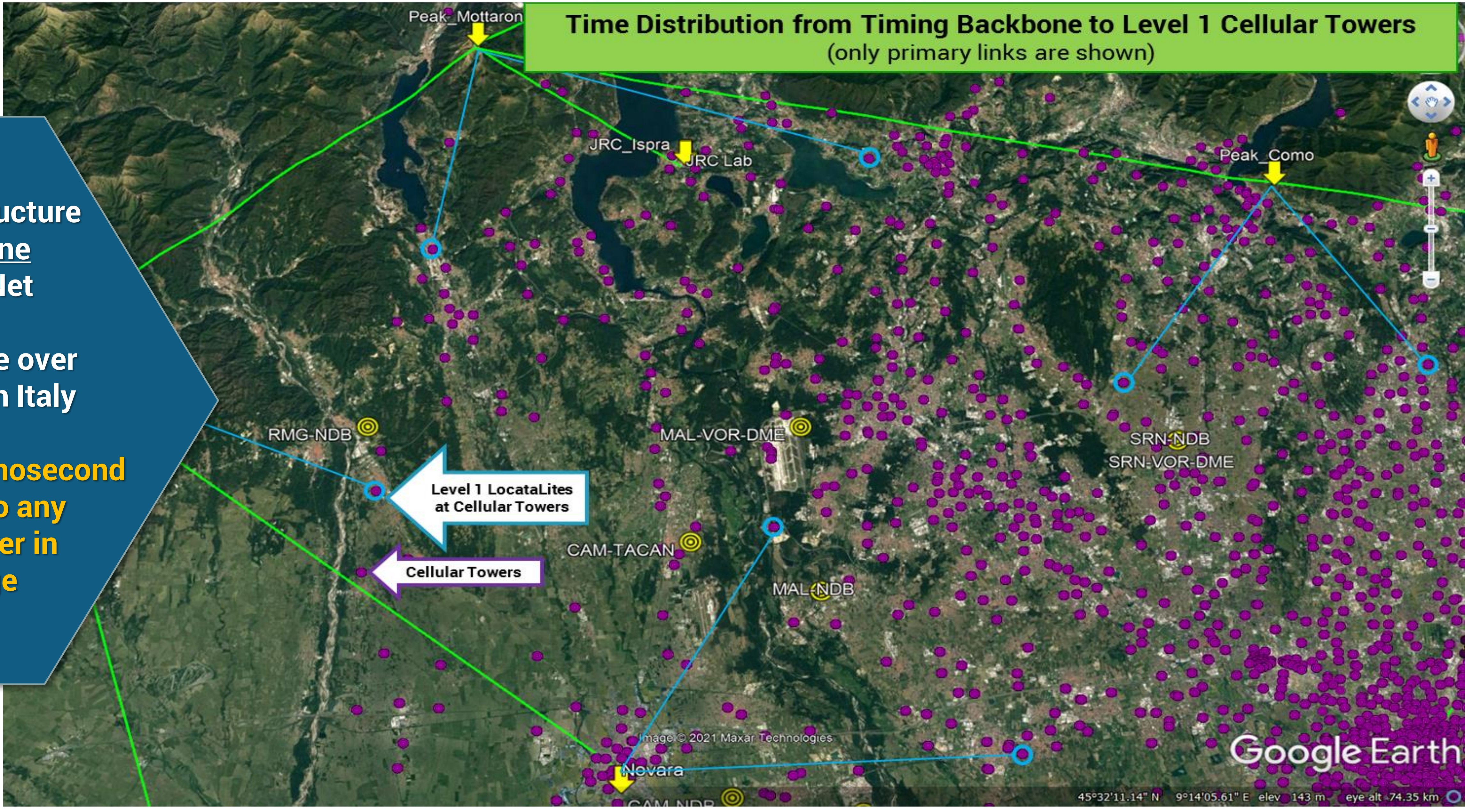
Just 21 LocataLites = 62,000 km²

Example Deployment – Time Distribution to Cell Network

Critical Infrastructure Backbone LocataNet

Example over northern Italy

Sub-nanosecond synch to any cell tower in coverage area

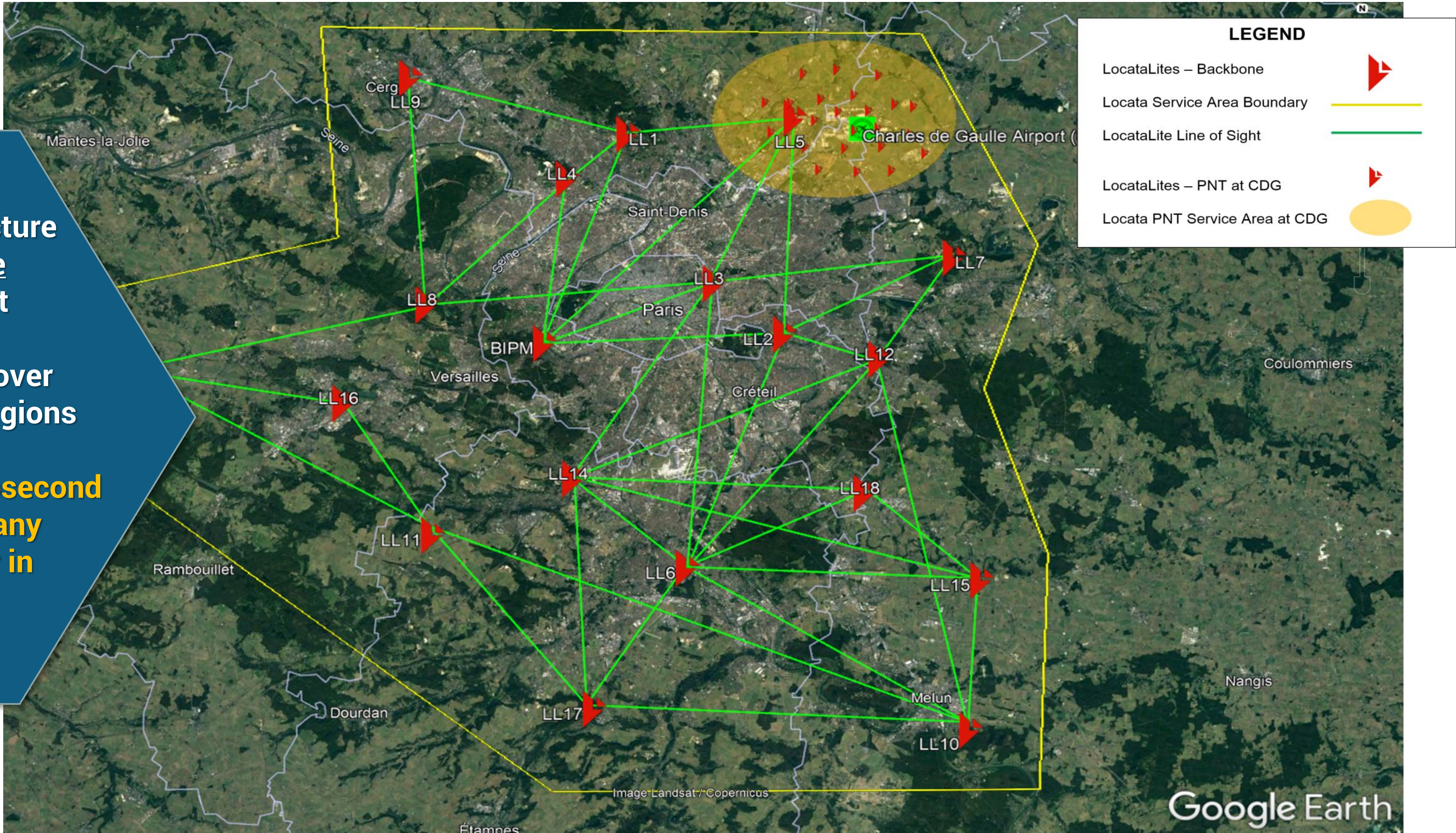


Example Deployment – Time Distribution for Paris

Critical Infrastructure Backbone LocataNet

Example over Paris & regions

Sub-nanosecond synch to any cell tower in coverage area

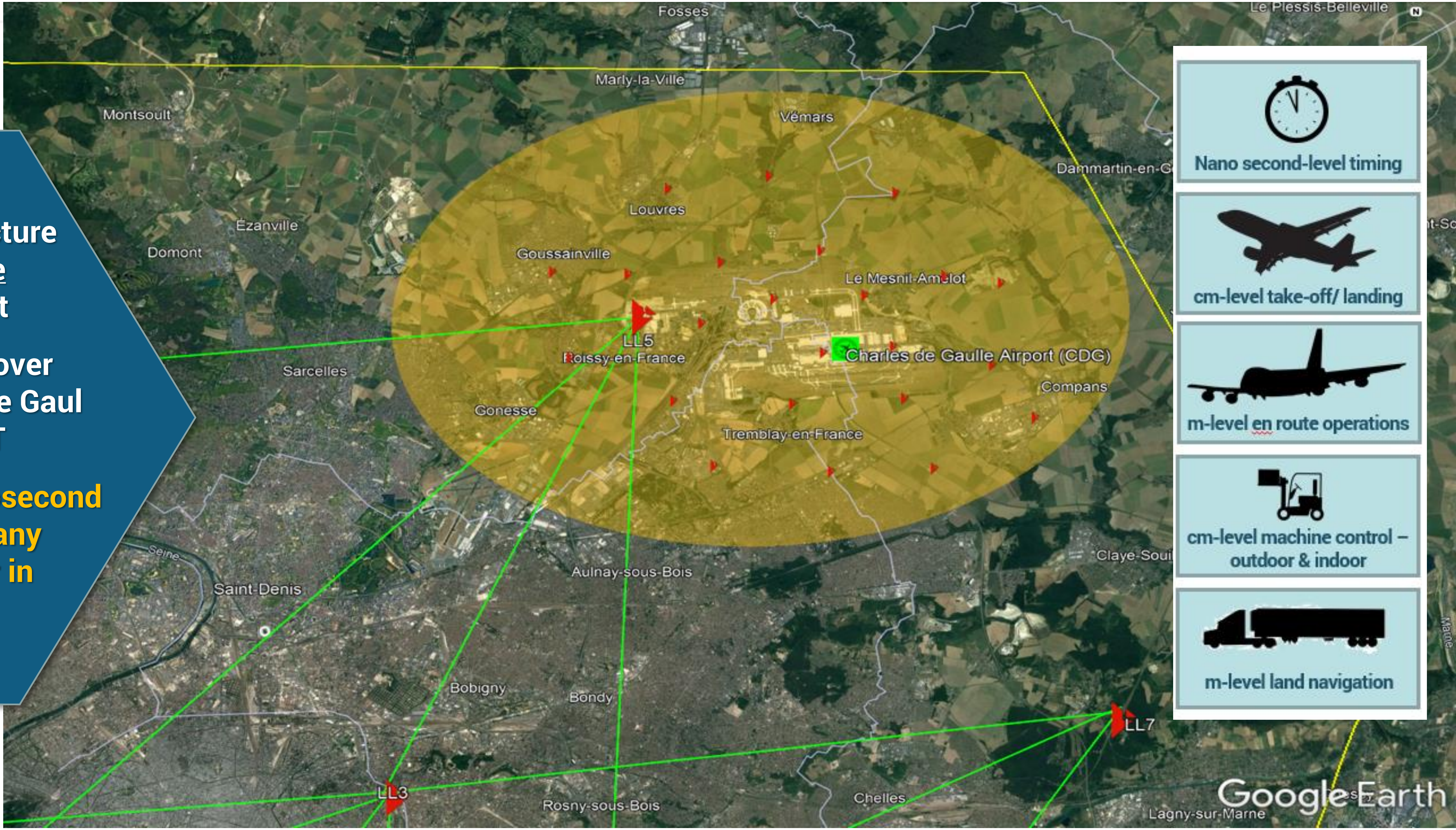


Example Deployment – PNT Distribution for Paris CDG

Critical Infrastructure Backbone
LocataNet

Example over Charles de Gaul for PN & T

Sub-nanosecond synch to any cell tower in coverage area

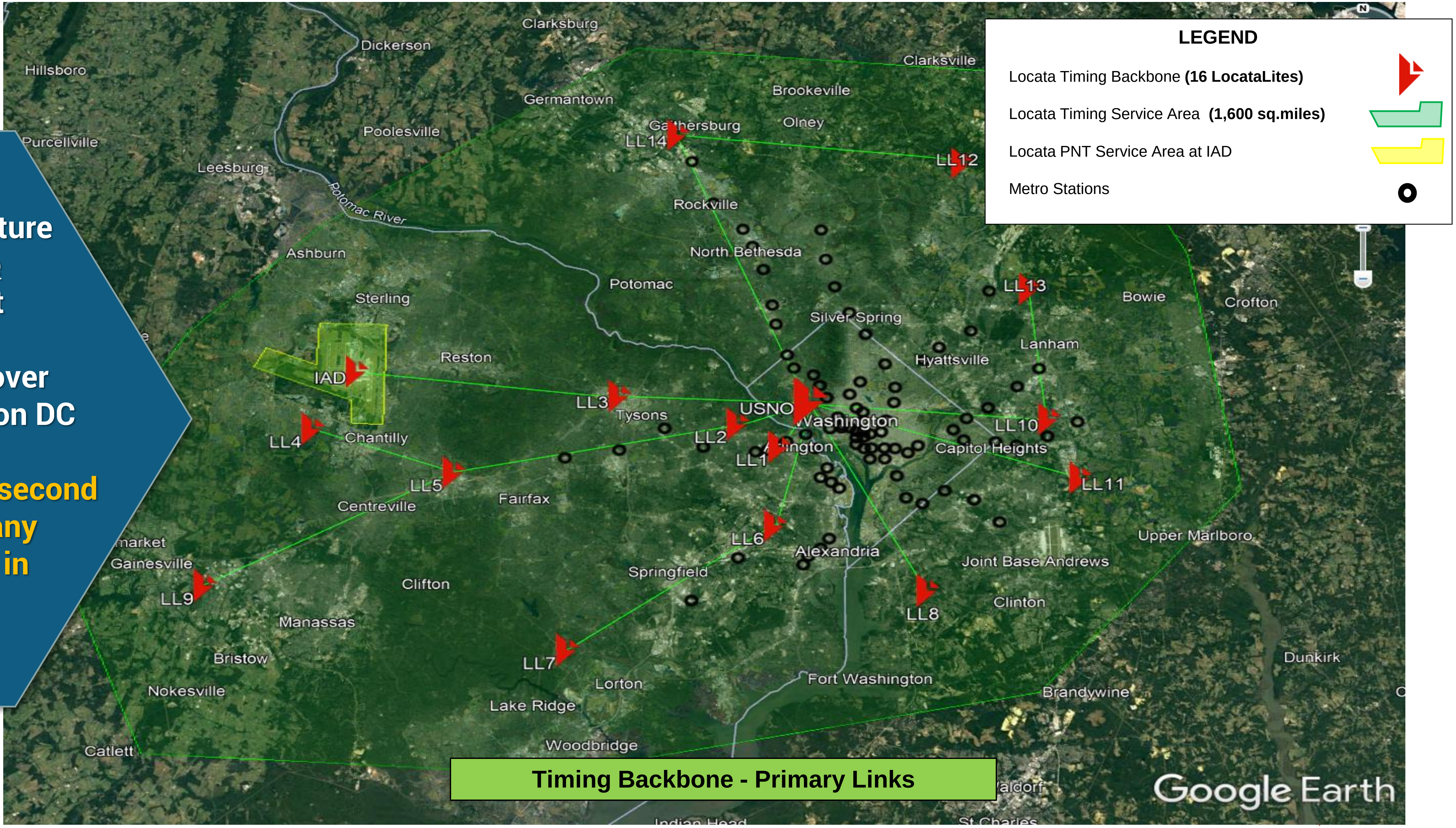


Example Deployment – Time Distribution for Washington DC

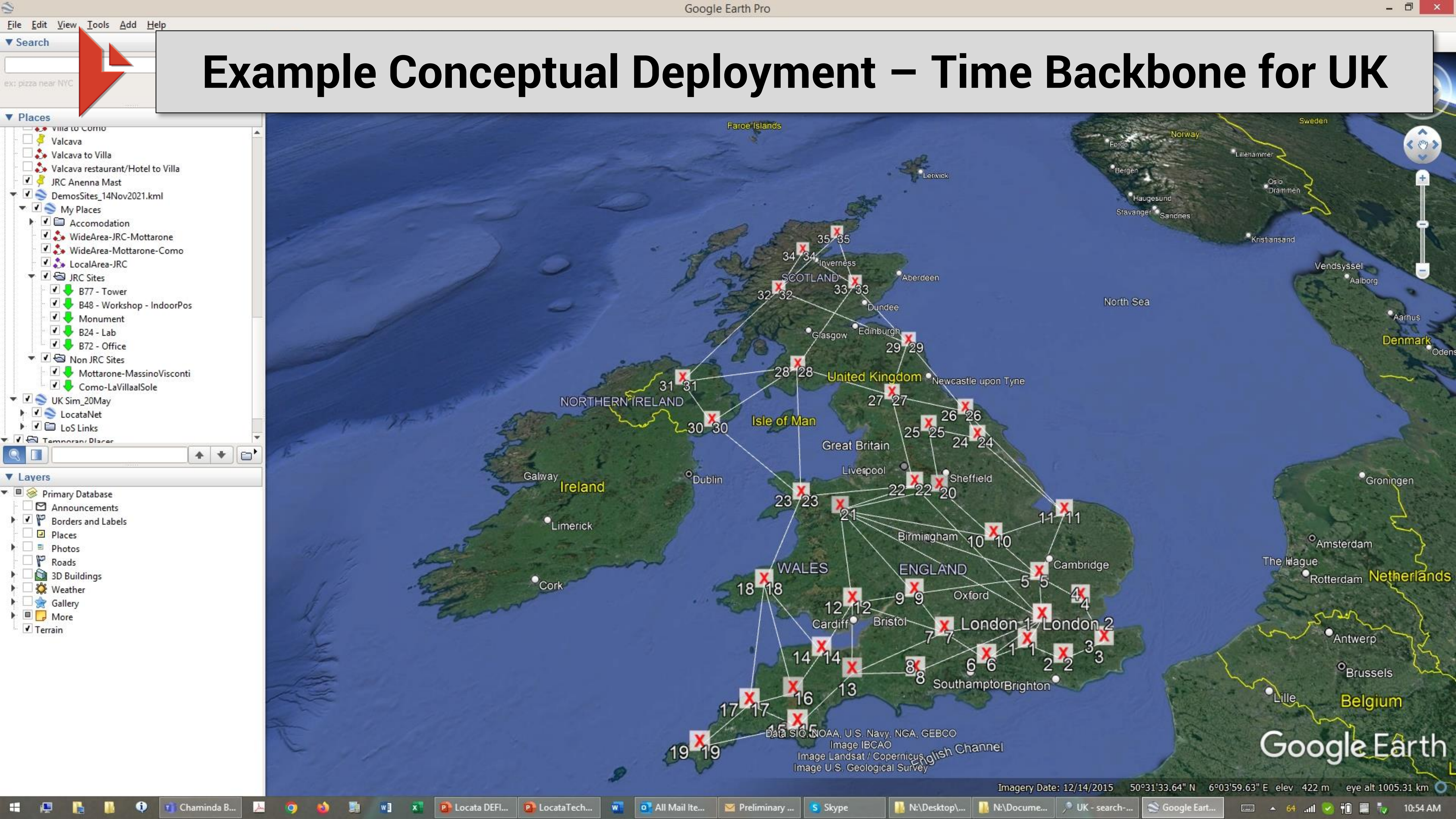
Critical Infrastructure <u>Backbone</u> LocataNet

Example over Washington DC

Sub-nanosecond synch to any cell tower in coverage area



Example Conceptual Deployment – Time Backbone for UK



Locata Timing Tests

Multiple Timing Tests were run over a period of 14 days

They included:

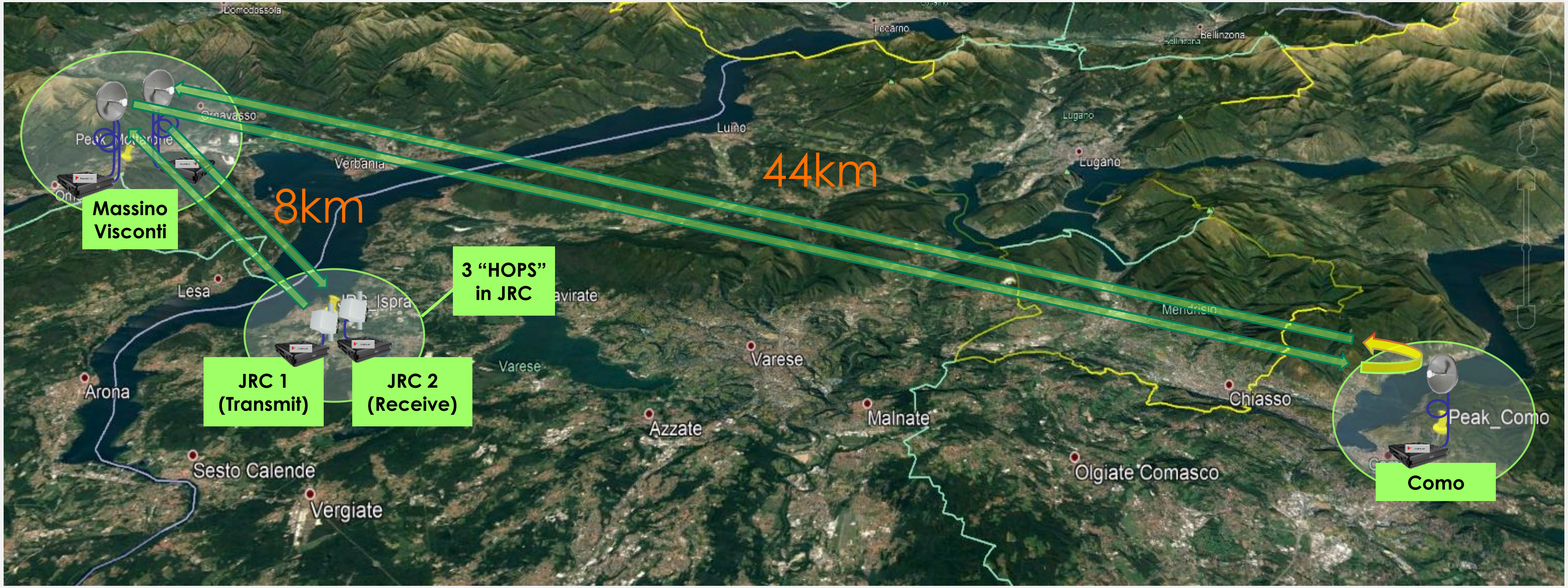
- Over-the-air outdoor wide area
- Over-the-air outdoor local area
- Over-the-air outdoor to indoor
- Over-the-air indoor
- Fibre optic cable
- Copper/coax cable

Indicative Test Results Follow…

RESULTS
#1

OVER-THE-AIR LONG-RANGE WIDE-AREA 24 HOUR TIME TRANSFER TEST

Demonstration of configuration for 'long-range time distribution'



Details of Test Configuration	**105km** total Time Transfer distance – JRC to Como & back	TimeLoc Cascaded through **8 "HOPS"**	**>24-hour test. Just 1 milliwatt transmission power!**	Tropospheric adjustments generated and applied continuously, in real time

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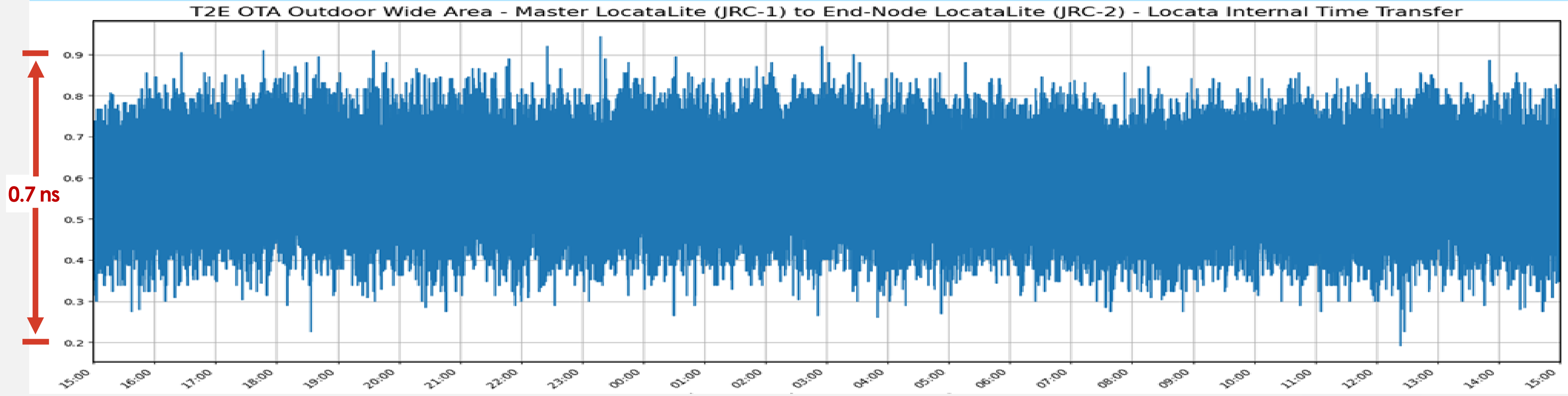
OVER-THE-AIR LONG-RANGE WIDE-AREA 24 HOUR TIME TRANSFER TEST
(105km JRC-Como return, 8 TimeLoc hops)

Locata Internal Time Transfer 24-hours



#1A Internal Time Transfer	#1B External Time Synchronization	#1C External Time Transfer
MEAN: **584 picoseconds**	MEAN: **180 picoseconds**	MEAN: **404 picoseconds**
STD DEV: **85 picoseconds**	STD DEV: **551 picoseconds**	STD DEV: **545 picoseconds**
ALAN DEV: **4.044E-15**	ALAN DEV: **3.209E-14**	ALAN DEV: **2.992E-14**

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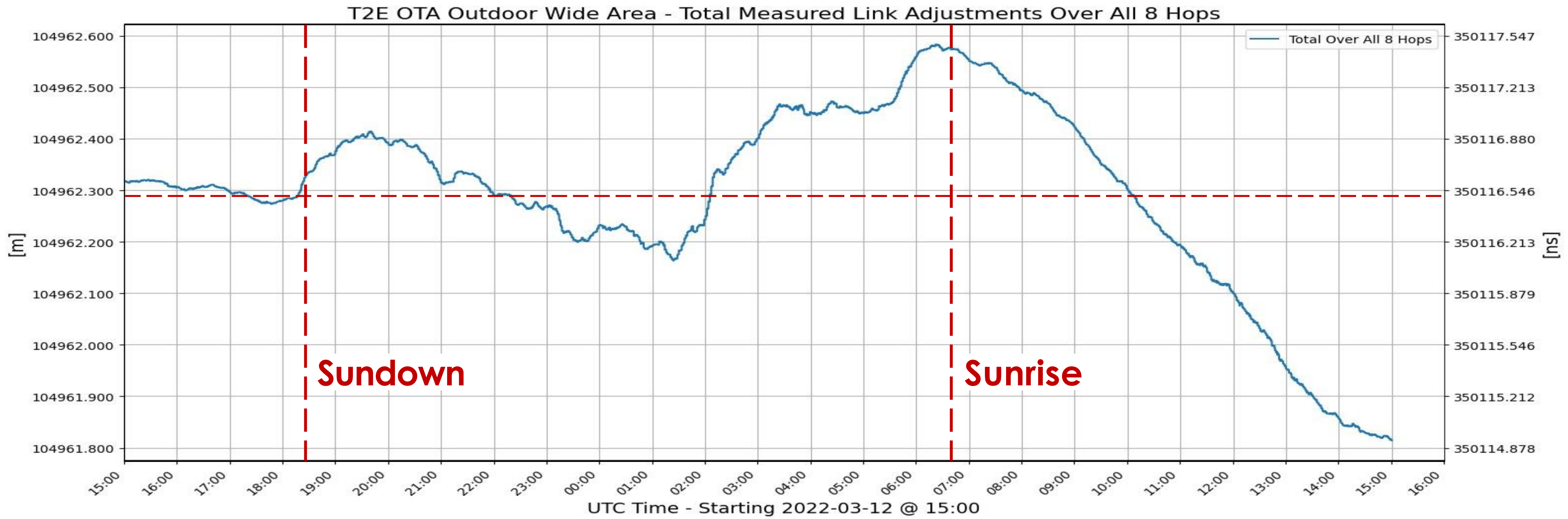
OVER-THE-AIR LONG-RANGE WIDE-AREA 24 HOUR TIME TRANSFER TEST
(105km JRC-Como return, 8 TimeLoc hops)

TimeLoc synchronization automatically adjusts to counter tropospheric effects that change the speed of light



Peak-to-Peak Time Adjustment (over 24 hours)	Peak-to-Peak Distance Adjustment (over 24 hours)
2.6 nanoseconds	0.8 metres

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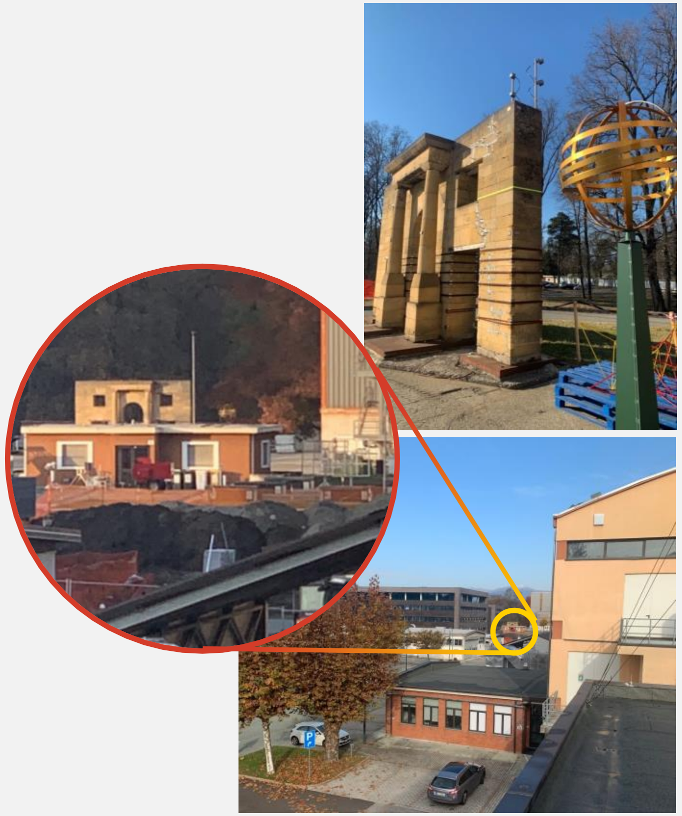
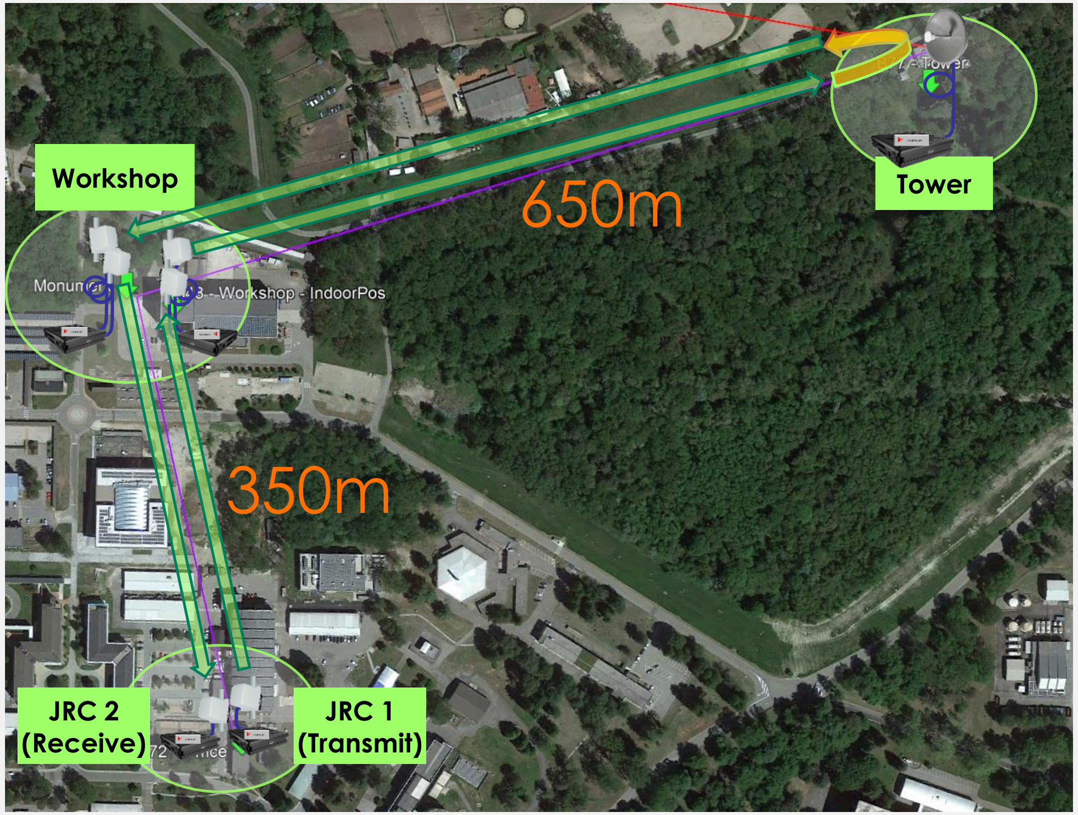
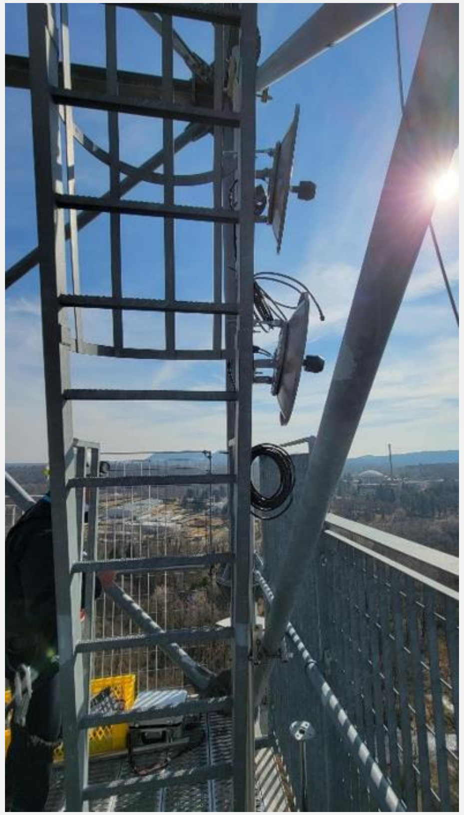
RESULTS
#2

OVER-THE-AIR LOCAL-AREA 24 HOUR TIME TRANSFER TEST
Demonstration of ‘campus-wide’ type configuration





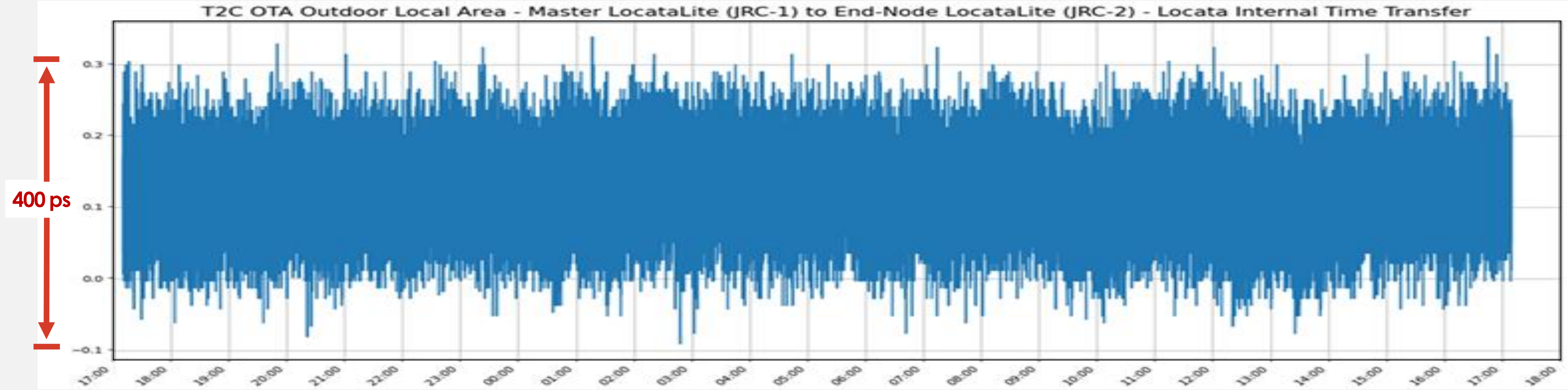


Details of Test Configuration	**2.2 km** total Time Transfer distance – all inside JRC campus	TimeLoc Cascaded through **4 “hops”**	**24-hour** duration	Tropospheric adjustments generated and applied continuously, in real time

RESULTS
#2

OVER-THE-AIR LOCAL-AREA 24 HOUR TIME TRANSFER TEST
Test configuration

Locata Internal Time Transfer 24-hours



#2A Internal Time Transfer	#2B External Time Synchronization	#2C External Time Transfer
MEAN: **126 picoseconds**	MEAN: **0 picoseconds**	MEAN: **125 picoseconds**
STD DEV: **50 picoseconds**	STD DEV: **616 picoseconds**	STD DEV: **613 picoseconds**
ALAN DEV: **5.204E-15**	ALAN DEV: **6.002E-14**	ALAN DEV: **6.433E-14**

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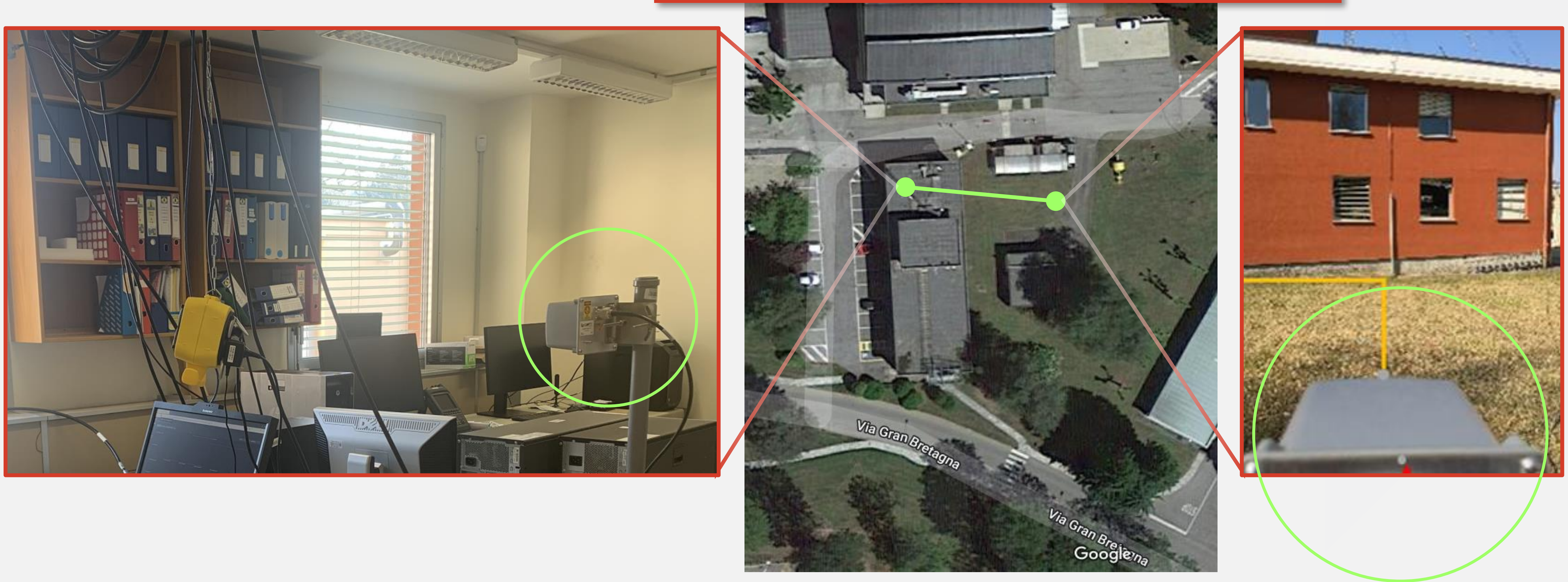
RESULTS
#3

OVER-THE-AIR OUTDOOR to INDOOR 24 HOUR TIME TRANSFER TEST
Test configuration

THROUGH BRICK WALL and BOOKCASE



Details of Test Configuration	**92 m** total Time Transfer distance – through brick-wall, non line-of-sight	TimeLoc point-to-point	**24-hour** duration	Tropospheric adjustments generated and applied continuously, in real time

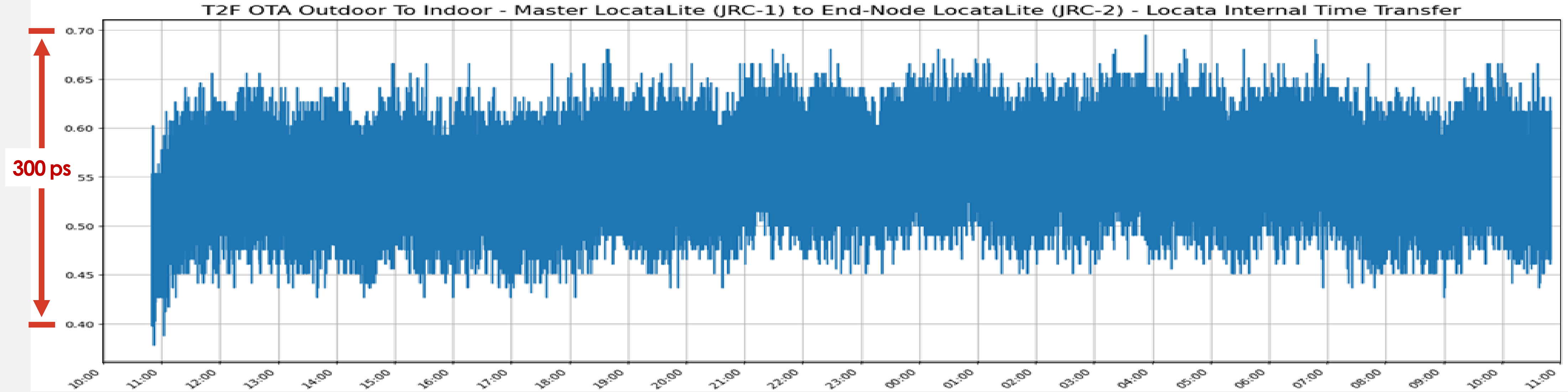
Locata

RESULTS
#3

OVER-THE-AIR OUTDOOR to INDOOR 24 HOUR TIME TRANSFER TEST

TimeLoc through brick wall, non-line-of-sight

Locata Internal Time Transfer 24-hours



#3A Internal Time Transfer	#3B External Time Synchronization	#3C External Time Transfer
MEAN: **552 picoseconds**	MEAN: **81 picoseconds**	MEAN: **624 picoseconds**
STD DEV: **35 picoseconds**	STD DEV: **571 picoseconds**	STD DEV: **570 picoseconds**
ALAN DEV: **2.040E-15**	ALAN DEV: **3.289E-14**	ALAN DEV: **3.386E-14**

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RESULTS
#4

TIMELOC OVER FIBRE 24 HOUR TIME TRANSFER TEST
Test configuration

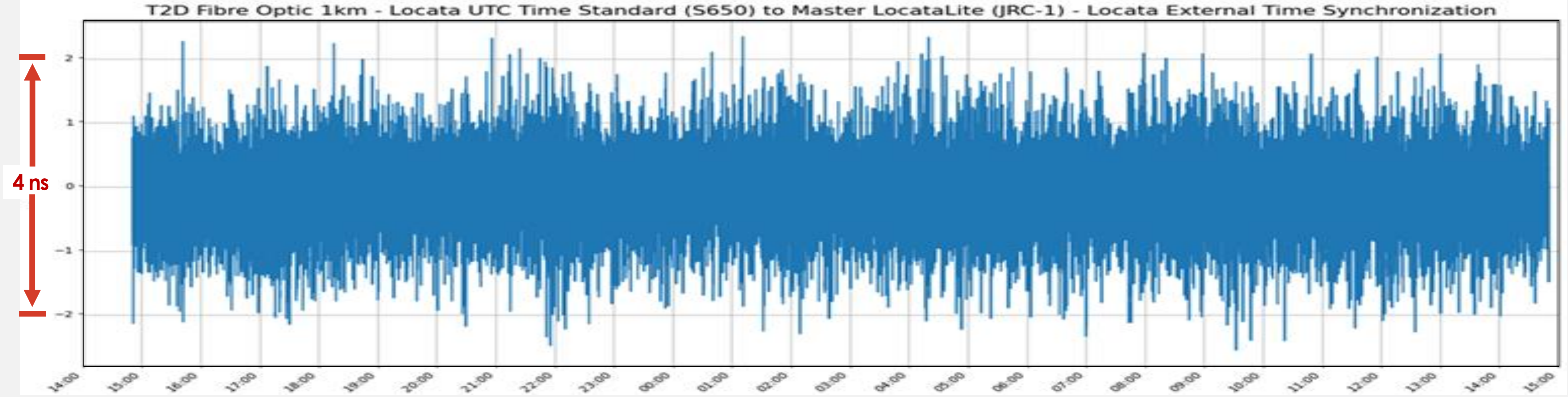
1km
Fibre optic
cable

Details of Test Configuration	**1 km** of Fibreoptic Cable	TimeLoc from LocataLite to LocataLite (no prior calibration!)	**24-hour** duration	Real time adjustments even adjusted for sunlight on cable during parts of the tests

RESULTS
#4

TIMELOC OVER FIBRE 24 HOUR TIME TRANSFER TEST
(1 km spool of fibre optic cable at JRC lab – no prior calibration required)

Locata Internal Time Transfer 24-hours



#4A Internal Time Transfer	#4B External Time Synchronization	#4C External Time Transfer
MEAN: **207 picoseconds**	MEAN: **-93 picoseconds**	MEAN: **114 picoseconds**
STD DEV: **42 picoseconds**	STD DEV: **549 picoseconds**	STD DEV: **550 picoseconds**
ALAN DEV: **4.106E-15**	ALAN DEV: **1.437E-14**	ALAN DEV: **1.064E-14**

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Summary of Timing Test Results

OVER 6 DAYS OF TESTING
Internal Time Transfer

MEAN: **261 picoseconds**

STD DEV: **49 picoseconds**

OVER 6 DAYS OF TESTING
External Time Synchronization

MEAN: **218 picoseconds**

STD DEV: **565 picoseconds**

Locata Time Transfer Type	Mean [ns]	Std Dev [ns]	MTIE [ns]	Peak-to-Peak [ns]	Samples [1 Hz]
Average Internal Time Transfer (over 6 days)	0.261	0.049	0.494	0.434	518,406
Average External Time Transfer (over 6 days)	0.218	0.565	3.062	5.641	518,406

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DEFIS Alt-PNT "Demo Day"

Locata Technology Overview

Positioning Tests Results

JRC Ispra Campus

18 May 2022

JRC EUROPEAN COMMISSION

Navigation Revolutions are Synchronized!

*Every major positioning revolution in the past 250 years has been built on the foundation of **a new way of synchronizing!***



John Harrison - inventor

Harrison's Chronometers – **synchronized to the sun**

- 18th Century British navigation revolution - **chronometer**
- Synchronization accuracy = 1 second in a month
- Helped make Britain's Navy the master of the seas


Modern GNSS – **synchronized to ground-based clock**

- 20th Century navigation revolution – **atomic clocks**
- Synchronization accuracy = ~50 nanoseconds
- Changed the world, enabled myriad new ideas for apps


David Small - inventor

Locata's TimeLoc – **synchronized to each other**

- 21st Century – synchronized **<u>without</u> atomic clocks**
- Synchronization accuracy = < 1 nanosecond
- Game-changer, enables new apps & national sovereignty

IMPORTANT! Our Business Model is for partnerships

R&D DELIVERS NEW CAPABILITIES → OWN THE TECHNOLOGY STACK FOR NEXT-GEN APPLICATIONS → COMMERCIALIZE via GLOBAL PARTNERS

How Locata delivers technology markets

3 fundamentals

1. **INTEL INSIDE** - to markets via OEM partners
2. Market development is **NOW-SOON-LATER**
3. Ever-larger markets via **MINIATURIZATION**


Locata Partner
Container Terminals

Fully-Autonomous Port Straddles "**Powered by Locata**"

Locata = Unprecedented accuracy for automation

Fully autonomous, "no-human-in-the-loop" industrial machine control – 3cm GNSS-free positioning across entire port area


Locata Partner
Mining
56
CAT
793F

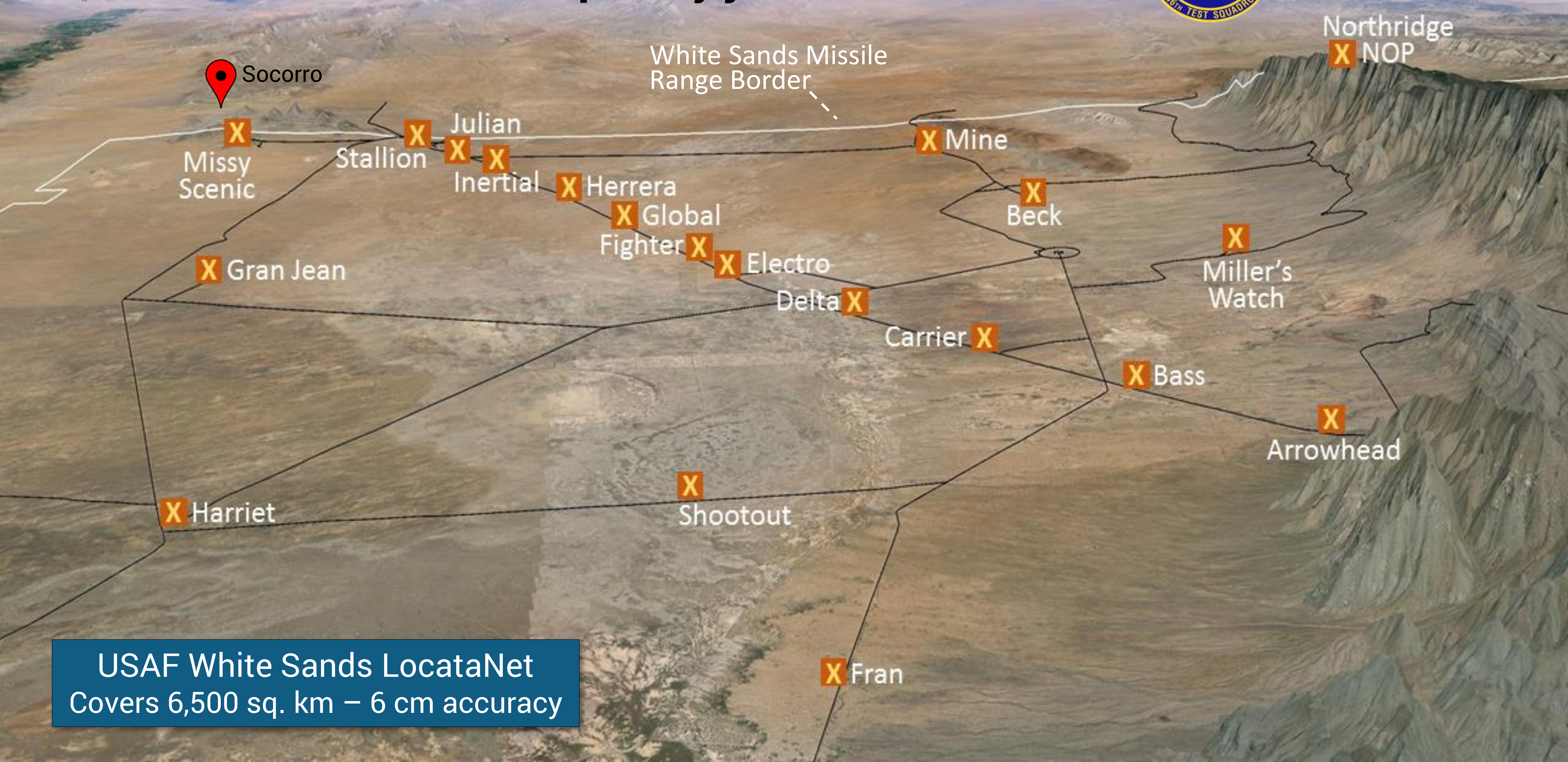

Locata Partner
Warehousing &
Logistics Hubs
Target


Locata Partner
UAV
Research
NASA
Langley Research Center
PROTEUS
N281PR


Locata Partner
Another LocataLite
Master LocataLite Transmitter
White Sands Missile Range, USA
Military

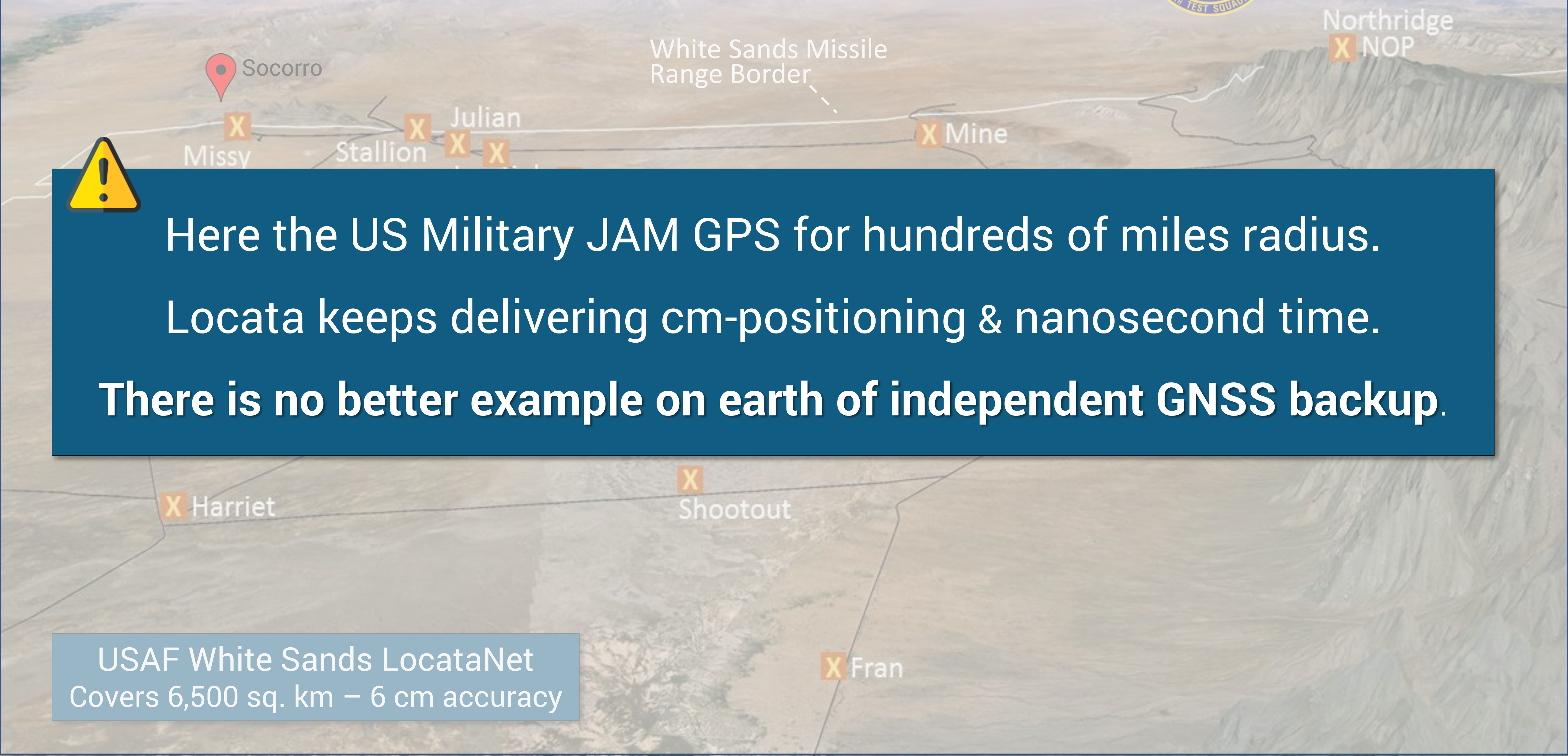

Locata
UNITED STATES AIR FORCE
HT
60080
DANGER
DANGER
Locata Antenna

New USAF Truth Reference System when GNSS is completely jammed



USAF White Sands LocataNet
Covers 6,500 sq. km – 6 cm accuracy

New USAF Truth Reference System when GNSS is completely jammed



Here the US Military JAM GPS for hundreds of miles radius.

Locata keeps delivering cm-positioning & nanosecond time.

There is no better example on earth of independent GNSS backup.

USAF White Sands LocataNet
Covers 6,500 sq. km – 6 cm accuracy

Indoor Positioning Tests

Multiple Position Tests were run over a period of several days, in JRC Workshop Building 48

They included:

- Static occupation over surveyed points on the floor, measured against a Total Station prism on the Locata VRay Orb Antenna
- Kinematic positioning measured against Total Station cross-track

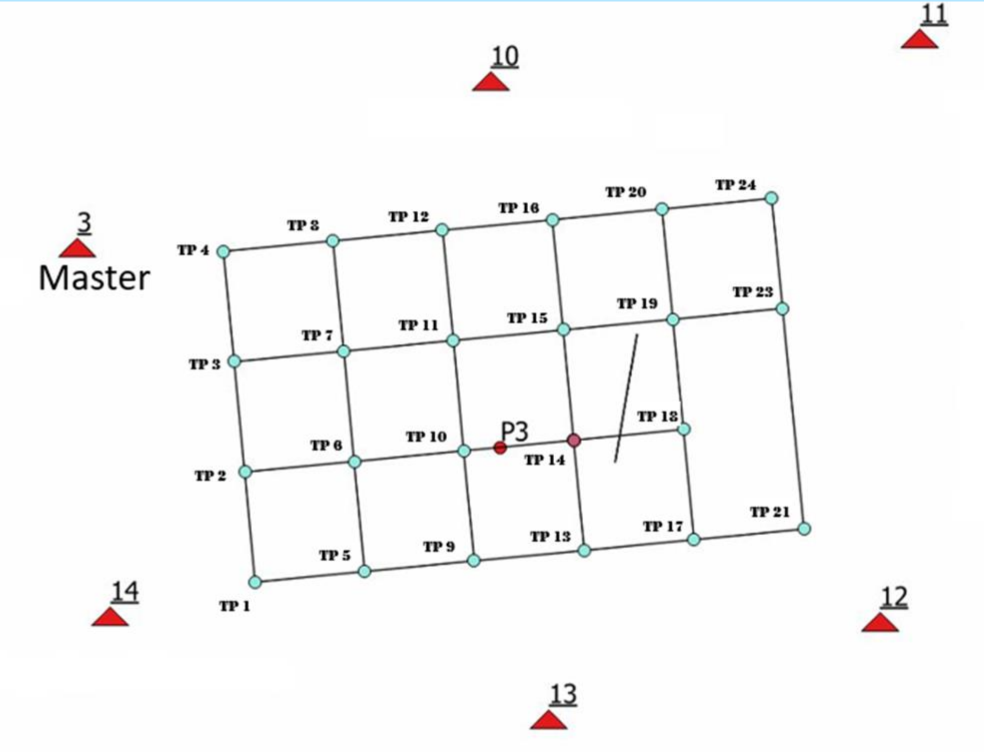
Indicative Test Results Follow…

RESULTS
#5

INDOOR POSITIONING TESTS (BOTH STATIC & KINEMATIC)
EXTREME MULTIPATH

Workshop – JRC Building 48

23 Indoor Surveyed Test Points on Workshop Floor



Details of Test Configuration

Large Indoor Workshop – JRC Building 48 – metal walls & ceiling = **<u>extreme</u> multipath**

TimeLoc Synchronization Cascaded indoors from Outdoor Locata Network

6 LocataLites mounted on the walls **– No GNSS –** **– No IMU's –**

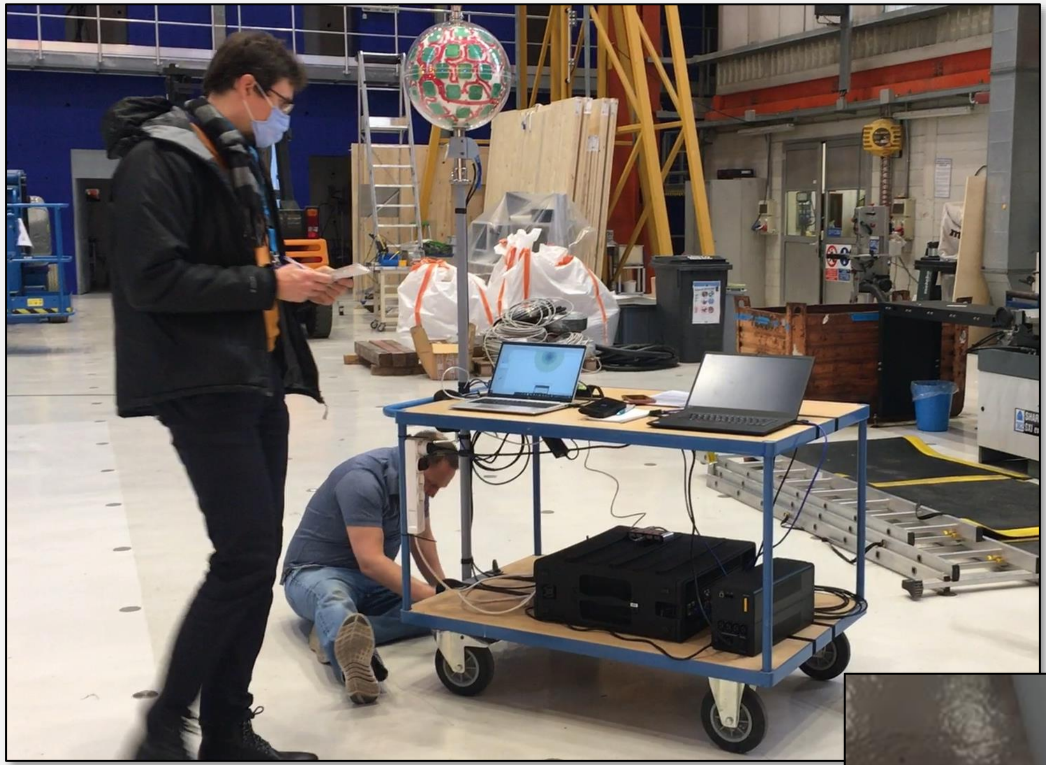
Locata Positioning compared against Total Station surveyed points

Locata

RESULTS
#5A

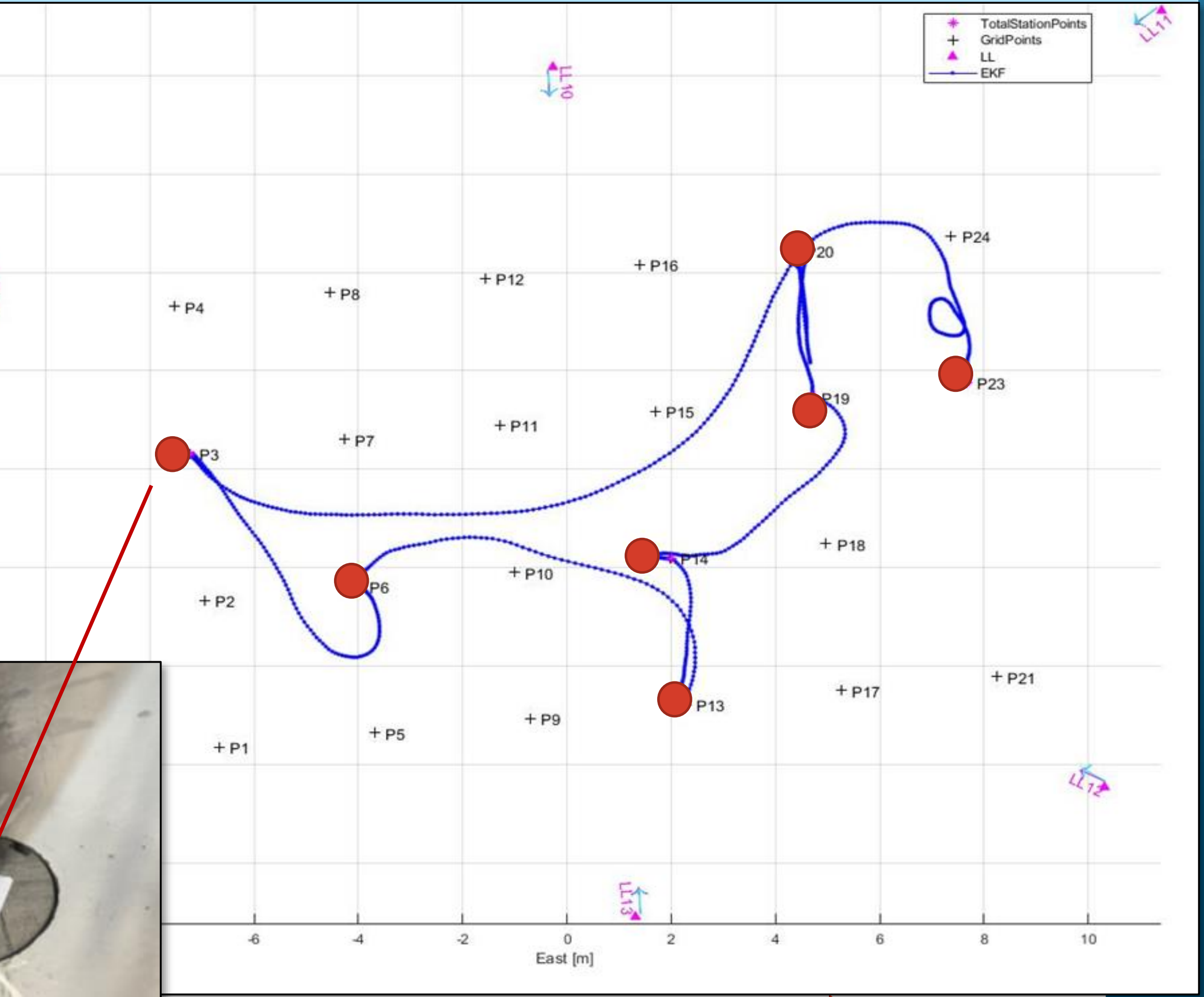
STATIC INDOOR POSITIONING TEST – vs LASER TOTAL STATION

#5A – STATIC Indoor Positions vs Total Station



Locata position solutions output at 10Hz

Multiple Tests Conducted. This is Test 2 – Static Points Measured



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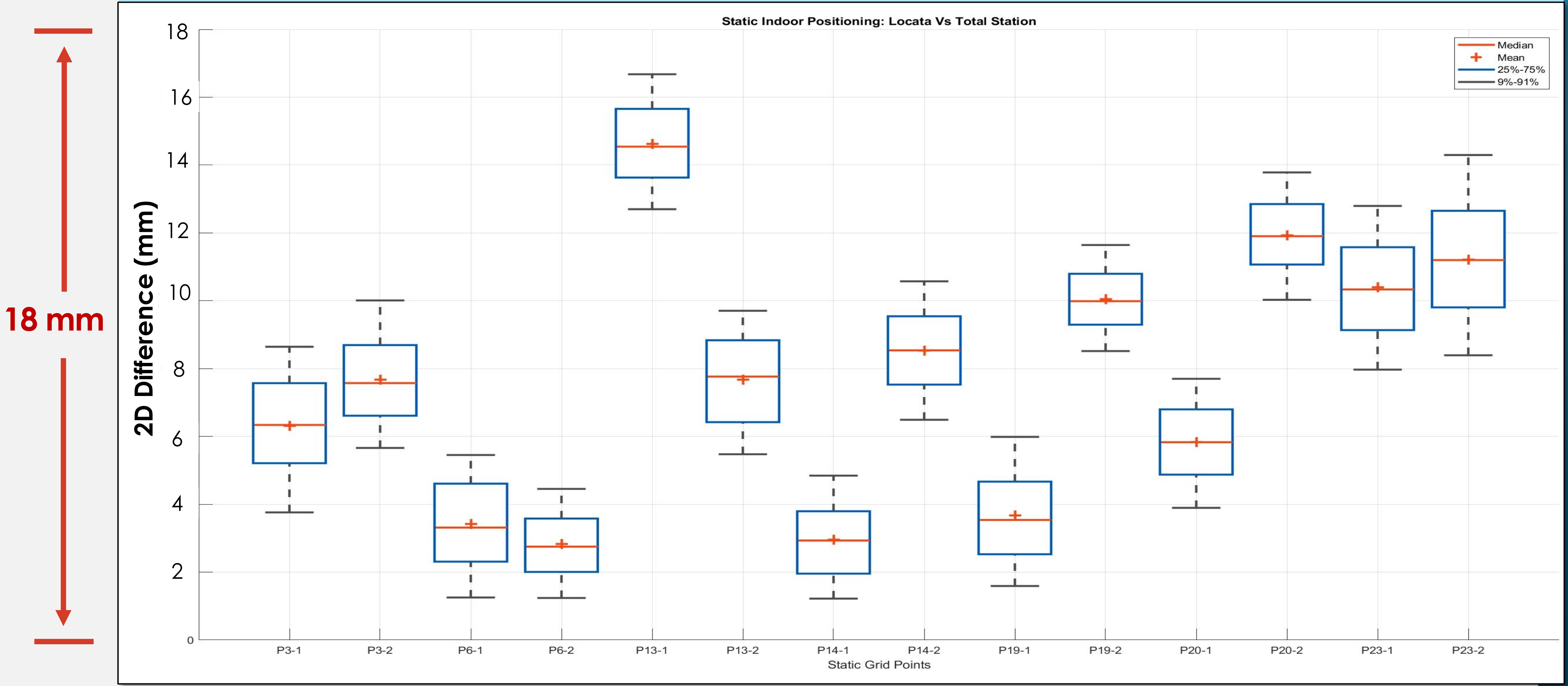
STATIC INDOOR POSITIONING TEST – vs LASER TOTAL STATION

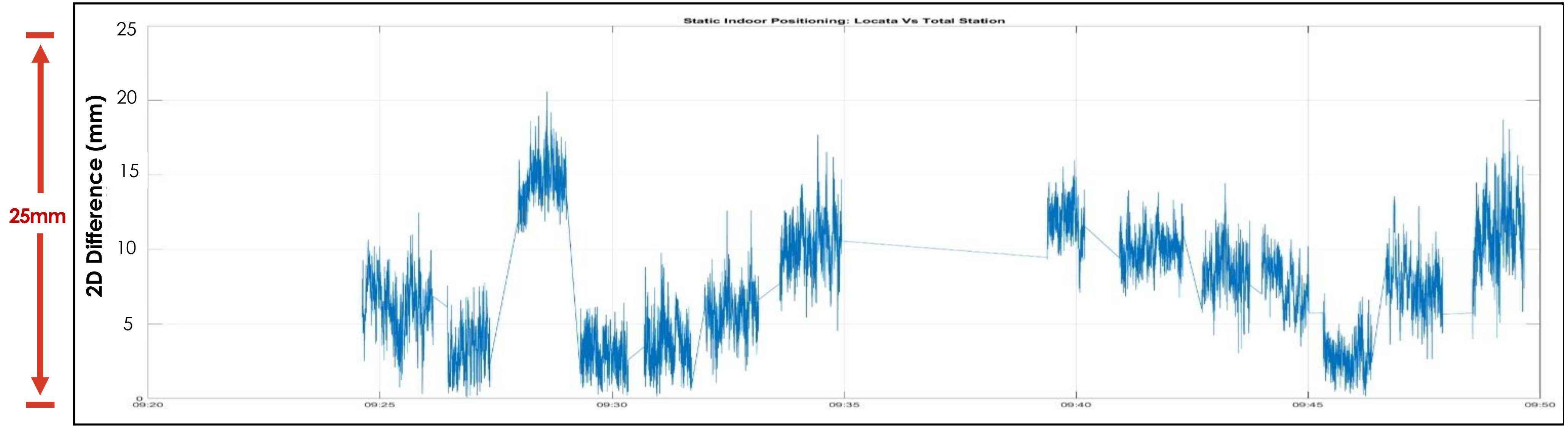
#5A – STATIC Indoor Positions vs Total Station Box Plot



RESULTS
#5A

STATIC INDOOR POSITIONING TEST – vs LASER TOTAL STATION

#5A – STATIC Indoor Positions Time Series



RESULTS ALL TESTS

Mean Difference	Standard Deviation	RMS Error
8 millimetres	4 millimetres	9 millimetres

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RESULTS
#5B

KINEMATIC INDOOR POSITIONING TEST – RANDOM MOVEMENTS

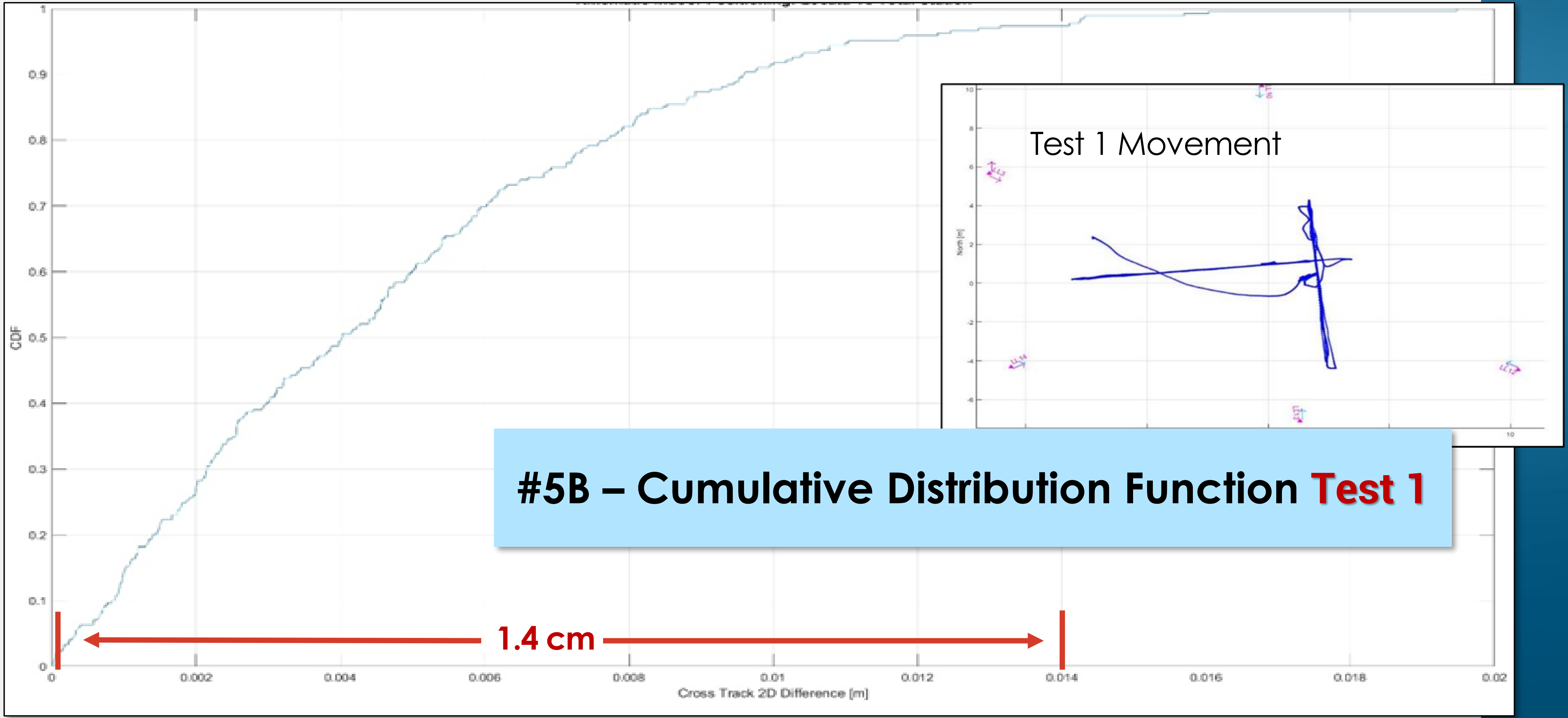
#5B – Example Indoor Random Movement over 30 x 30 metre area (Test 2)

Locata position solutions output at 10Hz

Locata

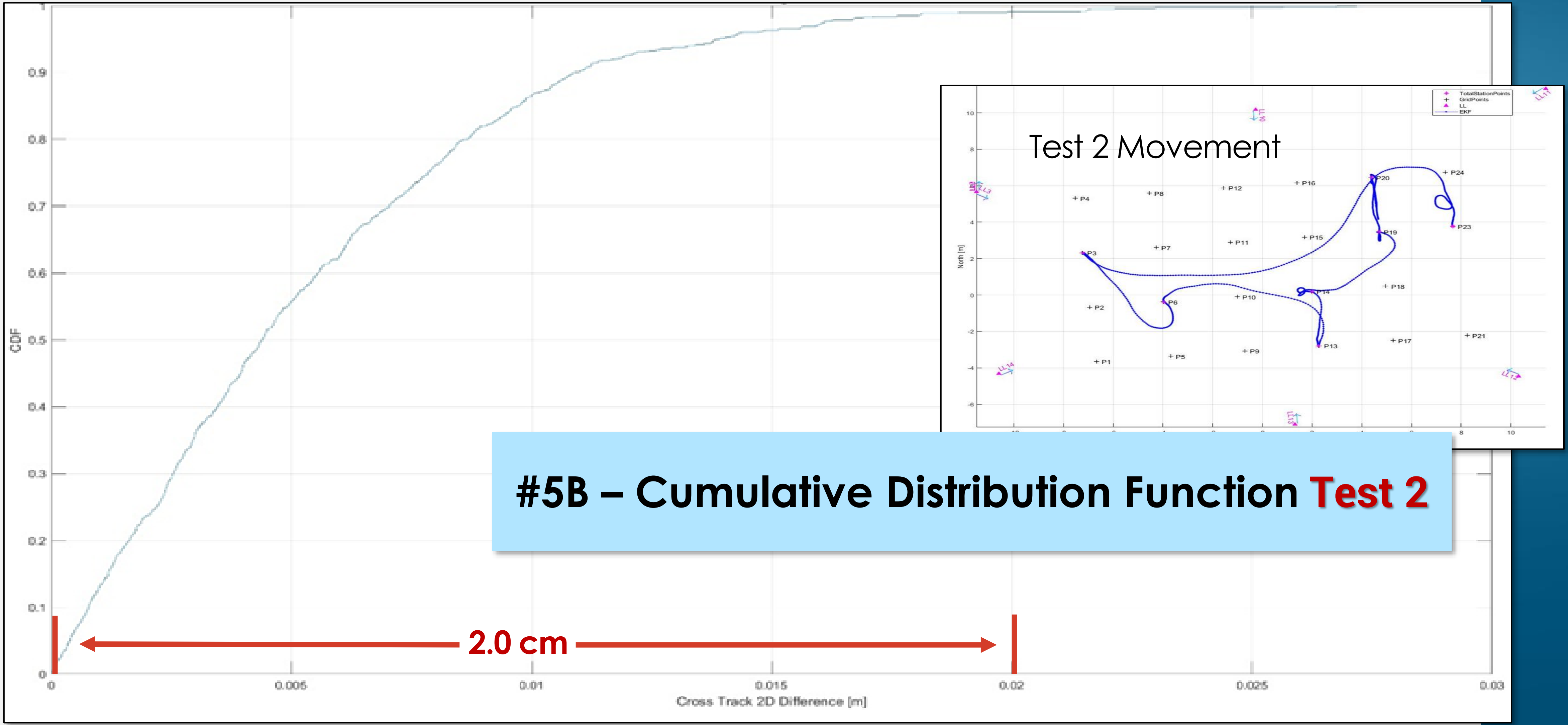
RESULTS
#5B

KINEMATIC INDOOR POSITIONING TEST – RANDOM MOVEMENTS



#5B – Cumulative Distribution Function Test 1

KINEMATIC INDOOR POSITIONING TEST – RANDOM MOVEMENTS



#5B – Cumulative Distribution Function Test 2

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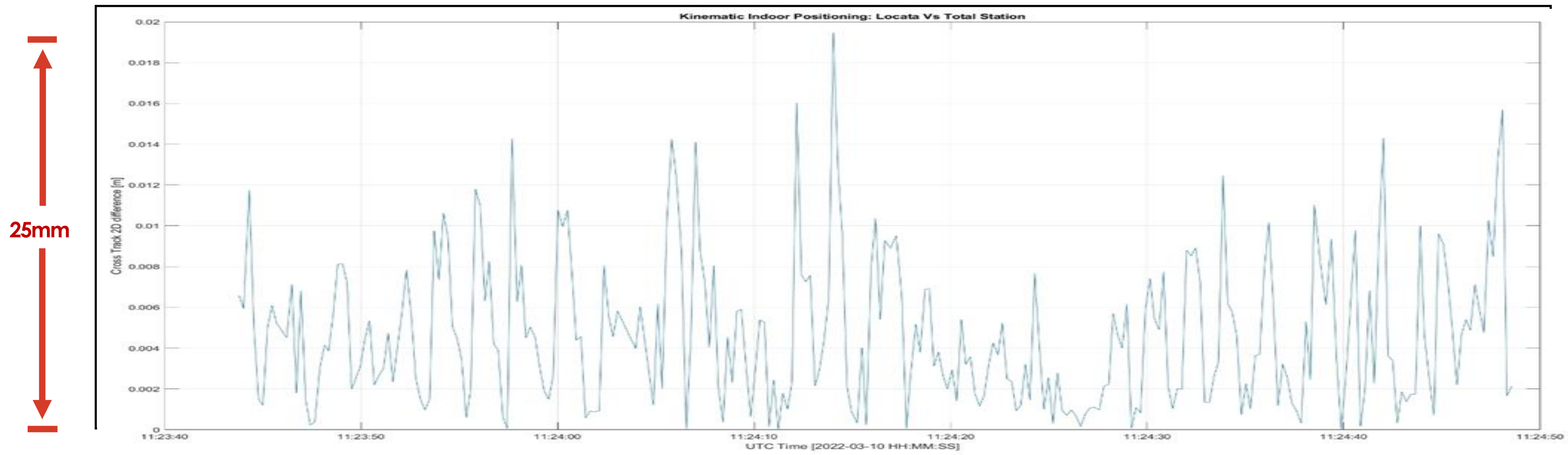
RESULTS
#5B

KINEMATIC INDOOR POSITIONING TEST – RANDOM MOVEMENTS

#5A – KINEMATIC Indoor Positions Time Series



RESULTS ALL TESTS

Mean Difference	Standard Deviation	RMS Error
5 millimetres	4 millimetres	6 millimetres

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Outdoor Positioning Tests

Multiple Position Tests were run over a period of one day.
Customer Test Site, Germany

They included:

- Static occupation over surveyed points on the ground, measured against a Total Station prism on the Locata VRay Orb Antenna
- Kinematic positioning measured against Total Station cross-track

Indicative Test Results Follow…

RESULTS
#6

OUTDOOR POSITIONING TESTS (REAL-WORLD GERMAN TEST FACILITY)

Dusseldorf Test Field, Germany

Autonomous Straddle at Test Field

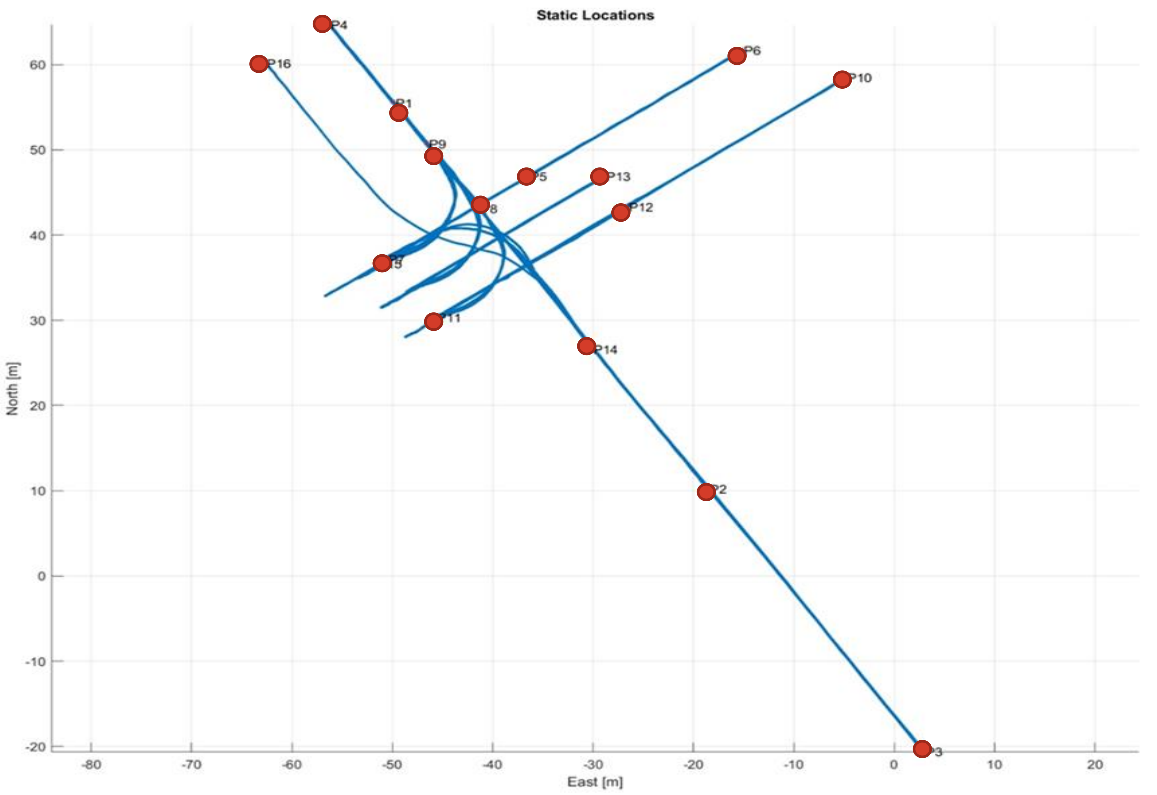
Details of Test Configuration	Large Outdoor Test Facility – Dusseldorf Test Field, Germany	Real-world facility replicating container port environment – 6 LocataLites permanently installed	Fully-autonomous 60-ton, 4-story high straddle machines use Locata-only solutions – NO GNSS	Locata Positioning tested against surveyed points, measured with Total Station

Locata

RESULTS
#6A

OUTDOOR POSITIONING TESTS (BOTH STATIC & KINEMATIC)

Outdoor Site Layout for Static & Kinematic Tests @ Dusseldorf Germany



Picture of part of Dusseldorf Test Field Area

Details of Test Configuration

Approx. Size of Available Test Area: **110 x 100 metres**

16 Static Points compared against Total Station solution

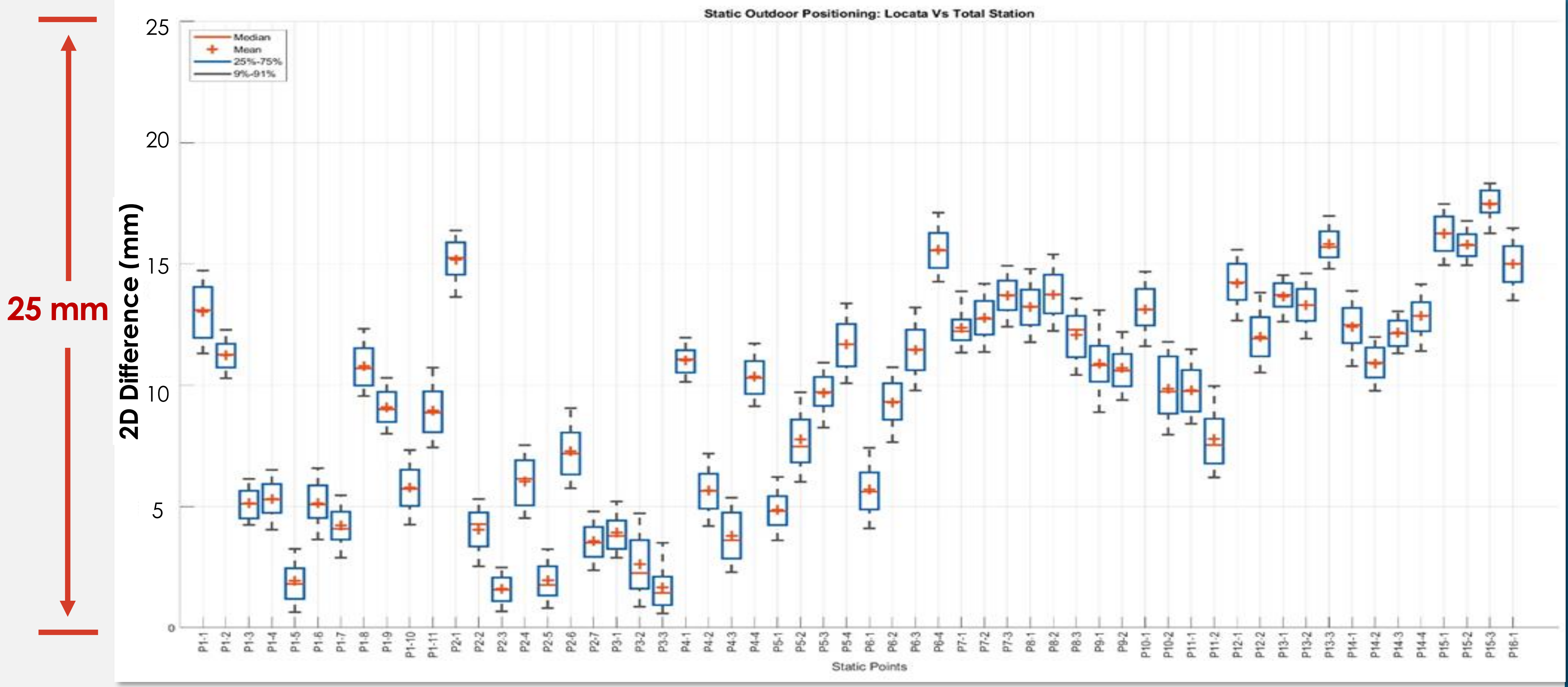
Locata Kinematic Solution compared to RTK GNSS

Straddle moves ran fully-autonomous – no human control

Locata

STATIC OUTDOOR POSITIONING TEST – vs LASER TOTAL STATION

#6A – All STATIC Outdoor Positions vs Total Station

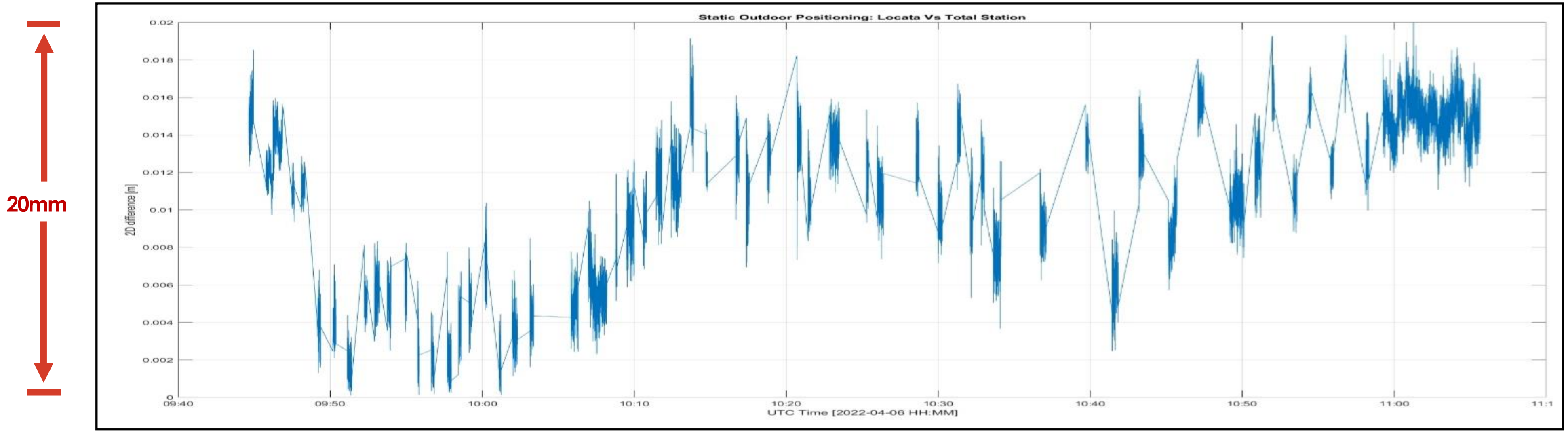


Locata

RESULTS #6A

STATIC OUTDOOR POSITIONING TEST – vs LASER TOTAL STATION

#6A – STATIC Outdoor Positions Time Series

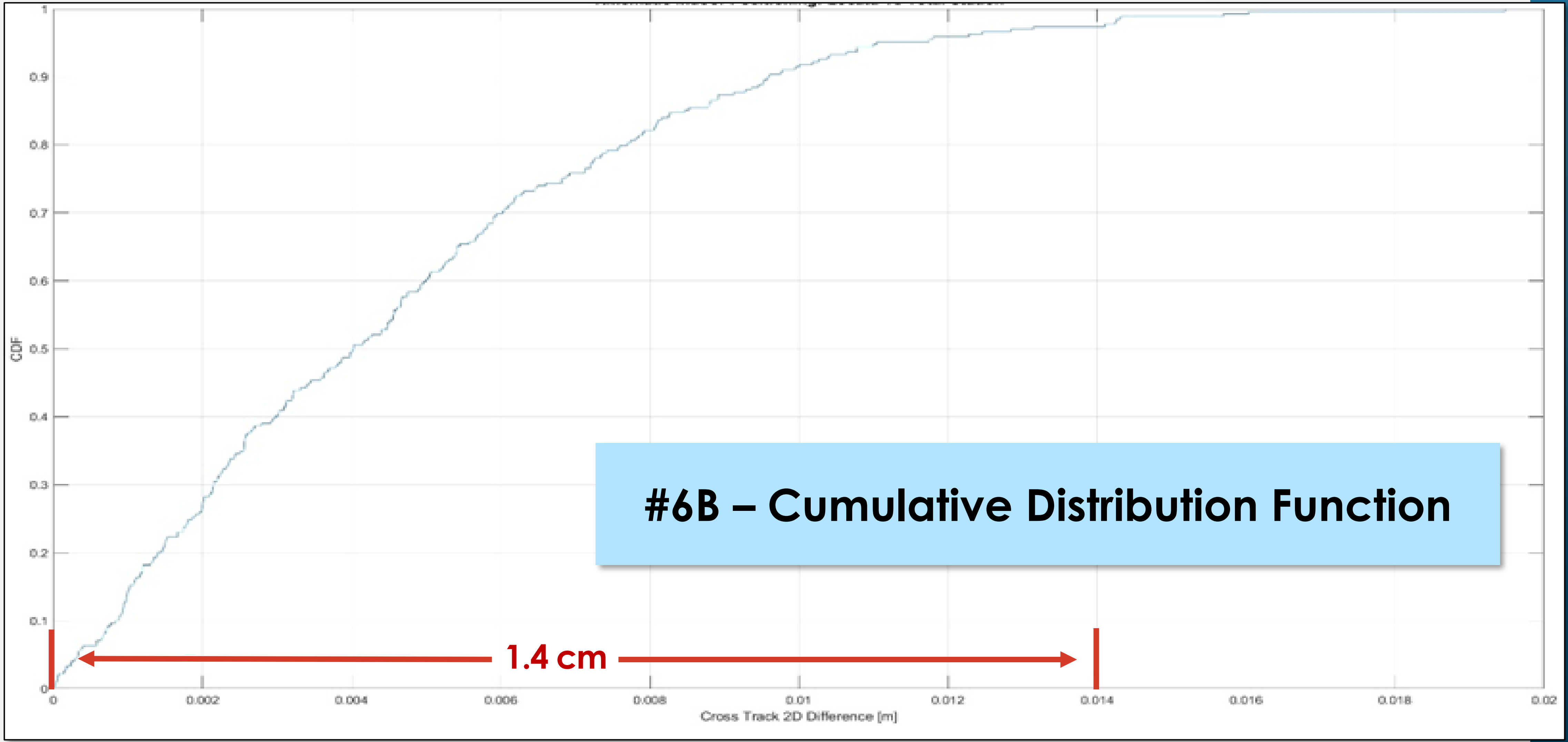


RESULTS ALL TESTS

Mean Difference	Standard Deviation	RMS Error
1.1 centimetres	4 millimetres	1.2 centimetres

Locata

KINEMATIC OUTDOOR POSITIONING TEST – RANDOM MOVEMENTS



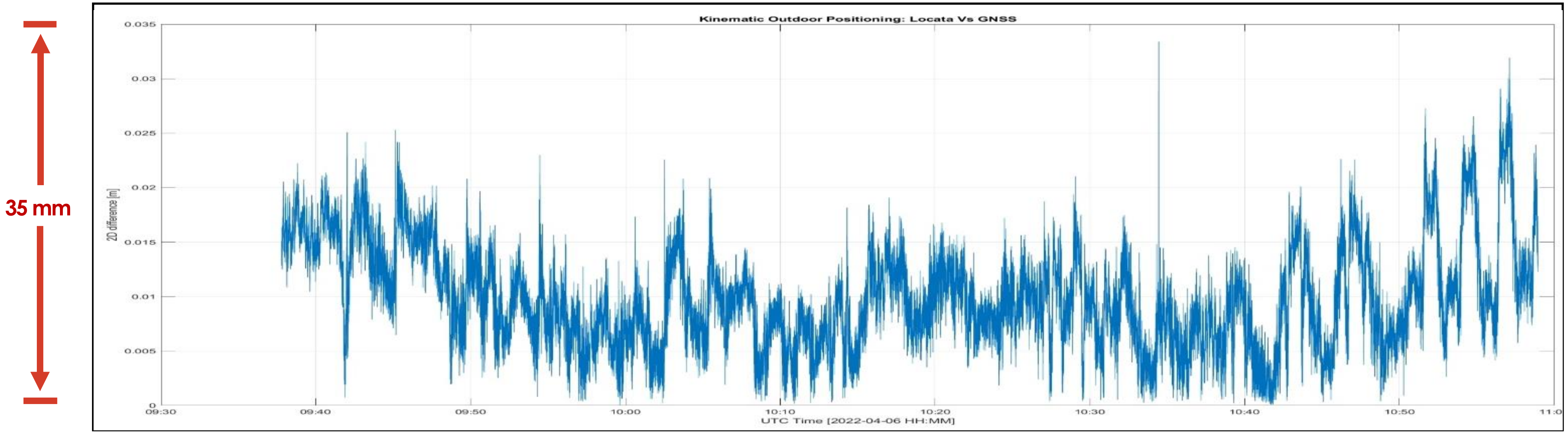
Locata

RESULTS

#6B

KINEMATIC OUTDOOR POSITIONING TEST – RANDOM MOVEMENTS

#6A – KINEMATIC Outdoor Positions Time Series



RESULTS ALL TESTS

Mean Difference	Standard Deviation	RMS Error
1 centimetre	5 millimetres	1.1 centimetres

Locata

Summary of Positioning Test Results

INDOOR POSITIONING

STATIC: **8 millimetres**

KINEMATIC: **5 millimetres**

OUTDOOR POSITIONING

STATIC: **11 millimetres**

KINEMATIC: **10 millimetres**

Locata Positioning Type	2D Mean Difference (mm)	2D Standard Deviation (mm)	2D RMSE (mm)	Reference	Number of Points
Average Outdoor Static	11	4	12	Total Station	58
Average Outdoor Kinematic	10	5	11	GNSS (2D difference)	48,701
Average Indoor Static	8	5	10	Total Station	14
Average Indoor Kinematic	5	4	6	Total Station (cross-track)	269

EU's tested Timing performance

Including Locata results compared to "other candidate technologies"

Locata is

- ✓ Only technology to deliver timing in every timing/synchronization test
- ✓ Only technology to deliver picosecond-level timing over RF + other mediums*
- ✓ Performance quality is thousands of times better than any other RF system
- ✓ Picosecond-level timing tested long-range (>105km) & campus-wide (2.2km)

Timing Performance	Time Generation [days]	MTIE [ns]	Time Transfer Fibre [ns]	Time Transfer Networks [ns]	Time Transfer OTA Outdoors [ns]	Time Transfer OTA Indoors [ns]
OPNT	N.A.	N.A.	0.057	N.A.	< 200 (±100)	N.A.
7 Solutions SL	80	280	0.089	N.A.	N.A.	N.A.
SCPTime	1	< 1000	N.A.	35	N.A.	N.A.
GMV	100	57	1	500	N.A.	N.A.
Satelles Inc	110	364	N.A.	N.A.	145	< 340
Locata	1	< 1000	0.4 (4.9)	0.4 (6.1)	0.7 (6.1)	0.2 (5.2)
NextNav LLC	11.6	40	N.A.	N.A.	N.A.	< 39

Extracted: Table 17 on Page 76, EU's Test Summary Report

* Radio, fibre, coax cable (any mix)

EU’s tested Positioning performance

Including Locata results compared to “other candidate technologies”

Locata is

- ✓ Only technology to deliver positioning in every required positioning test
- ✓ Centimetre-level or better, in every outdoor and indoor test environment
- ✓ Performance quality is hundreds of times better than any other
- ✓ Only technology shown to deliver cm-levels, whilst moving, indoors

2D Positioning Performance	Static Outdoors [m]	Static Indoor [m]	Kinematic Outdoors [m]	Kinematic Indoors [m]
Satelles Inc	17.0	15.0	N.A.	N.A.
Locata	< 0.01	< 0.01	< 0.02	< 0.02
NextNav LLC	9.0	14.0	11.0	N.A.

Extracted: Table 18 on Page 76, EU’s Test Summary Report

Frankly… we didn't enter DEFIS Tests "just to meet spec"

CHILD
Play

If the bar is only
"**100 metres**" or
"**1 microsecond**"

EVERYONE
CAN DO THAT.

DEFIS let us show the world our gold-medal performance!

HARD
Play

Set a <u>real</u> bar!

"x cm" *and*
"x picoseconds"

WHO ELSE
BUT LOCATA
CAN DO THAT?

Demonstrated Bottom Line

PICOSECONDS & MILLIMETRES

- Over the air
- Over fibre
- Over cable

New enabling technology for the industry & our partners