Surveying in 2030: Where are we heading?

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Canadian Geodetic Survey, Natural Resources Canada

October 10, 2025

Quicker, more accurate surveys…with more value added

Outline

- Precise Point Positioning
- Galileo High Accuracy Service
- LEO PNT
- Market Trends
- A modernized Canadian Spatial Reference System

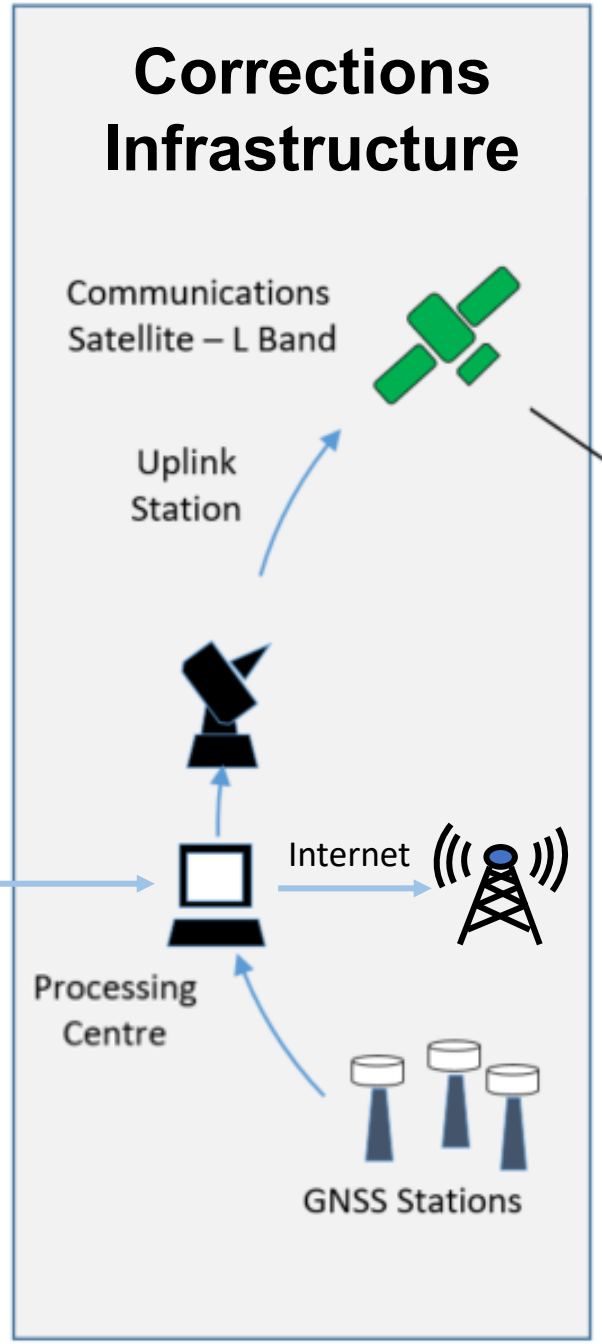
Precise Point Positioning

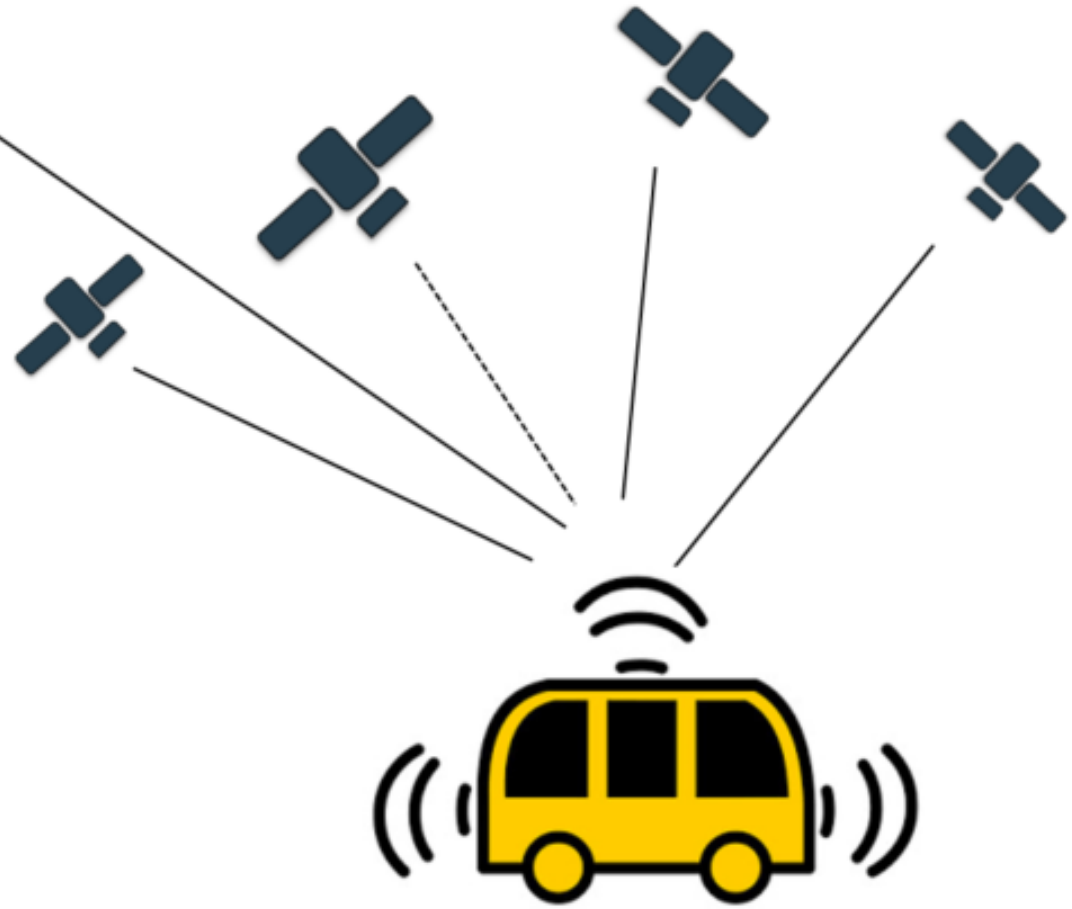
Precise Point Positioning

- Absolute Positioning
- No user reference station required
- Post processing and real-time (free/subscription) options

Real-time PPP distributes corrections over the air

Corrections calculated:
- Satellite orbits
- Satellite clocks
- Satellite biases
- Atmospheric biases





	RTK	RTK-PPP	PPP
Accuracy after initialization	~1 cm	2 - 8 cm	3 - 10 cm
Initialization time	Immediate	Fast (< 1 min)	Slow (~20 min)
Coverage	Local	Regional	Global
Bandwidth requirements	High	Moderate	Low
Infrastructure density	~10 km	~100 km	~1000 km

https://www.septentrio.com/en/learn-more/insights/gnss-corrections-demystified

CSRS (Post Processed) PPP is easy to use

Store raw GNSS data on receiver

Processing mode — CSRS-PPP

◉ Static ○ Kinematic

NAD83 | ITRF

Epoch (Adopted)

Vertical datum

CGVD2013

Contribute to passive control maintenance? (What is this?)

☐ Authorize the Canadian Geodetic Survey to archive and publish CSRS-PPP submission and solution

Official Canadian federal or provincial geodetic marker number

▶ More options

RINEX observation file(s), 300 MB max (.zip, .gz, .Z, .tar, .??O)

Note: You may submit multiple RINEX files in a single .zip or .tar archive

Choose File | No file chosen

☐ Remove plots from CSRS-PPP solution PDF report (Why?)

Submit to PPP

CSRS-PPP 5.11.0 (2025-05-05)

acht0320.24o
ACHT

Data Start	Data End	Duration of Observations
2024-02-01 00:00:00.00	2024-02-01 23:59:30.00	23:59:30
Processing Time	**Mode**	**Product Type**
15:28:07 UTC 2025/05/27	Static	Final

Observations

GPS : C1 C2 L1 L2 GLONASS : C1 C2 L1 L2

Elevation Cut-Off	Rejected Epochs	Fixed Ambiguities	Estimation Steps
7.5 degrees	0.00 %	98.65 %	30.00 sec
Antenna Model	**APC to ARP**		**ARP to Marker**
TRM59900.00 NONE	REF PCO : GPS GLONASS		H:0.077m / E:0.000m / N:0.000m

(APC = antenna phase center; ARP = antenna reference point; REF PCO = reference phase center offset)

Estimated Position for acht0320.24o

	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2010.0)†	45° 30' 45.99029"	-61° 1' 35.81059"	22.149 m
SIG_PPP(95%)‡	0.002 m	0.002 m	0.007 m
SIG_TOT(95%)‡	0.007 m	0.005 m	0.009 m

CSRS-PPP now supports Galileo

Table 1: Products used in CSRS-PPP (for data collected after 27 November 2022)

Products	GNSS	Availability	Latency
Ultra-rapid	GPS GLONASS	Hourly	90 minutes after the hour
Rapid	GPS GLONASS Galileo	Daily	17-18 hours after the end of the day
Final	GPS GLONASS Galileo	Weekly	12-15 days after the end of the week

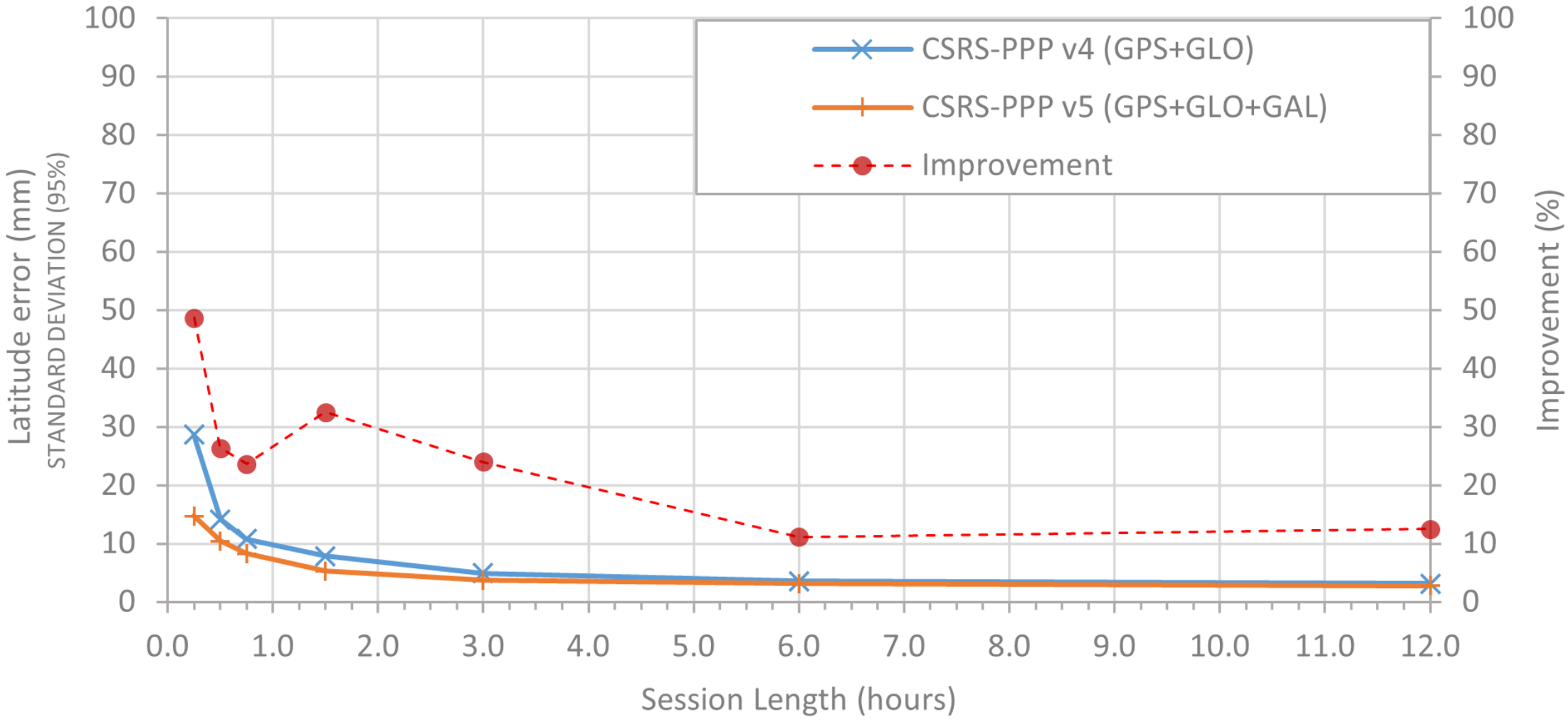
CSRS-PPP now supports modernized signals

The currently supported signals in CSRS-PPP are:

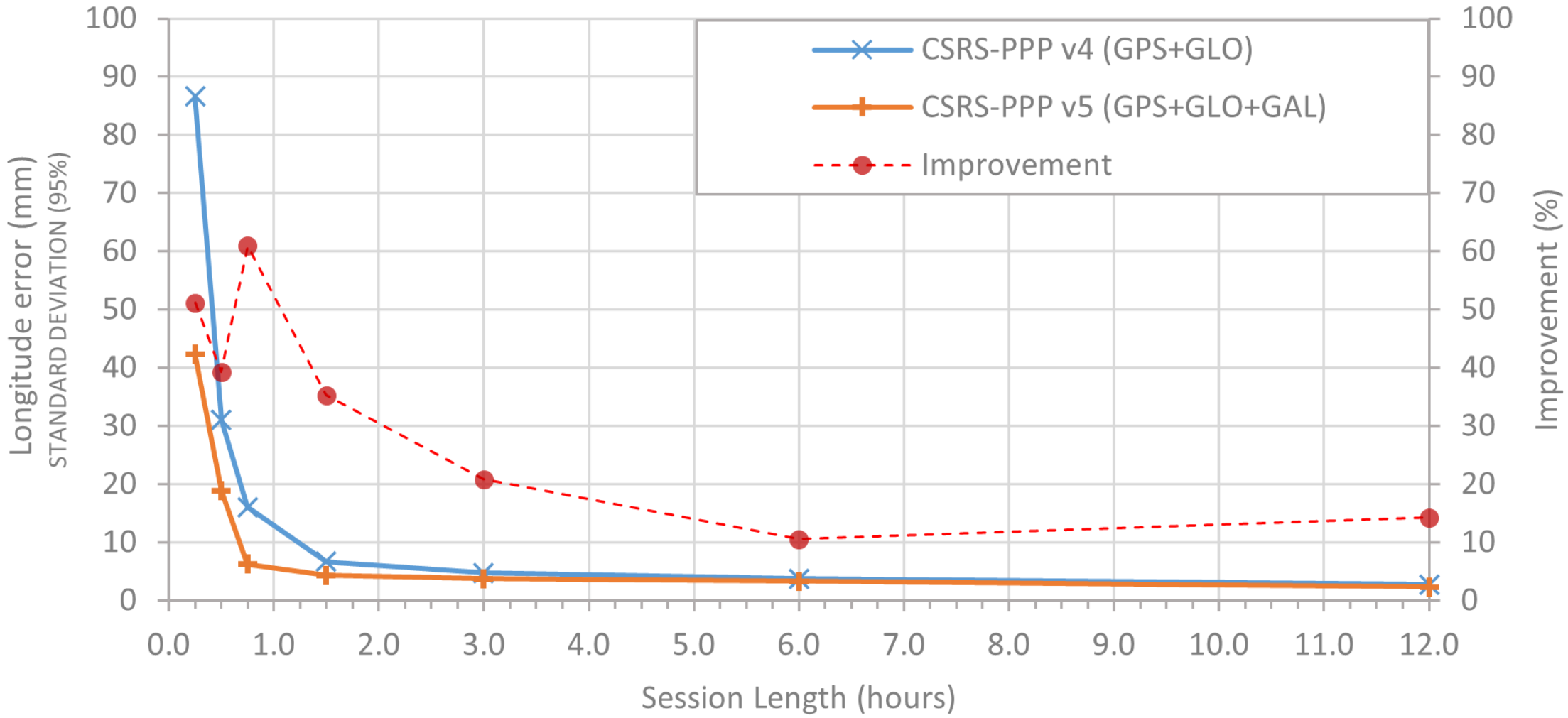
- GPS: C1C, L1C, C2C, L2C, C1W, L1W, C2W, L2W, C1L*, L1L*, C2L, L2L, C2S, L2S, C1X*, L1X*, C2X, L2X
- GLONASS: C1C, L1C, C2C, L2C, C1P, L1P, C2P, L2P
- Galileo: C1X, L1X, C5X, L5X, C1C, L1C, C5Q, L5Q

* As of 15 July 2025, CSRS-PPP accepts GPS signals C1L L1L C1X L1X

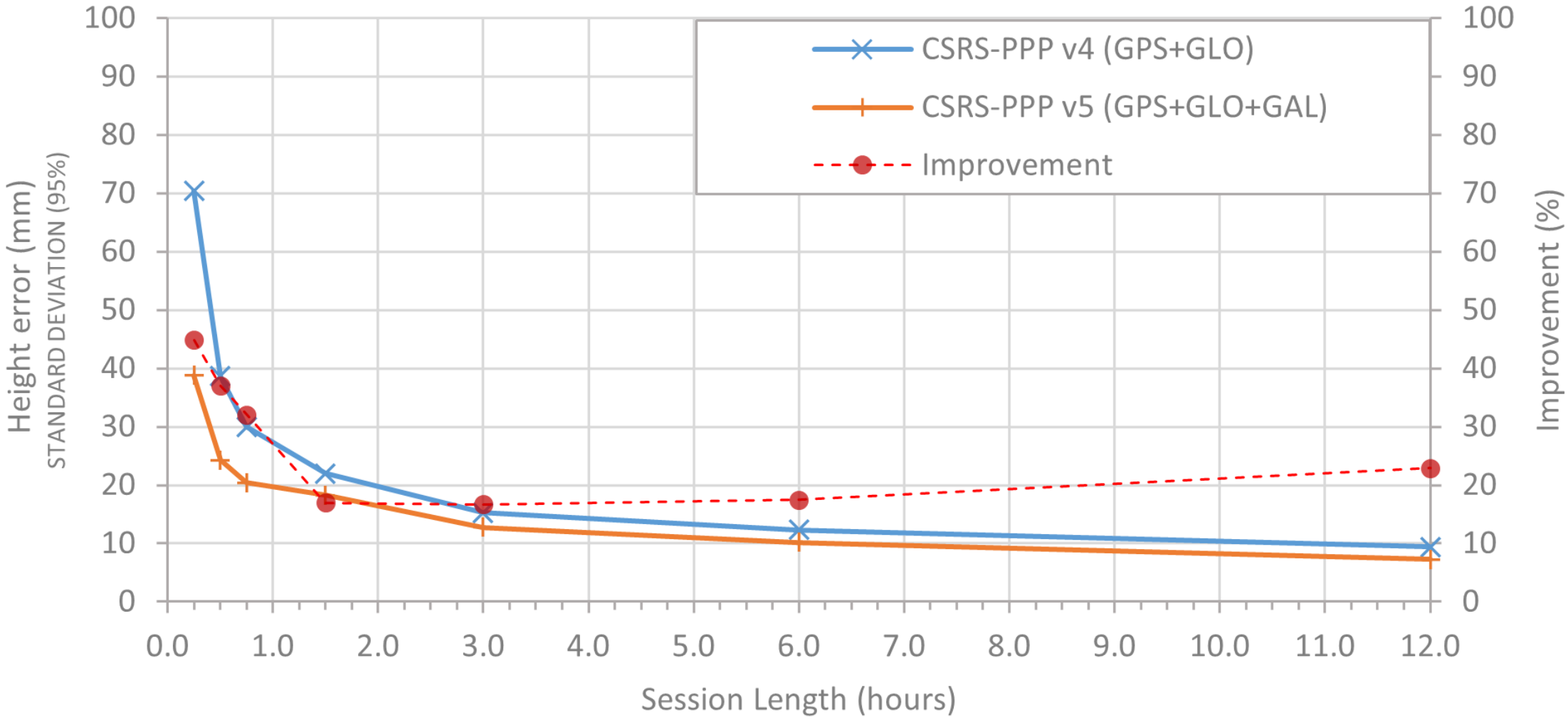
Support for Galileo improves convergence time and accuracy



Support for Galileo improves convergence time and accuracy



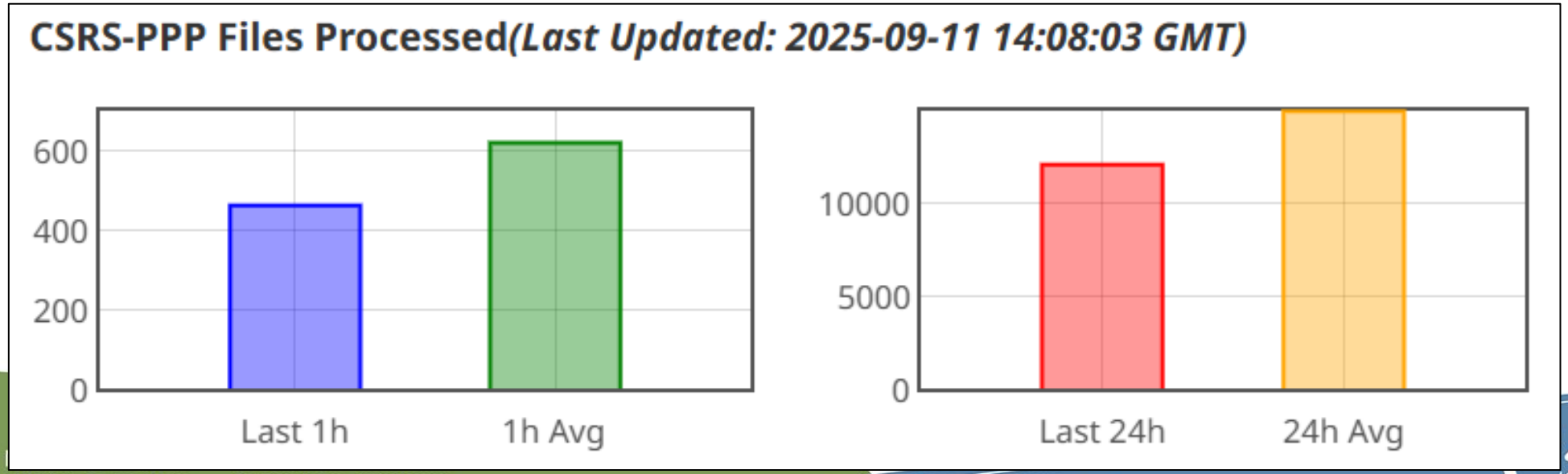
Support for Galileo improves convergence time and accuracy



CSRS-PPP Usage

- With 1 hour of GNSS observations, ±1 cm in horizontal components and ±2 cm in vertical at 95% confidence is possible

- 10 years ago: ±3 cm horizontal in 3 hours



In 2030, we can expect…

- More subscription-based real-time PPP services to emerge
- More free PPP corrections service to be available
- Continued enhancements to CSRS-PPP to allow for quicker, high accuracy surveys

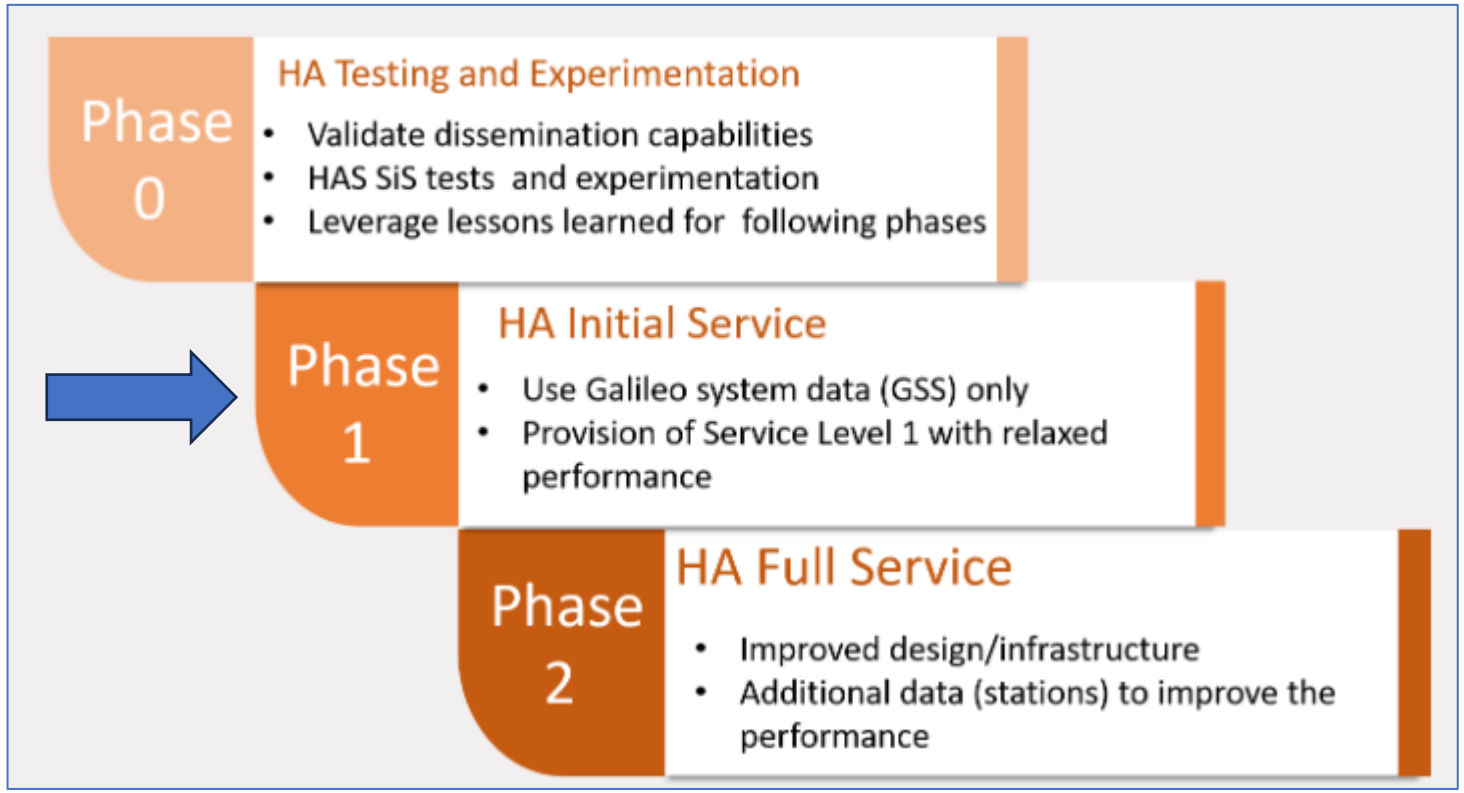
Galileo High Accuracy Service (HAS)

https://www.gsc-europa.eu/galileo/services/galileo-high-accuracy-service-has

Galileo High Accuracy Service (HAS)

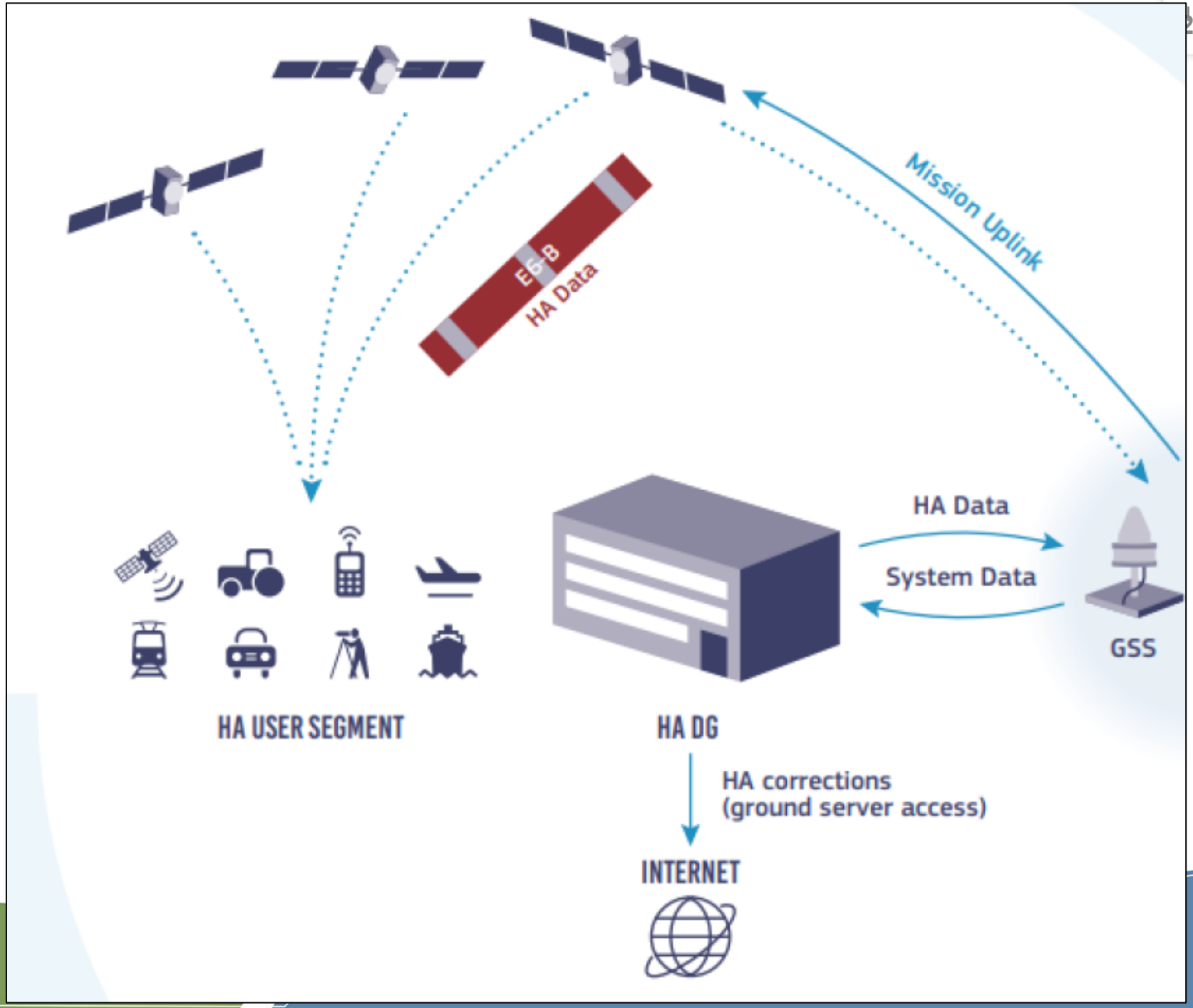
- Free
- Corrections broadcast in the Galileo E6-B signal and over internet
- Corrections: satellite orbit, satellite clocks, satellite biases, (atmosphere?)
- Implemented in real-time PPP
- Better than 20 cm accuracy horizontal, 40 cm vertical

Galileo High Accuracy Service (HAS)



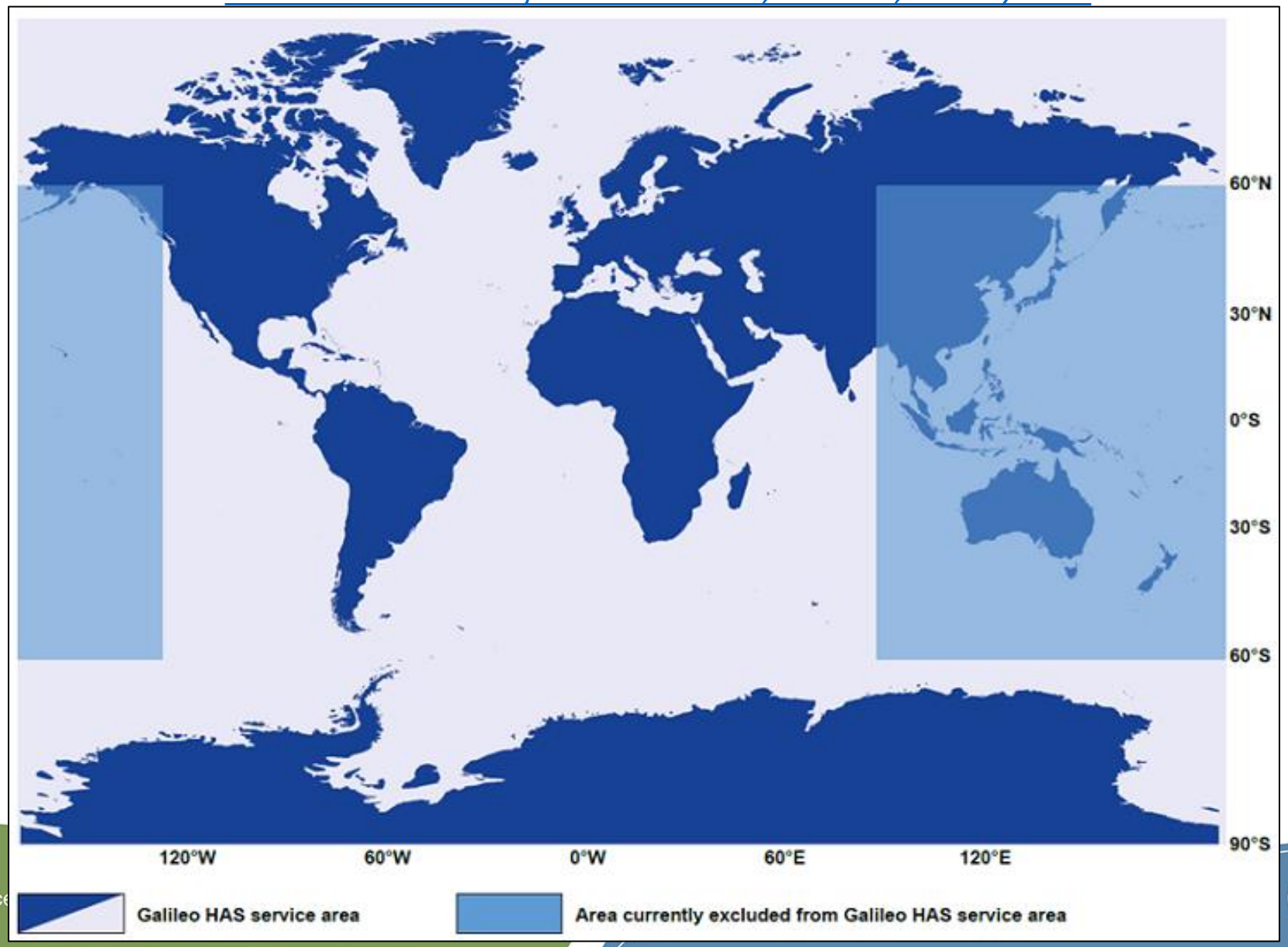
HAS	SERVICE LEVEL 1	SERVICE LEVEL 2
COVERAGE	Global	European Coverage Area (ECA)
TYPE OF CORRECTIONS	PPP - Orbit, clock, biases (code and phase)	PPP - Orbit, clock, biases (code and phase) incl. atmospheric corrections
CORRECTIONS DISSEMINATION	SIS (Galileo E6-B) and IDD (Ntrip)	SIS (Galileo E6-B) and IDD (Ntrip)
SUPPORTED CONSTELLATIONS & FREQUENCIES	Galileo E1/E5a/E5b/E6; E5 AltBOC GPS L1/L5; L2C	Galileo E1/E5a/E5b/E6; E5 AltBOC GPS L1/L5; L2C
HORIZONTAL ACCURACY 95%	<20 cm	<20cm
VERTICAL ACCURACY 95%	<40cm	<40cm
CONVERGENCE TIME	<300 s	<100 s
USER HELPDESK	24/7	24/7

Galileo HAS


E6-B
HA Data
Mission Uplink
HA Data
System Data
GSS
HA USER SEGMENT
HA DG
HA corrections
(ground server access)
INTERNET

Galileo HAS Coverage

Galileo HAS Service Definition Document, Issue 1.0, January 2023



Example HAS-enabled receivers

- Spectra SP100
- Trimble R10/R12
- Topcon Hiper HR
- Hemisphere S631
- Geode GNS3H
- EOS Skadi Gold

In 2030, we can expect…

- Most commercial receivers will support Galileo HAS corrections

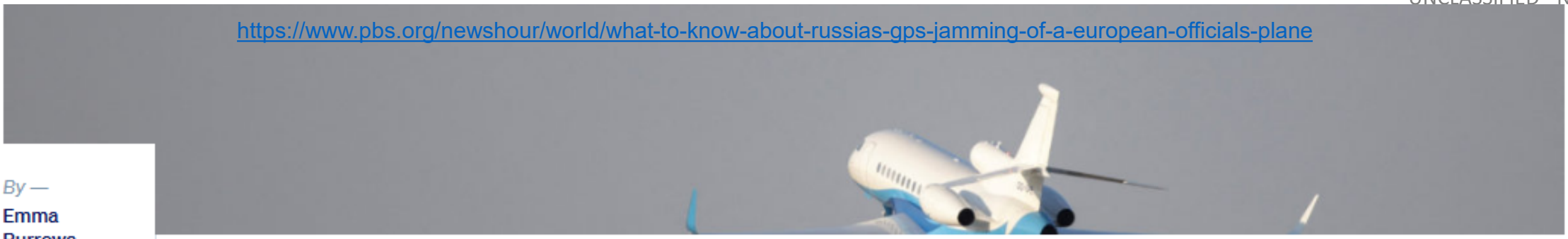
LEO PNT
Low Earth Orbit Positioning, Navigation & Timing

"We estimate that the loss of GPS service would have a $1 billion per day impact."

National Institute of Standards and Technology

June 2019 Report "Economic Benefits of the Global Positioning System"

https://www.pbs.org/newshour/world/what-to-know-about-russias-gps-jamming-of-a-european-officials-plane



By —
Emma Burrows, Associated Press

Leave your feedback

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What to know about Russia's GPS jamming of a European official's plane

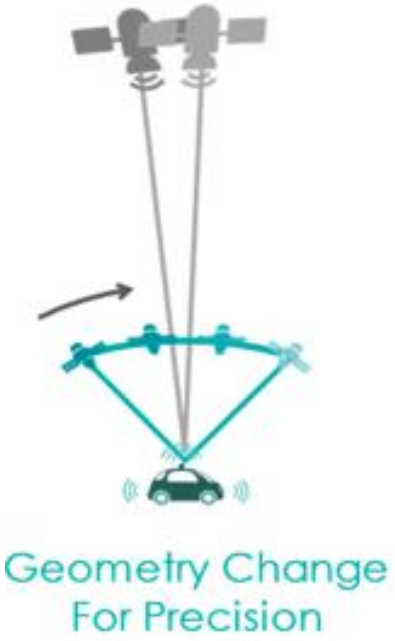
World Sep 2, 2025 2:42 PM EDT

LONDON (AP) — Bulgaria will not investigate suspected Russian electronic interference with a top European official's plane, officials said Monday — because this kind of GPS jamming is now so common.

How can satellite-based, PNT be bolstered?

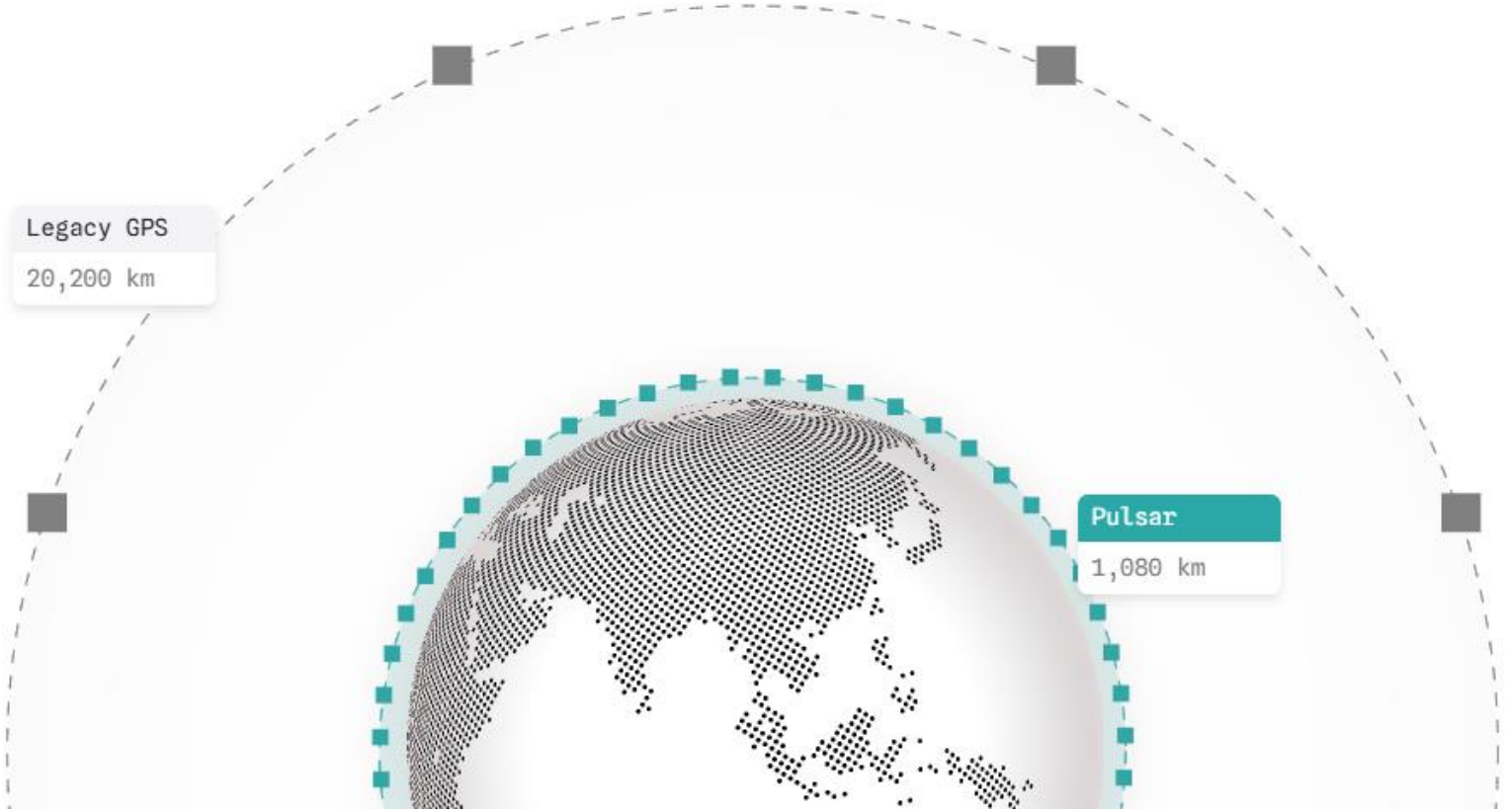
- Add redundancy through:
  - New orbits (multi-layered)
  - New signals (multi-frequency)
  - Encryption
  - Use of many satellites
  - Independent timing solution

https://www.gogoair.com/



https://www.mdpi.com/2673-4591/88/1/22

xona



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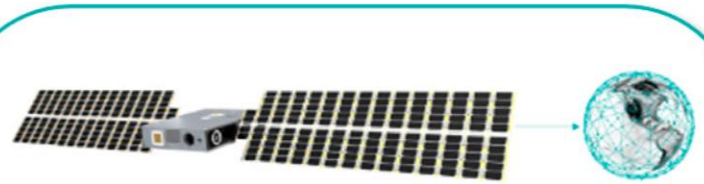


PULSAR Advantages

Near 260 satellites constellation

10-20 sats in view

Up to 170x stronger

2 cm Precision

High-security authentication

Compatible w/ existing GNSS devices

https://www.xonaspace.com/#pulsar

TrustPoint System Rollout

https://www.unoosa.org/documents/pdf/icg/2023/ICG_WG-S_LEO-PNT_Workshop_June_2023/ICG_LEO-PNT_Workshop_2023_03.pdf

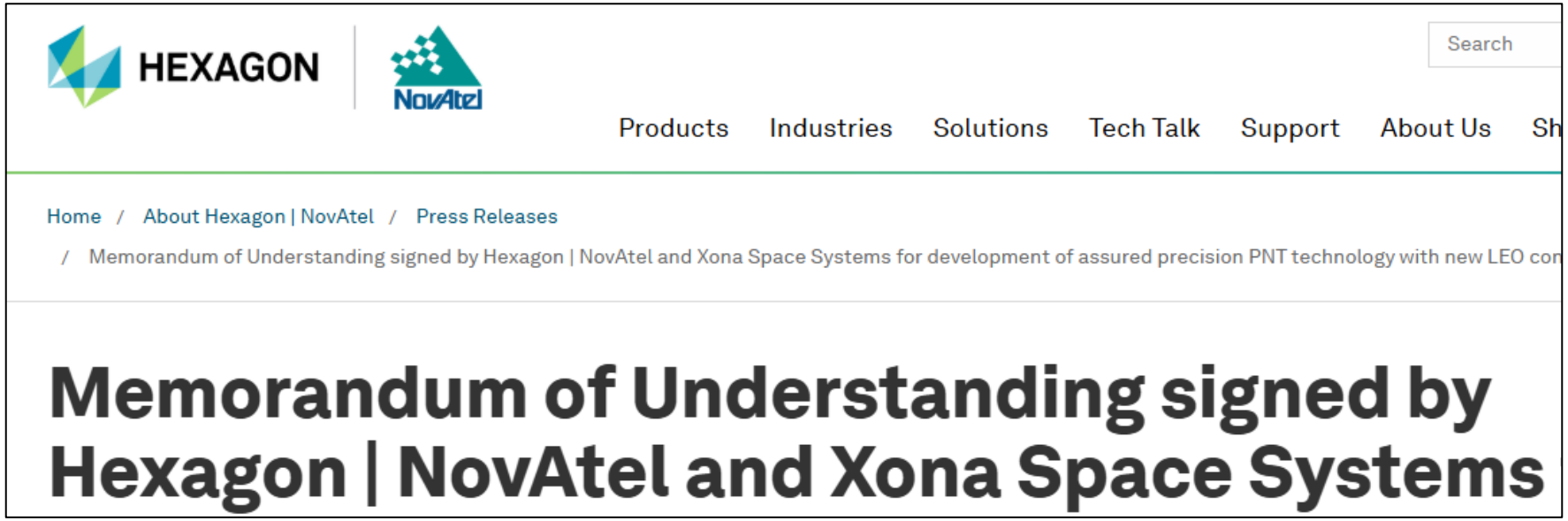
	Phase 0	Phase 1	Phase 2	Phase 3
System:				
	+2 Satellites	+32 Satellites	+64 Satellites	+288 Satellites
Coverage:	Global	Global	Global	Global
	4 Contacts Per Day	Hourly Contacts	Persistent	Persistent and Resilient
Services:	GPS Augmentation Secure Synchronization Timing Service Positioning Service	GPS Augmentation Secure Synchronization Timing Service Positioning Service	GPS Augmentation Secure Synchronization Timing Service Positioning Service	GPS Augmentation Secure Synchronization Timing Service Positioning Service

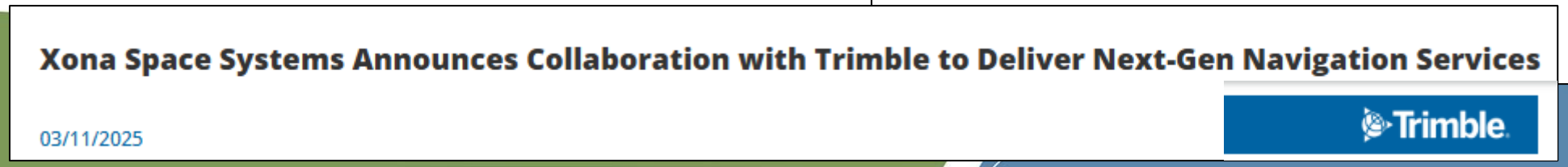
European Space Agency LEO- PNT

- “Celeste”
- In-orbit demonstrator phase
- 10 satellites, 2 spares
- 3 month launch period starting in December 2025
- Testing multiple frequencies
- 510 km orbit

https://www.esa.int/Applications/Satellite_navigation/LEO-PNT/ESA_s_LEO-PNT_satellites_set_to_launch_by_end_of_year

LEO PNT Enabled Receivers





Canada

In 2030, we can expect…

- LEO constellations contributing to the position solution on GNSS receivers
- LEO constellation tracking will be an upgrade feature in GNSS receivers
- Subscriptions will exist for LEO constellations
- What about ESA's Celeste? Free?

Market Trends

Demand for surveys to support the energy sector

- Assessing the energy output potential of solar and wind power plants
- Earth Observation and GNSS data are vital resources in identifying optimal sites for renewable energy
- Surveyors are critical in energy projects and disaster mitigation planning

https://energy.novascotia.ca/renewables/wind-energy

https://www.researchandmarkets.com/reports/6057072/land-surveying-equipment-market-outlook

Demand for Surveys to support Climate Change Studies and Environmental Regulations

- Climate change, natural disasters, and environmental conservation will continue to increase the demand for land surveying services
- High-accuracy surveys required to monitor erosion, flood zones, coastal changes, and deforestation.
- Stricter environmental regulations require detailed land assessments before approving construction projects
- Land surveying critical for determining compliance and sustainable development

https://www.cbc.ca

https://www.researchandmarkets.com/reports/6057072/land-surveying-equipment-market-outlook

Demand for surveys to support Infrastructure Expansion and Smart Cities Development

- Urbanization trend will continue: Global push for infrastructure development and smart city projects – highways, railways, airports, utilities
- Smart city initiatives rely on accurate geospatial mapping to optimize land use, traffic systems, and resource distribution.
- Surveyors have an invaluable skillset in being able to capture and integrate different sources for effective planning

https://www.researchandmarkets.com/reports/6057072/land-surveying-equipment-market-outlook

Demand for BIM contributions

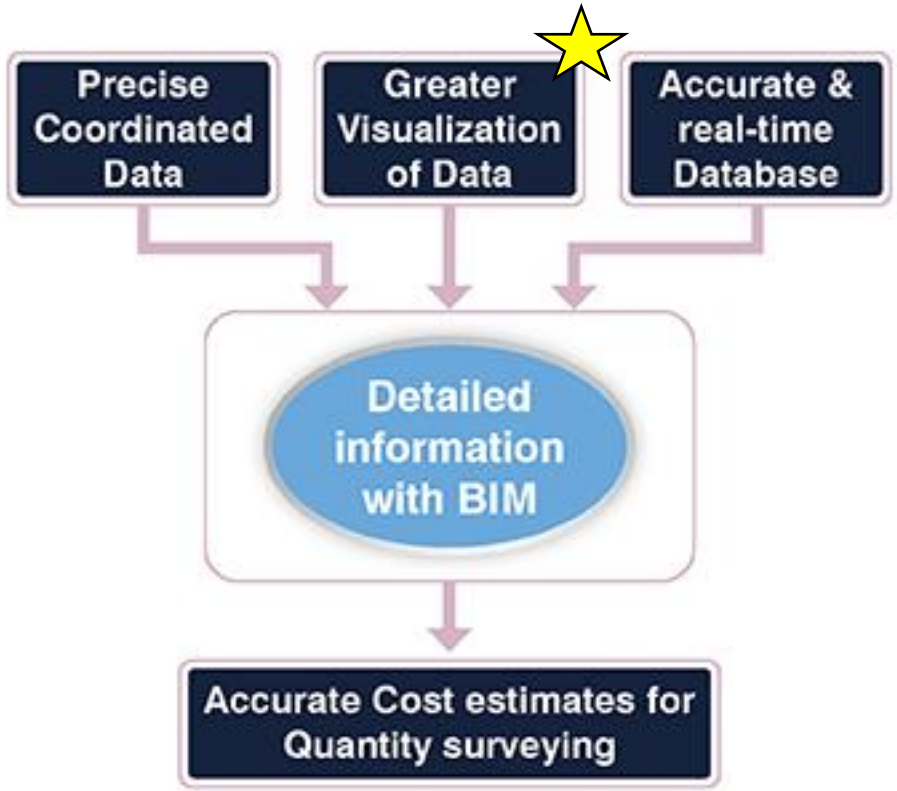
BIM (Building Information Modeling) is an intelligent process for creating and managing digital models of a building or other physical asset, which contain both its physical and functional characteristics. Supported by technology and collaboration, BIM creates a single, shared 3D model where all project information is contained and can be shared among stakeholders. - www.Autodesk.com

Demand for BIM contributions

- Surveyors – “BIM Enablers”

- Surveyors need to engage with other disciplines and contractors to create value-driven deliverables. Based on a single project management tool and BIM-ready deliverables, surveyors can collaborate with various disciplines to gain a thorough understanding of design and spatial geometry or data to ensure efficient construction.

[Geoweeknews]



“Greater Visualization of Data”

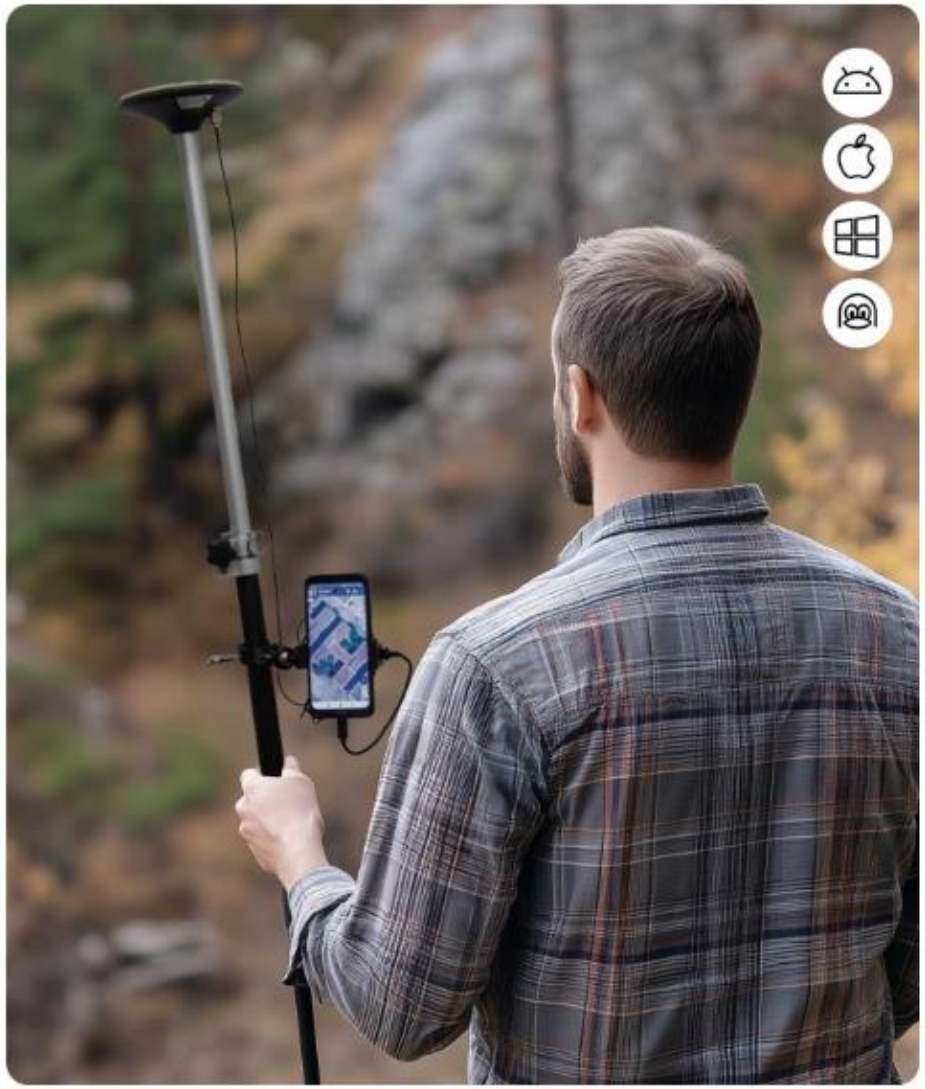
“Greater Visualization of Data”

Adding tools to the Toolbox…

Laser Scanners
(~$50K)

LiDAR Sensors for Drones
(~$20K)

RTK UAV
(~$10K)



Made in Europe

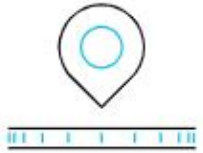
Professional

RTK Calibrated Surveyor Kit

Ready to work

Traditional survey performance at affordable cost.
Includes accessories.

Surveying job



High precision geolocation

$1K

Select options

Best possible accuracy	GNSS module options	Bands	Constellations	How to enable RTK mode
1 centimeter	ZED-F9P Mosaic-X5 (optional)	L1/L2	GPS, GLONASS, BeiDou, Galileo, QZSS, SBAS Navic (optional)	internet (NTRIP)

Canada

In 2030, we can expect…

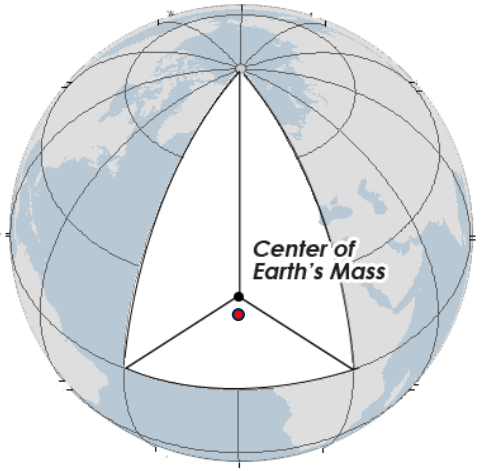
- Increased survey demand from:
  - Energy sector
  - Climate change studies
  - Smart planning
- Surveyors serving as geospatial data integrators/managers on complex projects will thrive
- Opportunities for the surveying profession to demonstrate value added services

A modernized Canadian Spatial Reference System (CSRS)

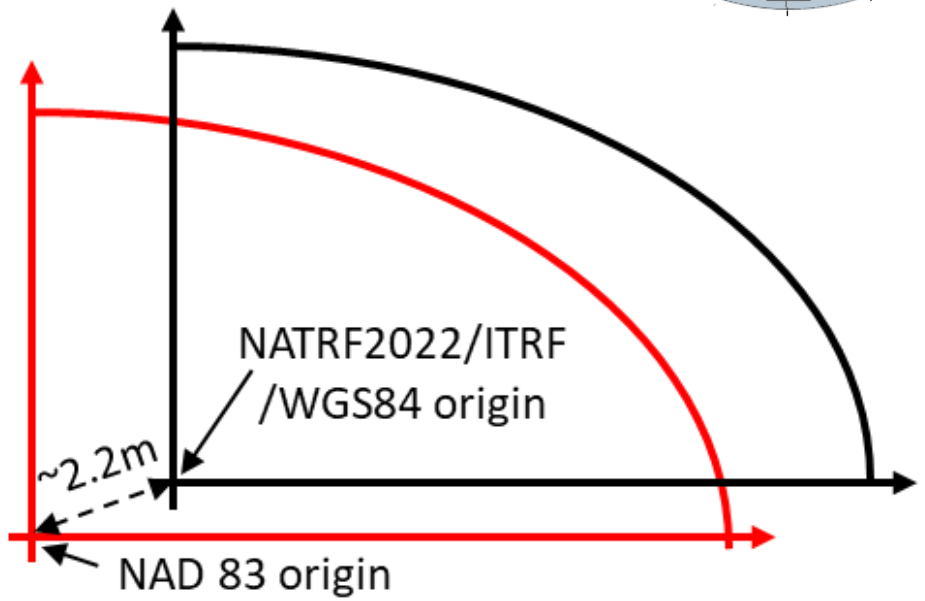
Canada will modernize the CSRS in 2026

- Federal adoption of North American Terrestrial Reference Frame of 2022 (**NATRF2022**) targeted for 2026
- Provincial adoption targeted by 2030

Why move to NATRF2022?



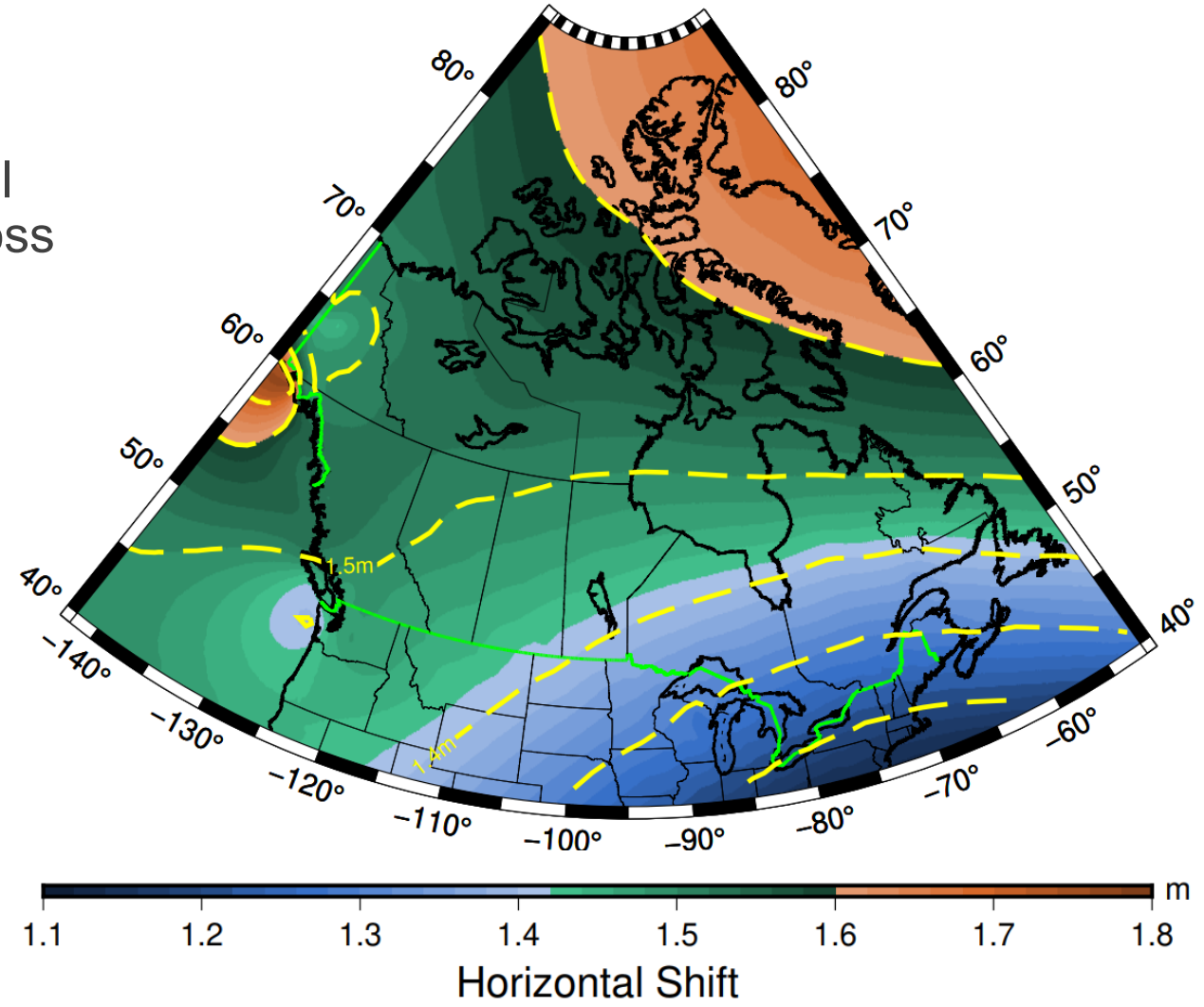
- NAD83 is not a geocentric reference system
- GNSS systems and the ITRF are geocentric
- NATRF2022 will better support applications requiring precise GNSS
- The US is moving to NATRF2022



NATRF2022 vs NAD83(CSRS)

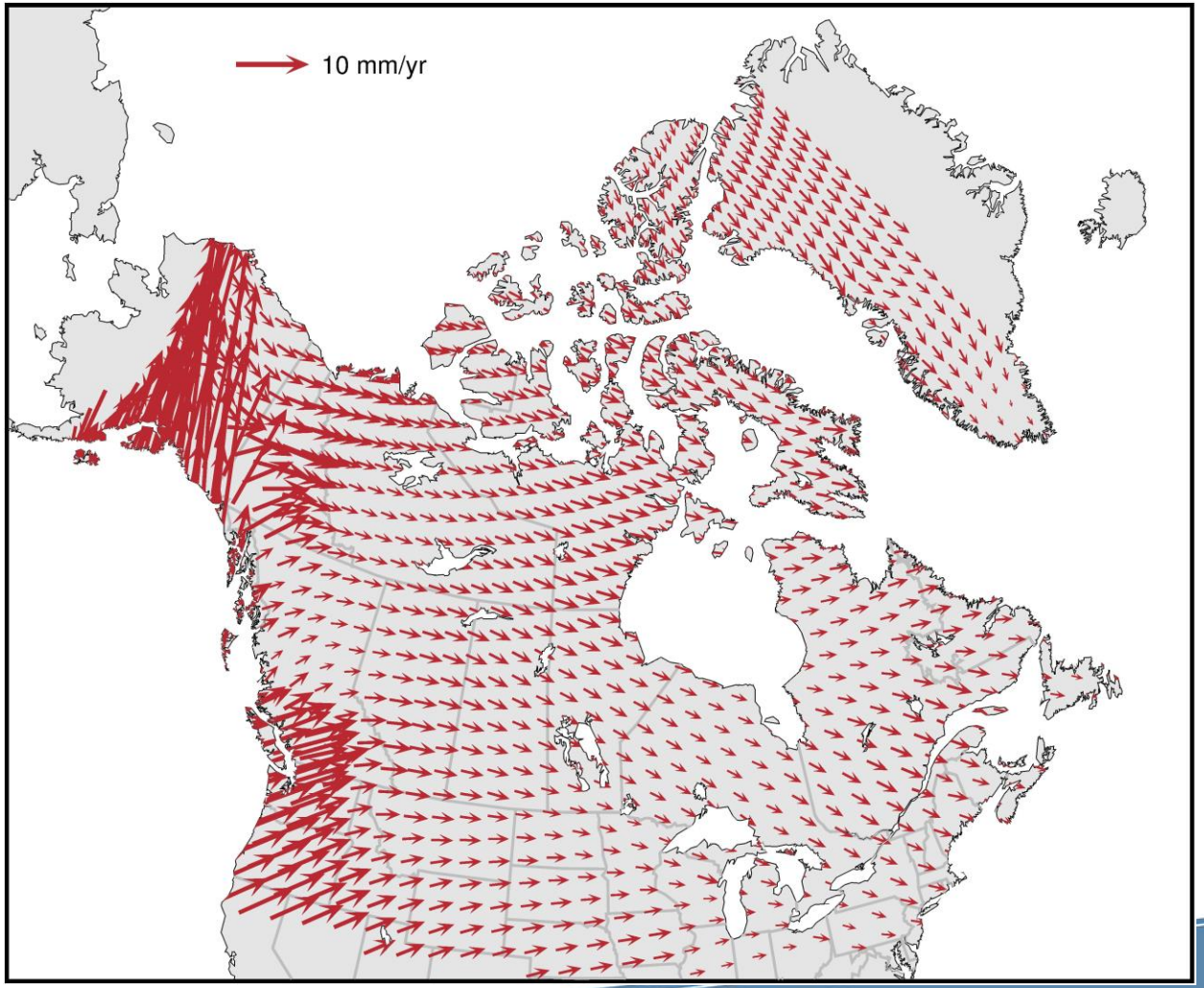
- Coordinates in NATRF2022 and NAD83 will have ~1-2 m 3D geometric differences across Canada

- For coordinates at the same epoch, the transformation between NAD83 and NATRF2022 is mathematical



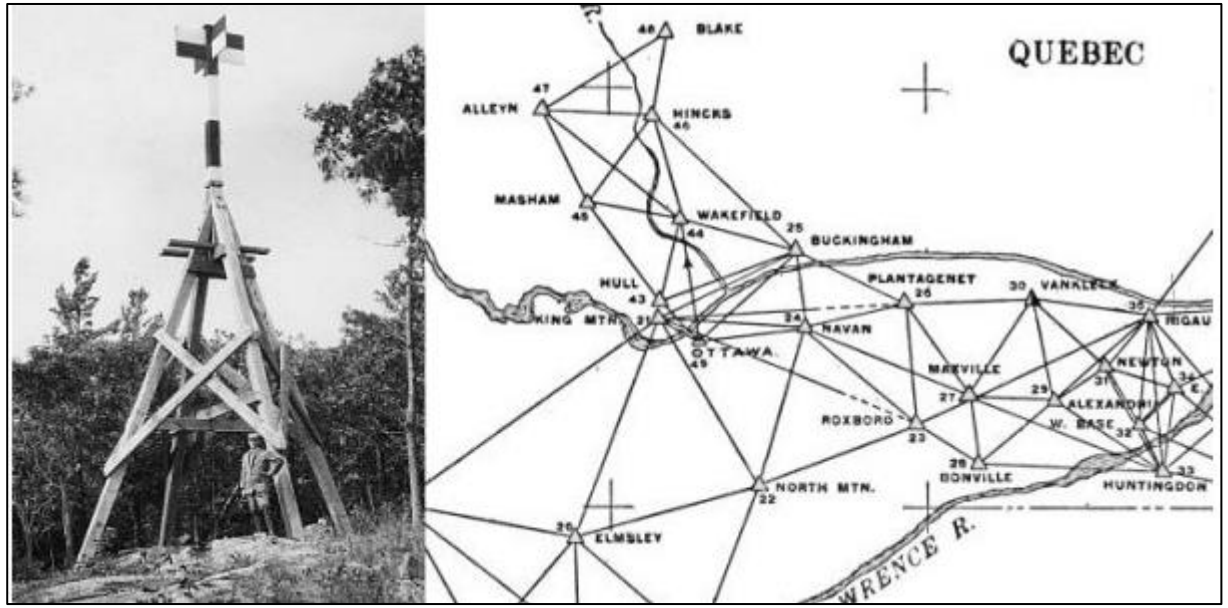
NATRF is a Dynamic Reference Frame

- NAD83(CSRS) v6/7/8; NATRF2022
- Allows for coordinates to change with time due to crustal or local motions
- Velocities estimated along with coordinates
- In Canada, accompanied with a velocity model to predict coordinates at other epochs
- Coordinates can be produced at any epoch



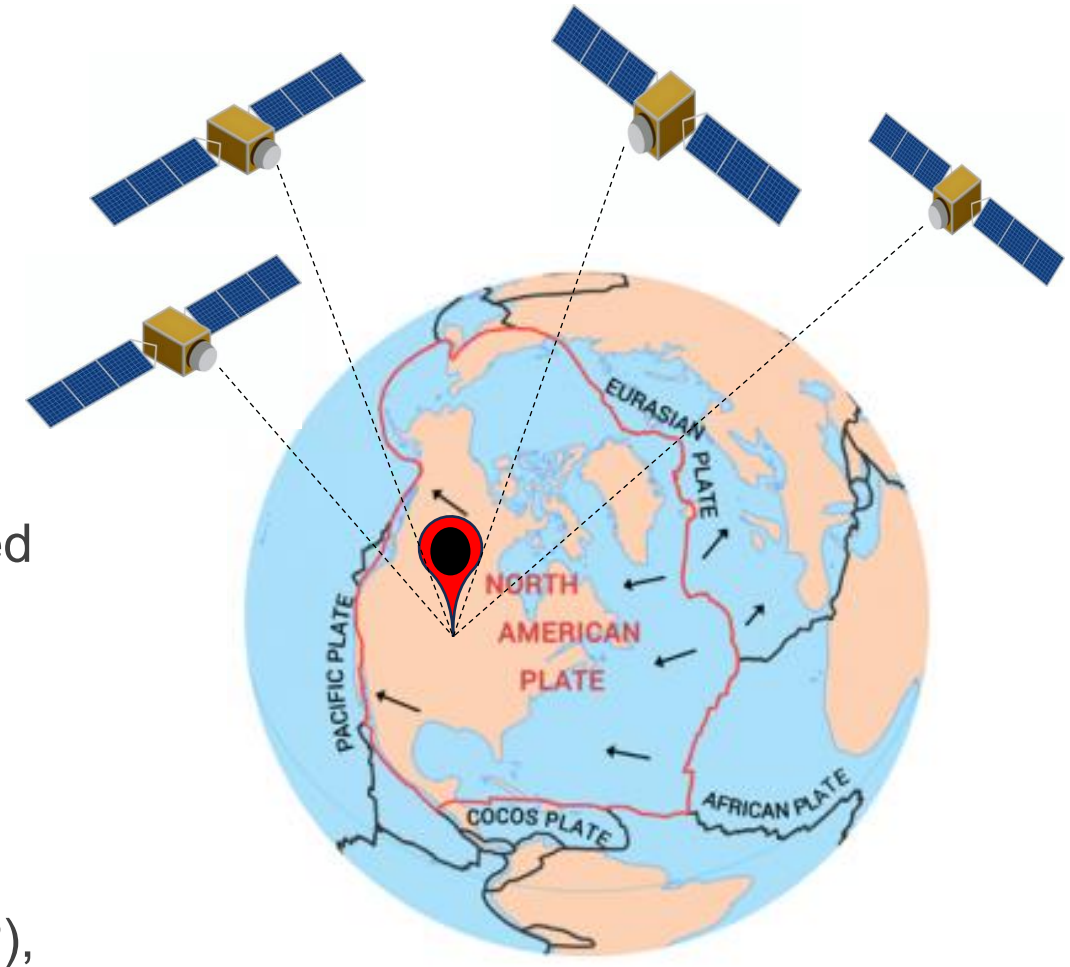
What is a Static Reference Frame?

- Coordinates don't change over time
- Velocity model not used
- Eg., NAD27, NAD83(Original), ATS77
- Based on an adjustment of observations from many different epochs/eras
- Lack of global ties, lower accuracy observations and infrequent observations made crustal motion difficult to detect
- Early NAD83(CSRS) versions used observations over a shorter time period – no velocities estimated



The use of PPP has necessitated the use of dynamic reference frames in Canada

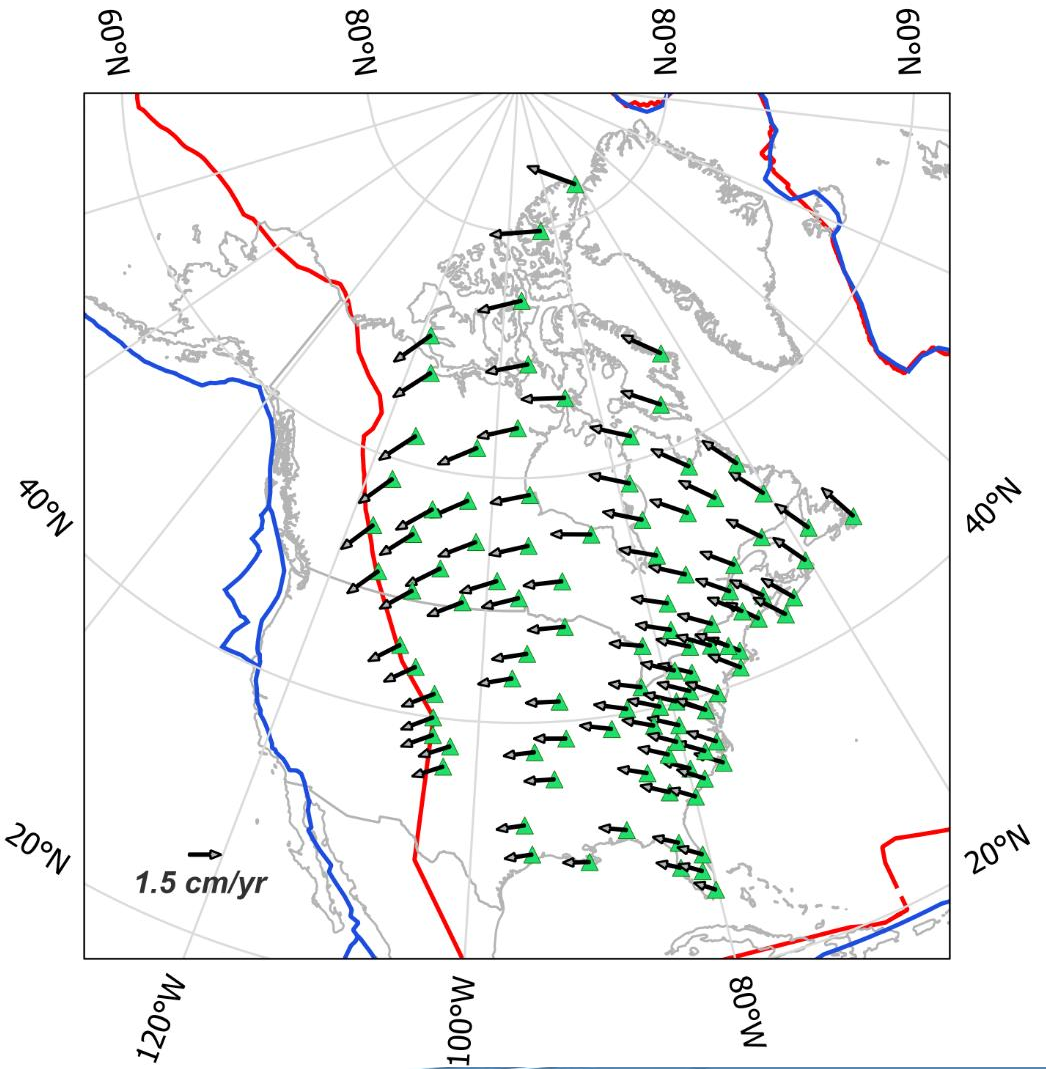
- GNSS measurements are made in the ITRF
- For most applications, we are looking to compare positions at a common epoch.
- Plate motion and residual motion must be considered
- When all positioning is relative to passive geodetic control, static reference frames work
- When satellite orbits serve as geodetic control (PPP), dynamic reference frames are needed



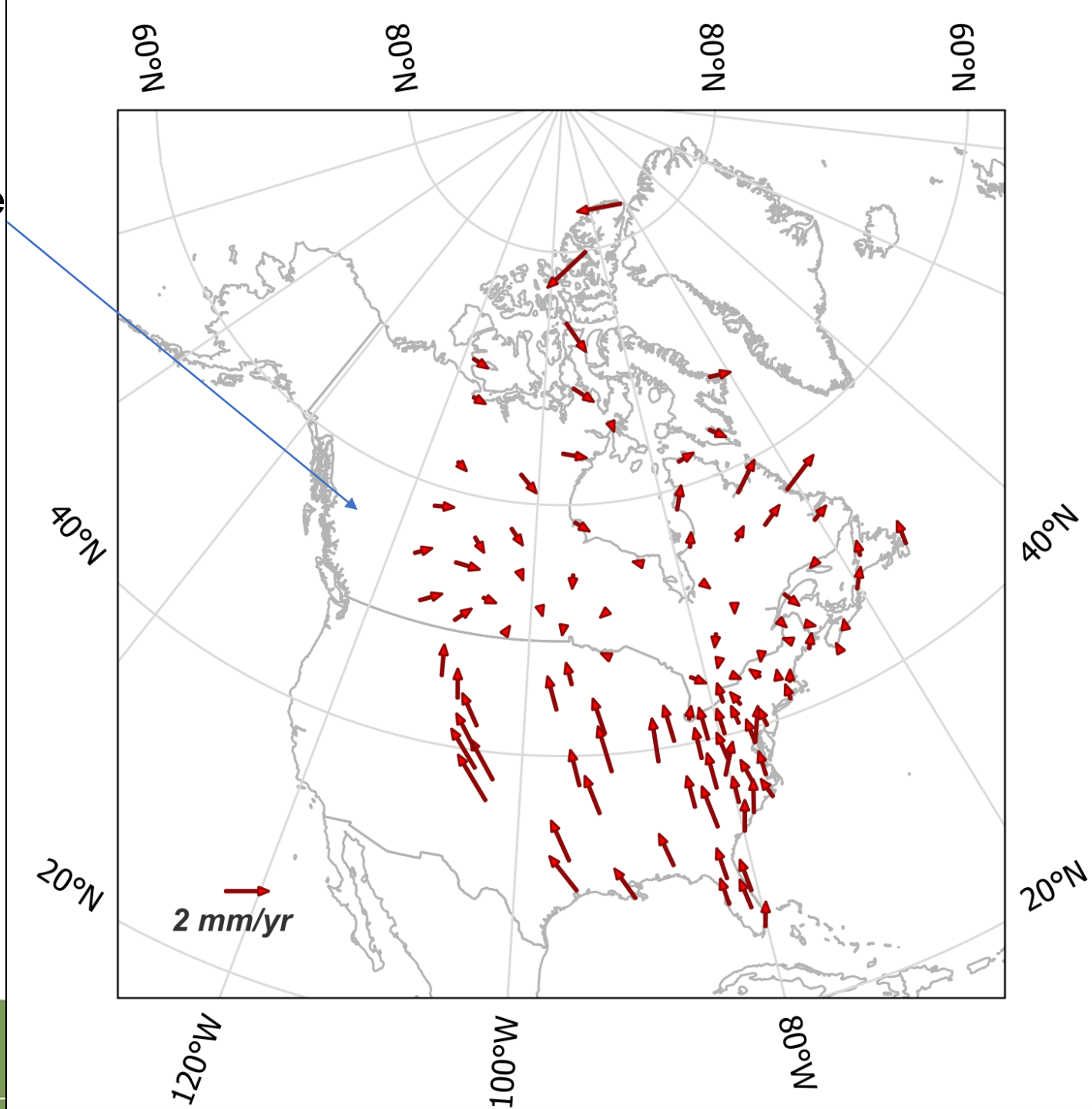
NATRF2022 is aligned to the ITRF2020

- NATRF2022 characteristics:
  - Geocentric
  - Aligned to ITRF2020 at 2020.0
  - Plate-fixed reference frame
  - Euler Pole Parameters define relationship between NATRF2022 and ITRF2020 (dynamic)

Lat. (°)	−3.821
Lon. (°)	−86.298
$\|\omega\|$ (°/Myr)	0.197
ω_X (mas/yr)	0.046
ω_Y (mas/yr)	−0.704
ω_Z (mas/yr)	−0.047

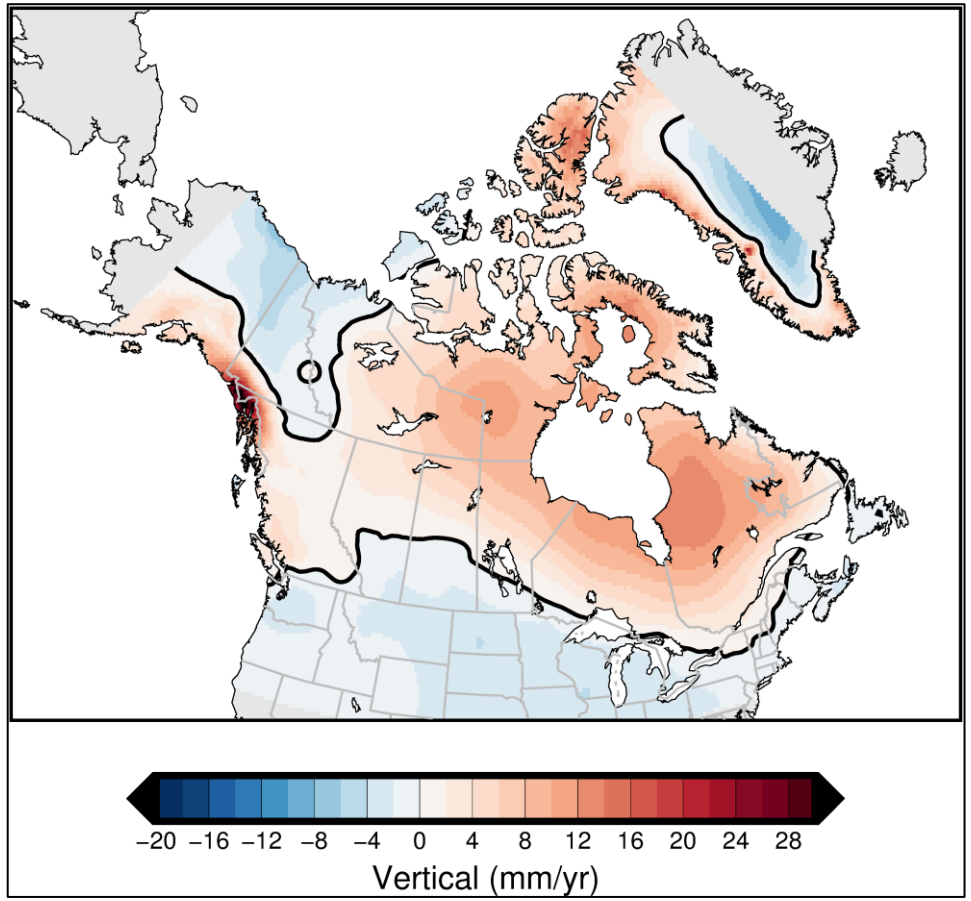


What's left after removing EPP rotations?



An Intraframe Deformation Model (IFDM) is used to capture residual motion not captured by the EPPs

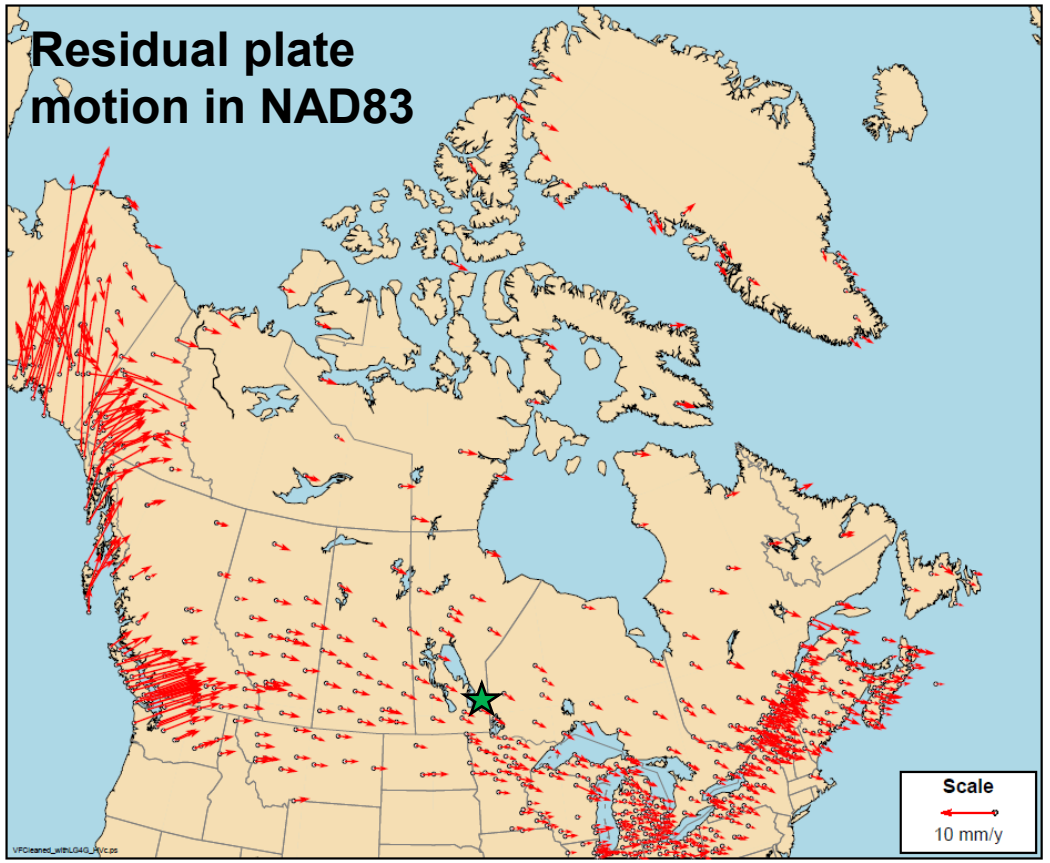
- IFDM is currently a velocity grid in Canada
- It may evolve to include more sophisticated modelling (coordinate functions and GGXF to be discussed)



NATRF2022 will better track North American Plate Motion using new EPPs

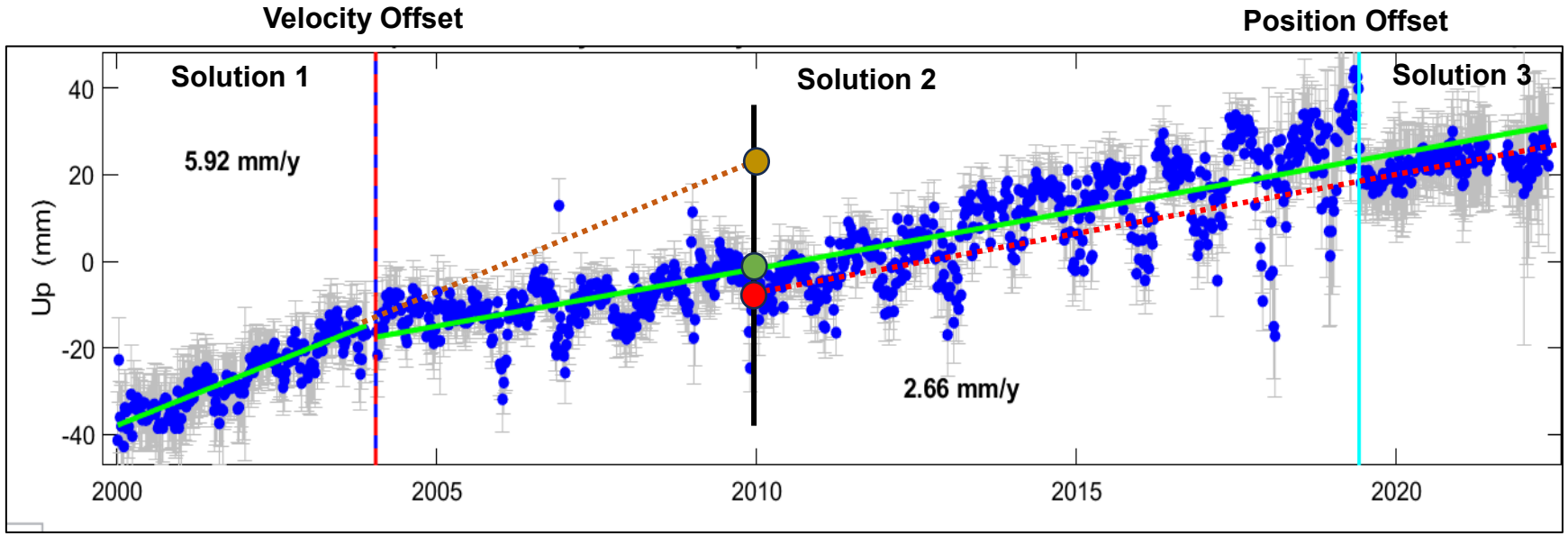
Example: DUBO CACS station (Lac Dubonnet): ★

Ref. Frame	Hor. Velocity	Hor. displacement since 2010
ITRF2020	18.1mm/yr	25.1cm
NAD83(CSRS)	2.5mm/yr	3.5cm
NATRF2022	0.65mm/yr	1.0cm

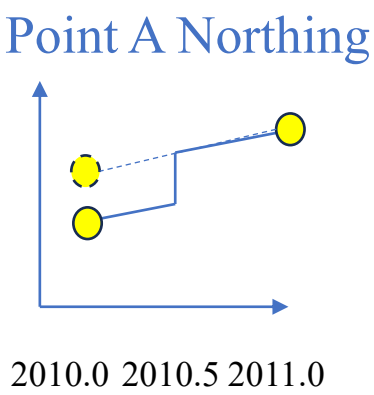


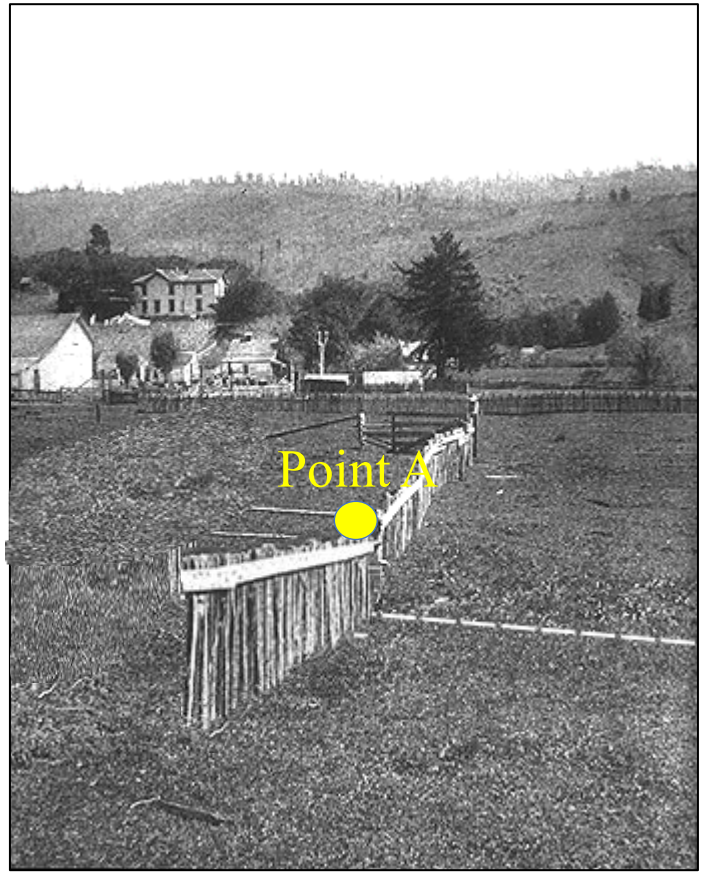
Coordinate Functions – Future Work

- Coordinate functions allow a station's position to be accurately retraced throughout its history
- Current velocity will place the station in the present reality.
- If you are looking to compare a historic coordinate with a present day coordinate, the full history of the point must be considered.

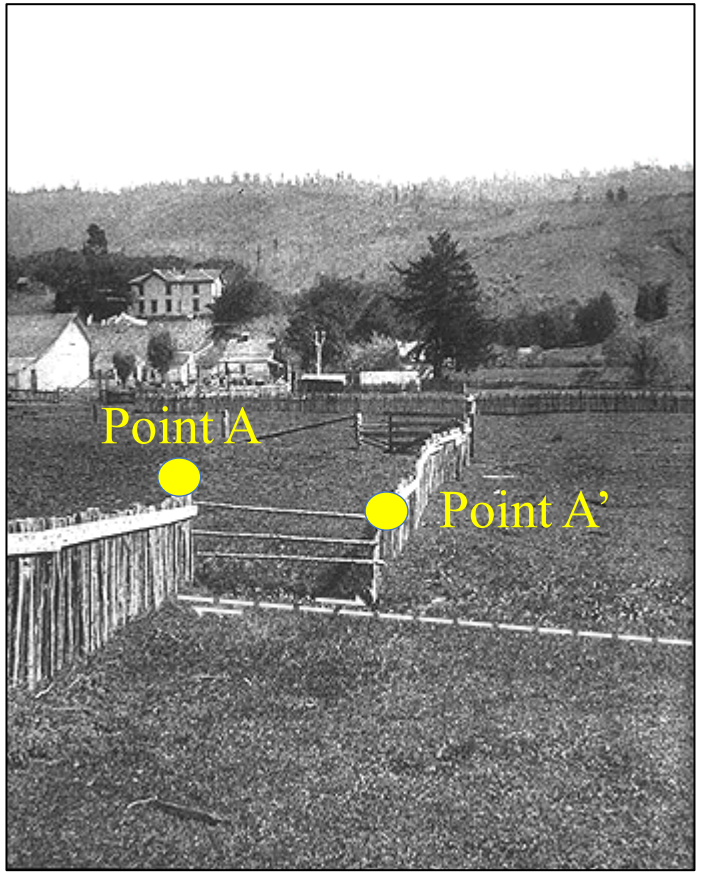


Coordinate Function Retracing of Position





Previous State



Current State

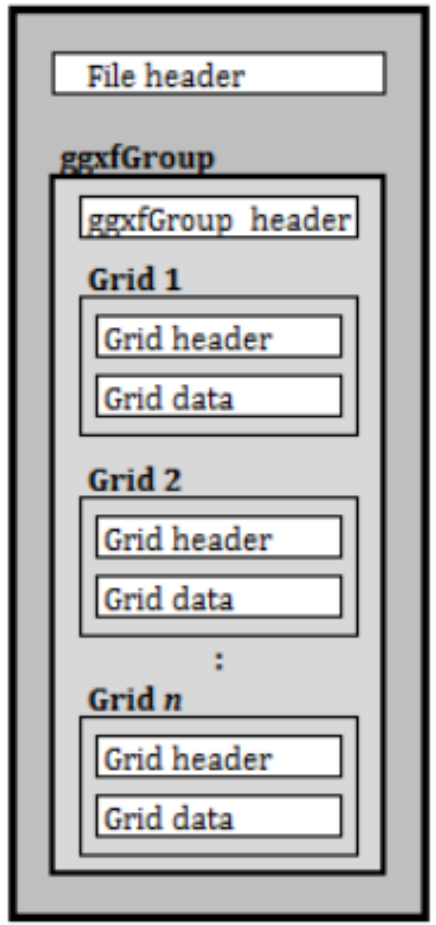
Using the current velocity alone, the current state would show the same fence location in previous state (Point A')

A coordinate function could be used to apply the Earthquake offset and recreate the actual previous fence location. Knowledge of the fault zone would be needed.

GGXF: Gridded Geodetic Data Exchange Format

Open Geospatial Consortium (OGC) Standard

- A **GGXF file** consists of:
  - A file header containing metadata applicable to the whole file
  - One or more ggxfGroups
- Each **ggxfGroup** consists of:
  - A ggxfGroup header containing metadata applicable to the ggxfGroup;
  - One or more grids
- Each **grid** consists of
  - A grid header containing metadata applicable to the grid;
  - An array of nodes with parameter values



Allows for complex modelling of deformation

Dynamic Reference Frame with Static Snapshots

- In a dynamic reference frame like the ITRF, observations are at the time of survey
- Is this practical for survey applications? It probably makes the most sense to publish coordinates at specified epochs – “snapshots”
- Dynamic reference frames are best suited for scientific applications
- This is sounding a lot like NAD83(CSRS)…what’s old is new again
- Implications for how the coordinate referencing system is coded in the registries.

Vertical Datum Updates

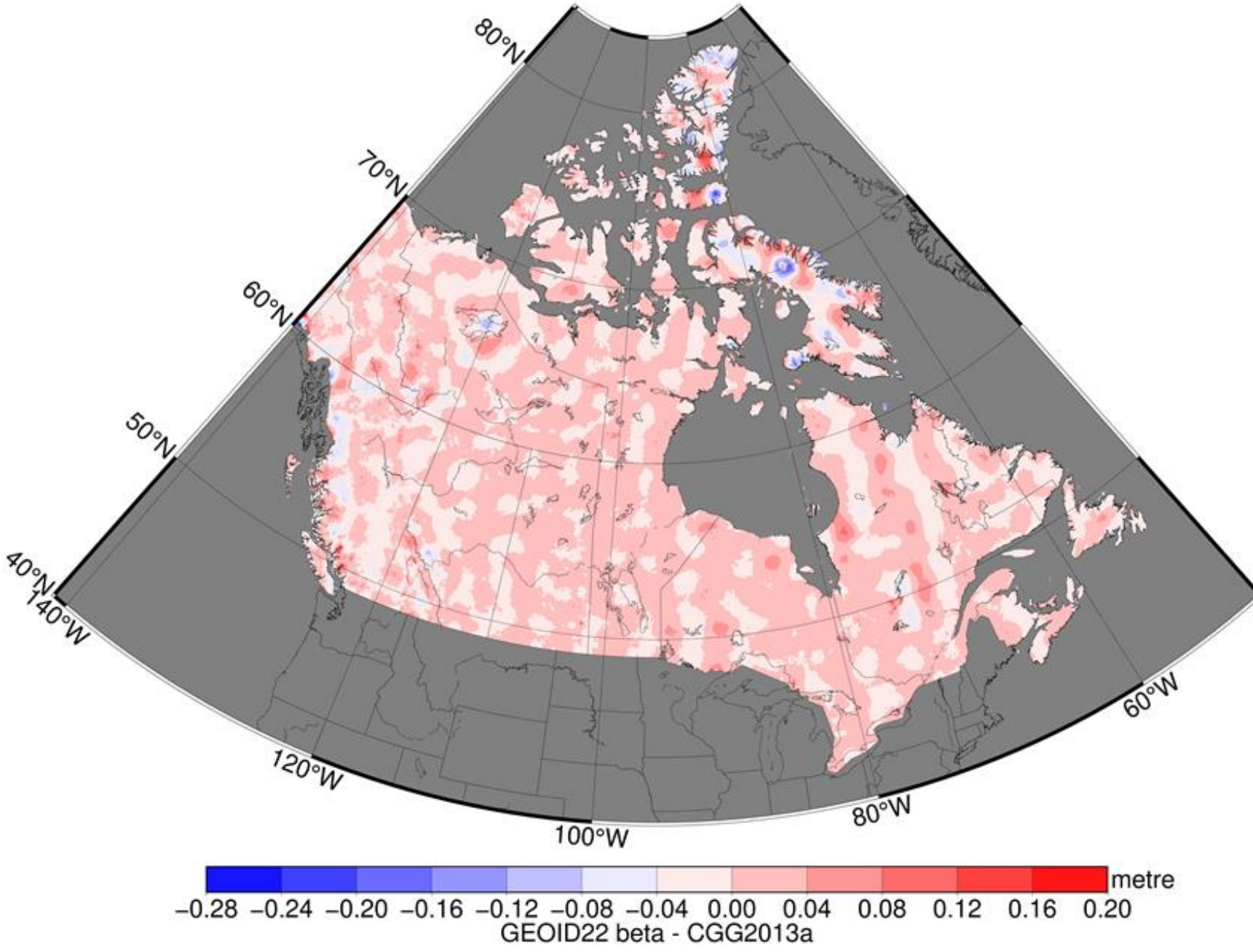
Vertical datum update in Canada

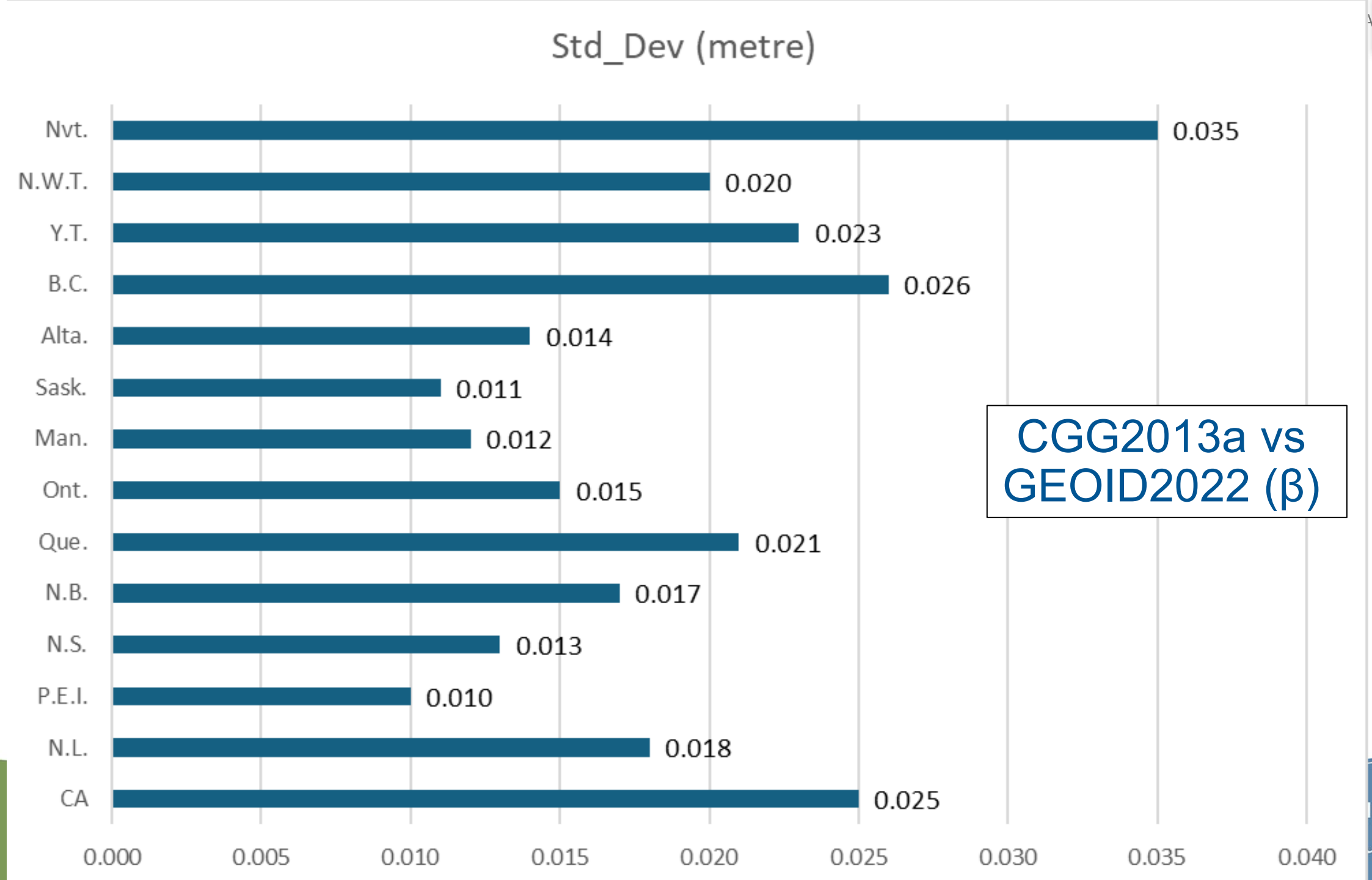
- Current adopted vertical datum: CGVD2013 (CGG2013a)
- The name CGVD2013 will be kept (same reference gravity value) but improved realization with SGEOID2022
- Proposed naming/versioning:

Compatible with the North American Pacific Geopotential Datum (NAPGD2022) (US)

Current Versioning	Modernized CGS Versioning
CGVD2013 (CGG2013)	CGVD2013 v0
CGVD2013 (CGG2013a)	CGVD2013 v0.a
CGVD2013 (SGEOID2022)	CGVD2013 v1

CGG2013a vs GEOID2022 (β)





CGG2013a vs GEOID2022 (β)

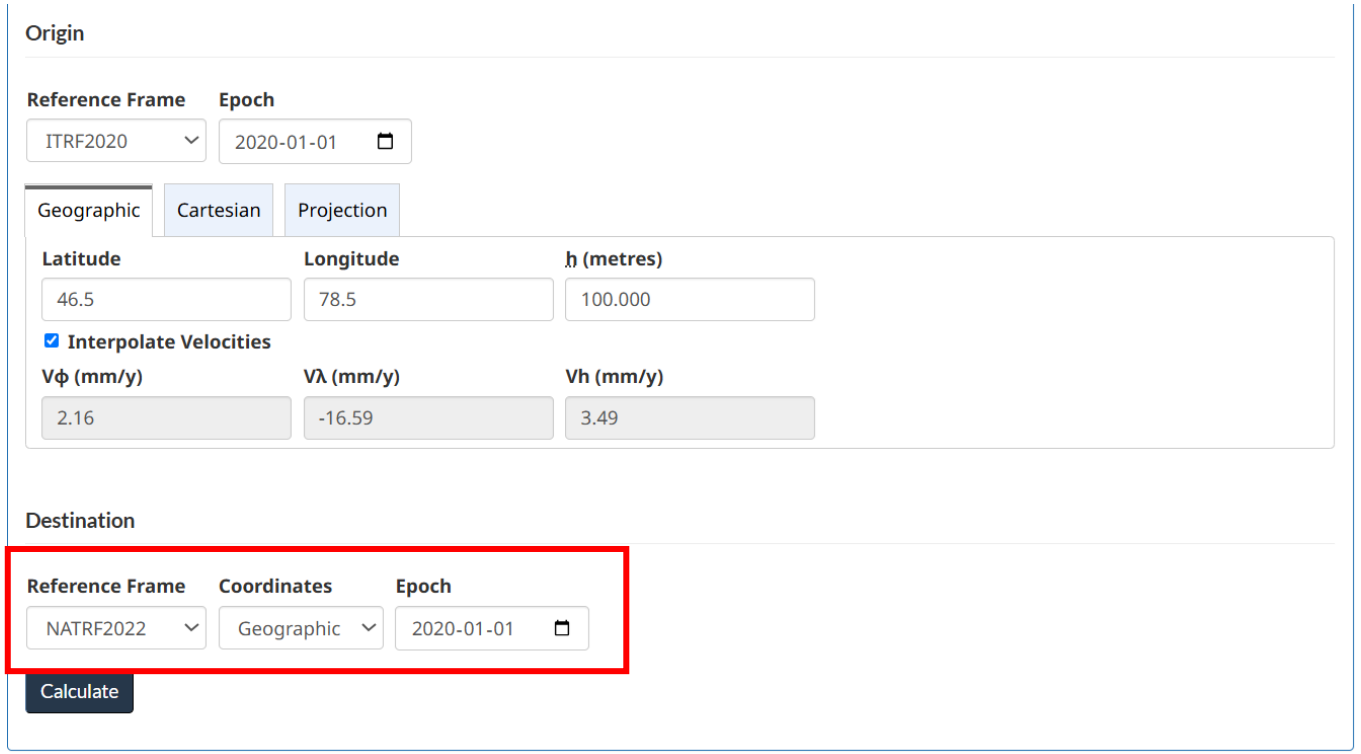
Updated CSRS Tools

CGS Tools will also be modernized

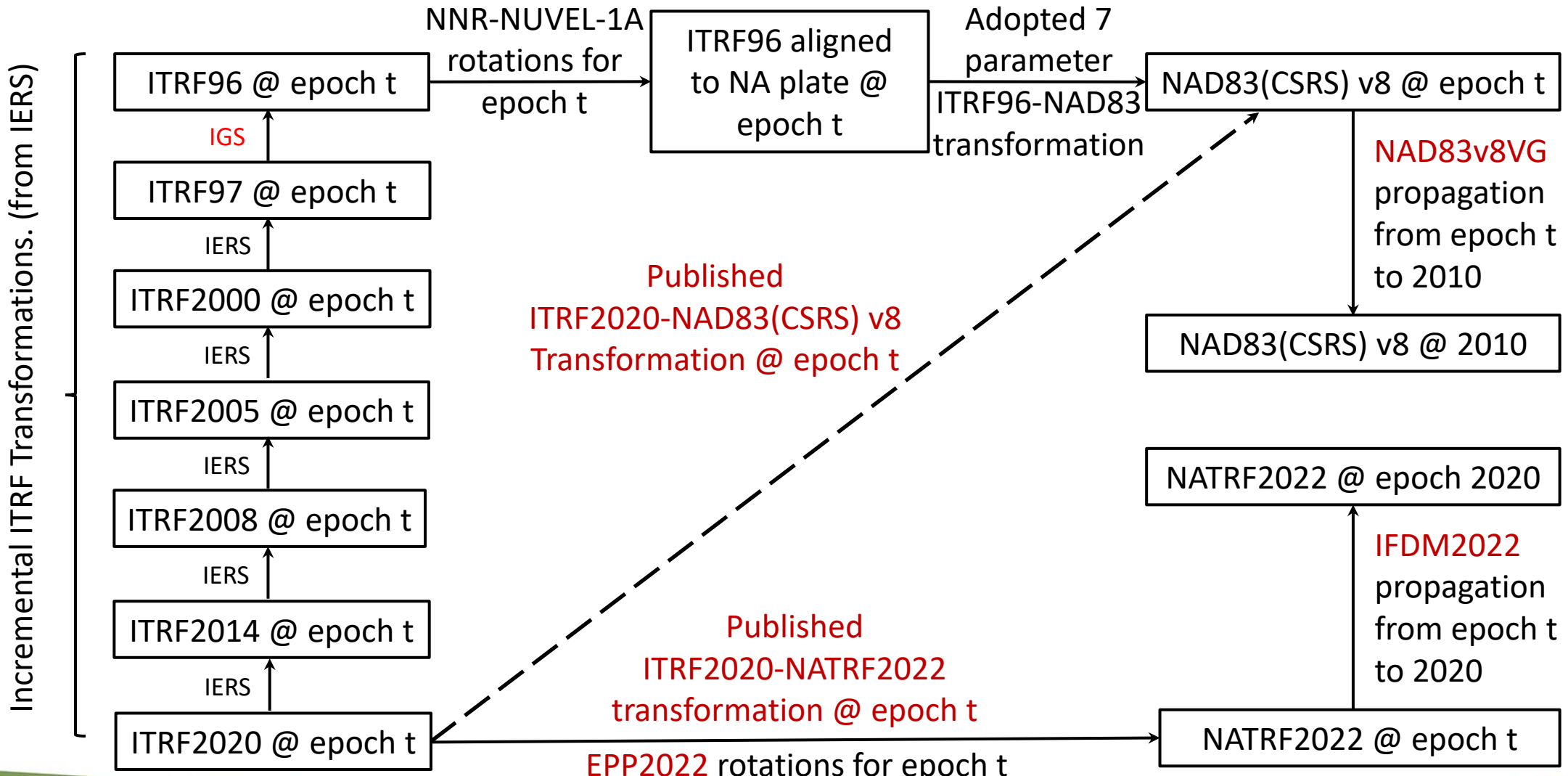
- Core modernization products will be available and implemented in CGS tools by 2026
- There will be no significant changes to CGS tool *functionality* in the modernized CSRS
- CGS will continue support for NAD83(CSRS) and legacy geodetic grid formats for some time
- Tools, models, and standards will be provided to transform between ITRF, NATRF2022, and NAD83(CSRS); as well as between different vertical datums

CGS Tools: TRX

- Transform between NATRF2022, NAD83(CSRS) and ITRF realizations
- Transform coordinates between epochs using the predicted motions from the Canadian IFDM2022
- Convert coordinates between geographic, Cartesian, and mapping projections (UTM, MTM, stereographic)
- Supports batch mode (CSV, GeoLab, GHOST formats)



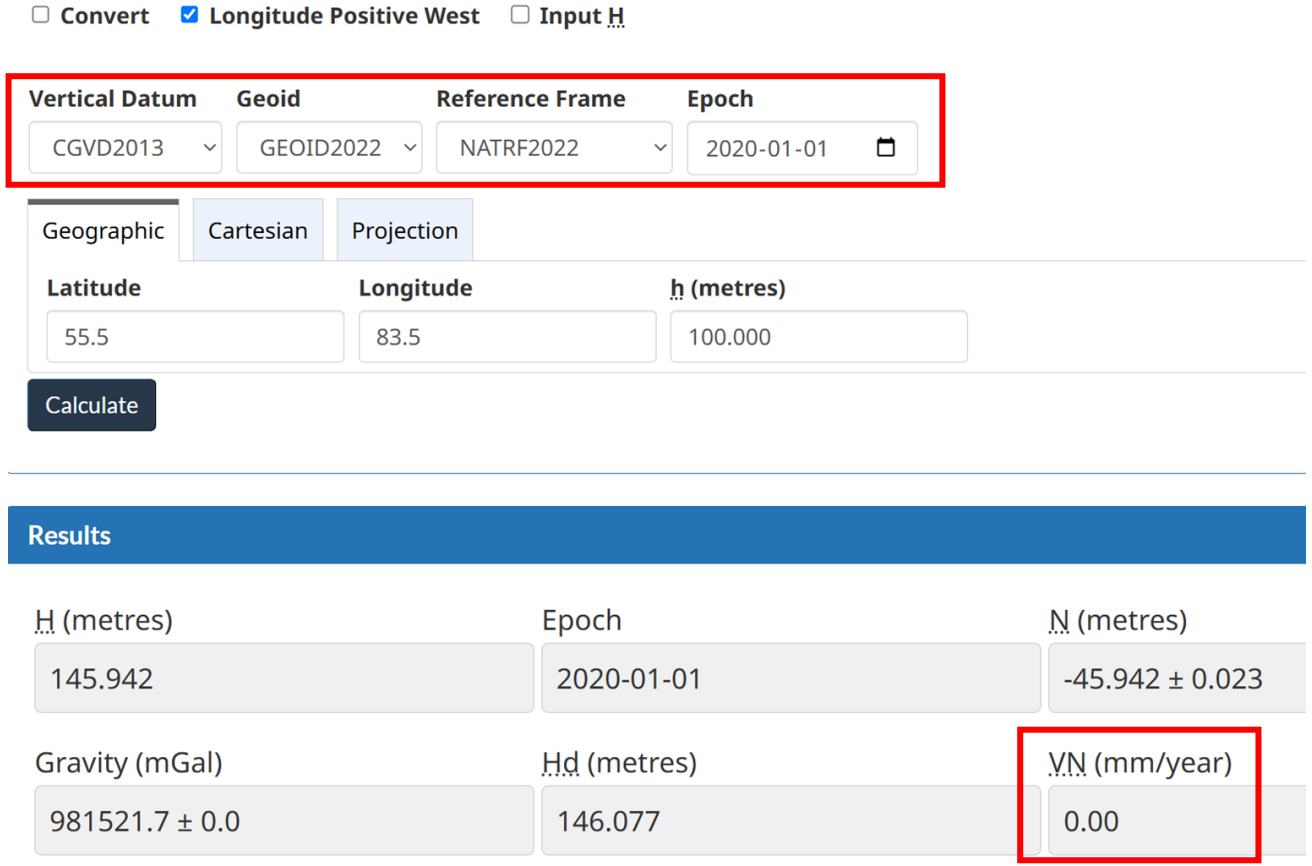
CGS Tools: Geometric Transformations



CGS Tools: GPS-H

- Convert ellipsoidal / orthometric heights
- Supports dynamic heights in CGVD2013
- Convert vertical datums and versions:
  - CGVD28 and CGVD2013 (CGG2013a - HTv2.0)
  - CGVD2013 v0 and CGVD2013 v1 (SGEOID2022 – CGG2013a)

Official adoption: CGVD2013 v1 SGEOID2022



In 2030, we can expect…

- NATRF2022 will be the adopted standard for positioning
- Software and hardware will support NATRF2022
- More sophisticated deformation models will be implemented to maintain accuracy between epoch transformations

Surveying in 2030…


Questions?