Ford Highway Driving RTK Dataset: 30,000 km of North American Highways

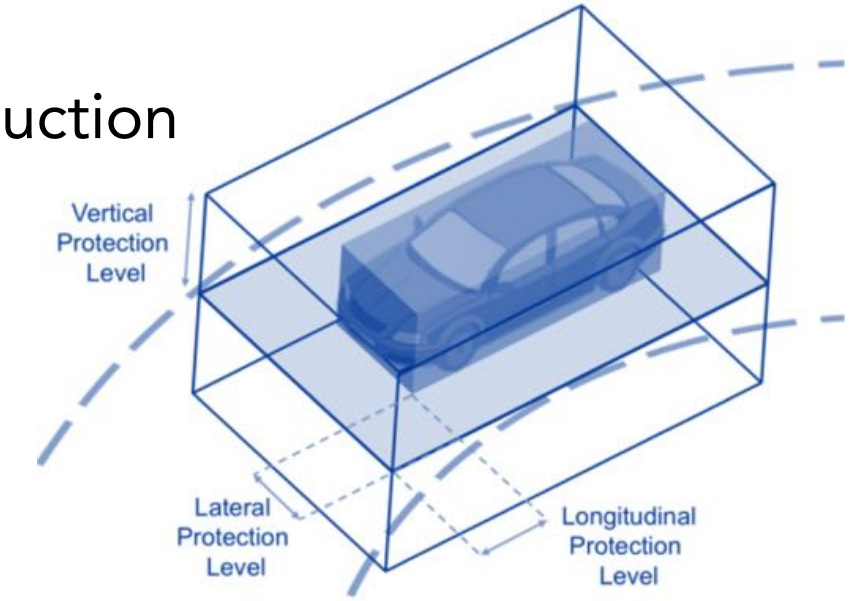
Sarah E. Houts[**], Tyler G. R. Reid[†], Nahid Pervez[*], Umair Ibrahim[**], Gaurav Pandey[*], Naveen K. R. Alla[*], Andy Hsia[*]

[*]*Ford Motor Company*
[**]*Ford Autonomous Vehicles, LLC*
[†]*Xona Space Systems*

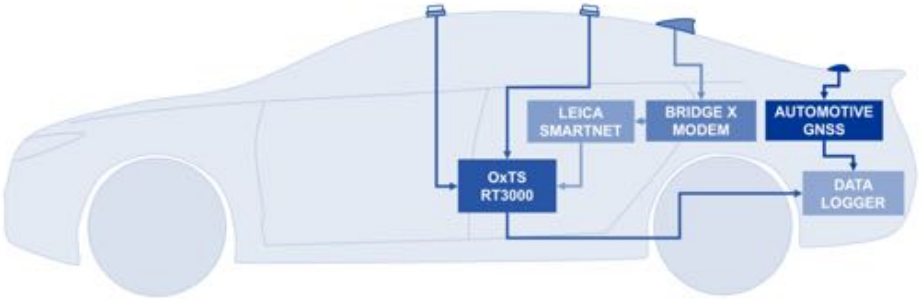
SCPNT Symposium, October 27-28, 2020

Outline

Introduction



GNSS Data Collection



Accuracy

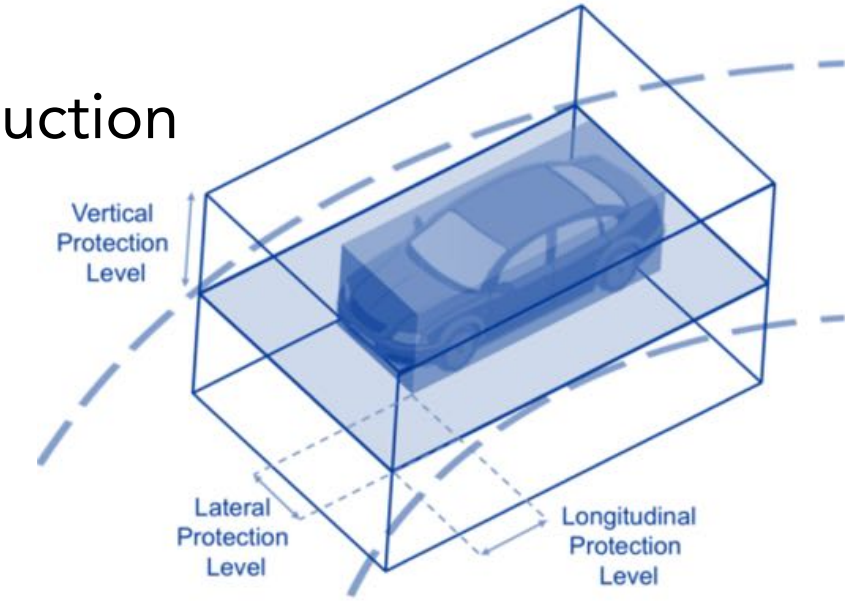
Availability

Continuity

RTK Performance

Outline

Introduction



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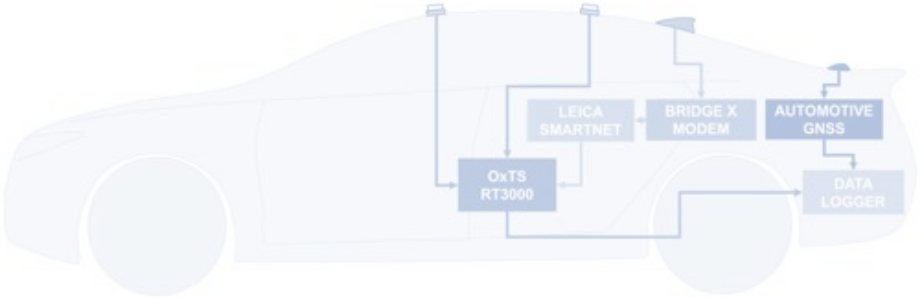


Accuracy

Availability

Continuity

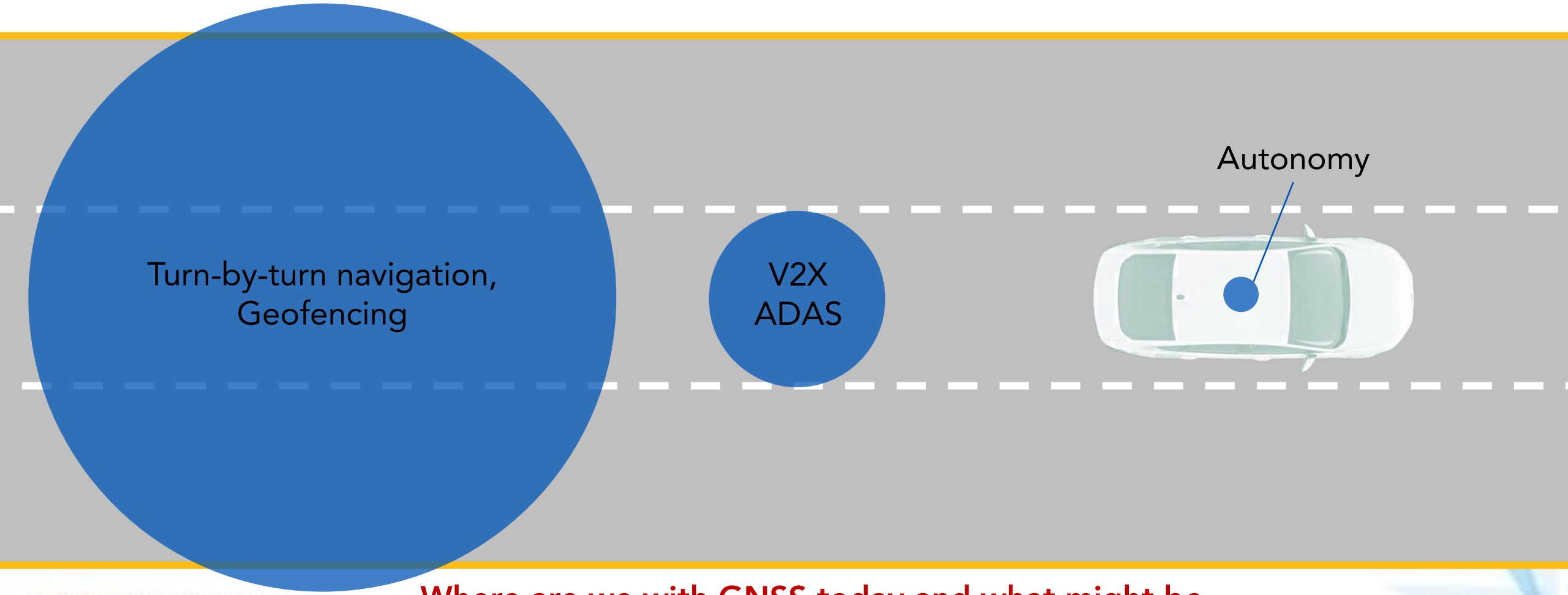
RTK Performance

Automotive Positioning Needs

Which Road
< 5 m

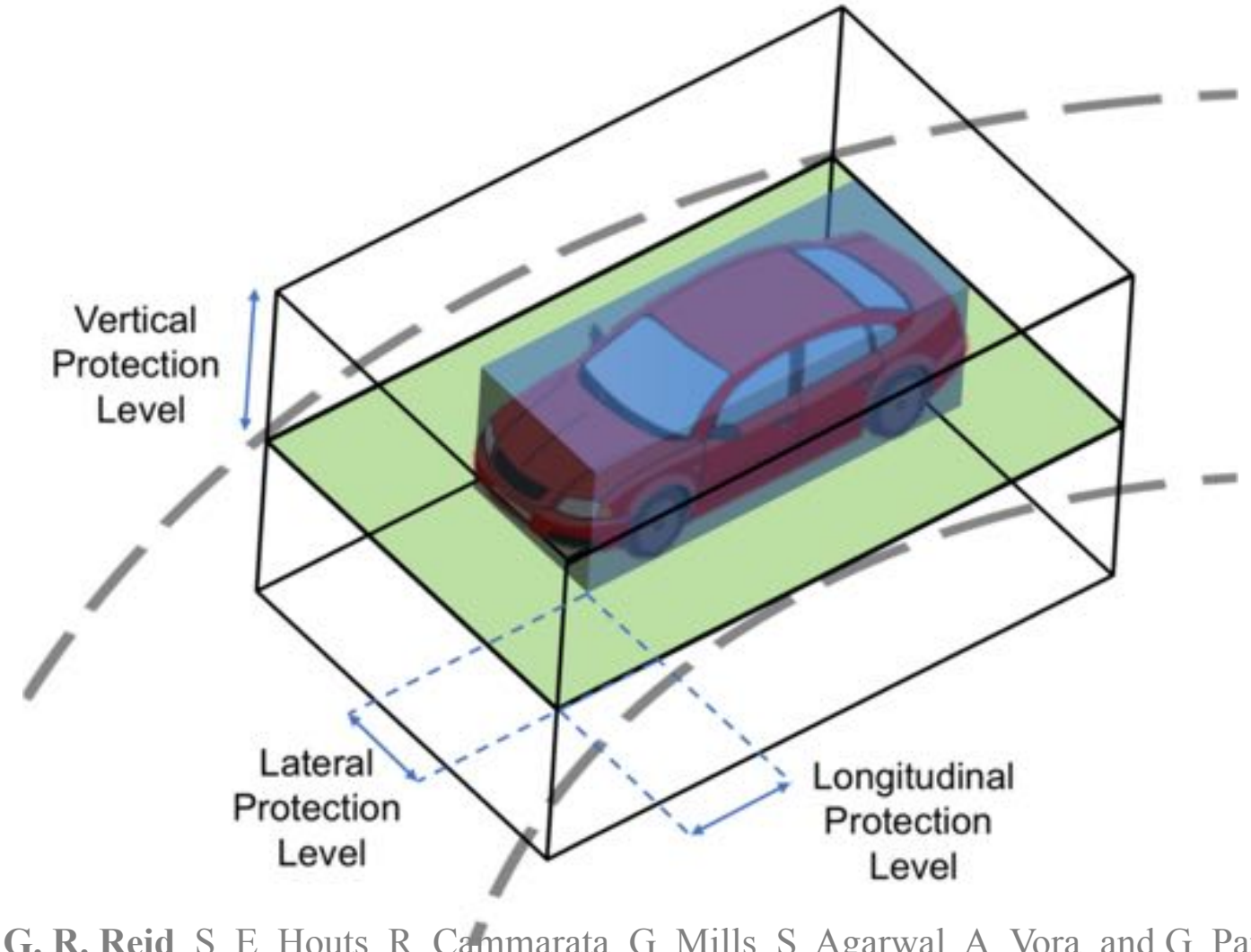
Which Lane
< 1.5 m

Where in Lane
< 0.3 m



Where are we with GNSS today and what might be possible in the future?

Localization Requirements for Autonomous Vehicles

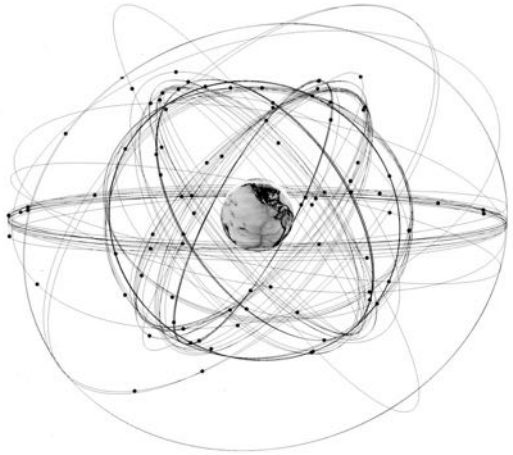


T. G. R. Reid, S. E. Houts, R. Cammarata, G. Mills, S. Agarwal, A. Vora, and G. Pandey, "Localization Requirements for Automated Driving," *SAE World Congress Experience (WCX) 2019*, Detroit, MI.

Recent Advances in Automotive GNSS

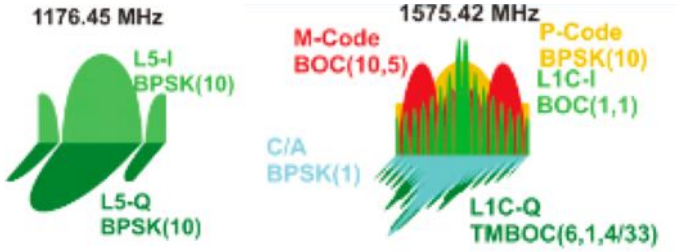
Satellites

More satellites from more countries means higher availability



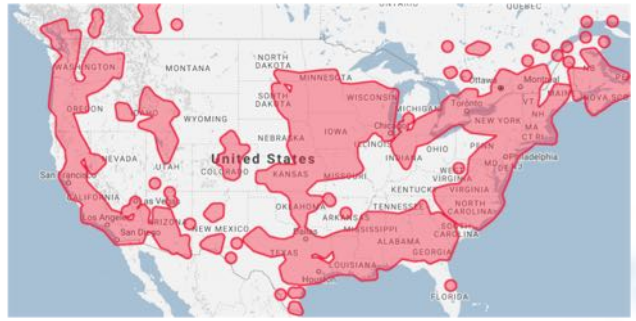
Frequencies

Modernized satellites have multiple civil frequencies, greatly improving accuracy and resistance to interference.



Infrastructure

Dense networks of GPS reference stations are being built to provide corrections for large scale precision.



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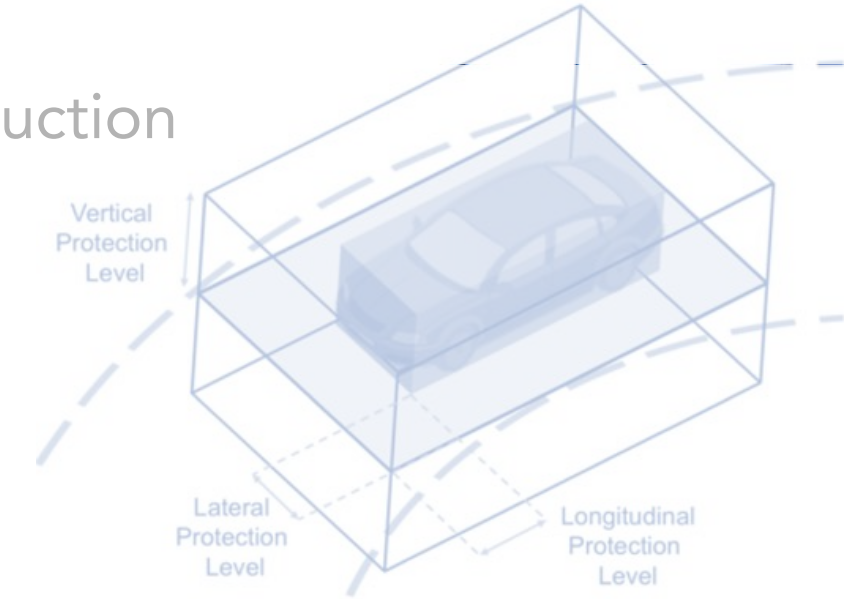
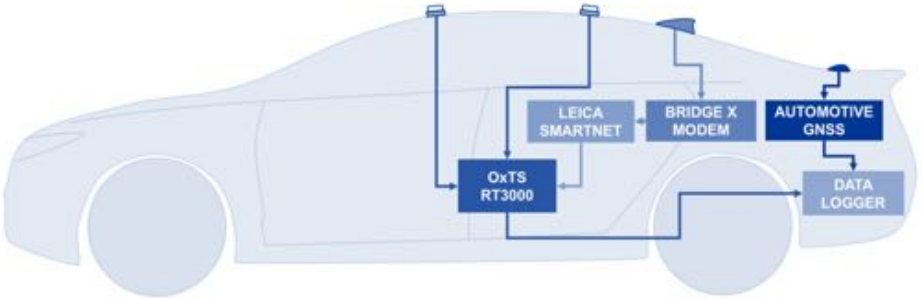


GNSS Data Collection



Accuracy

Availability

Continuity

RTK Performance

Data Collection

Automotive GNSS

L1
GPS + GLONASS + Galileo
Single antenna

Ground Truth

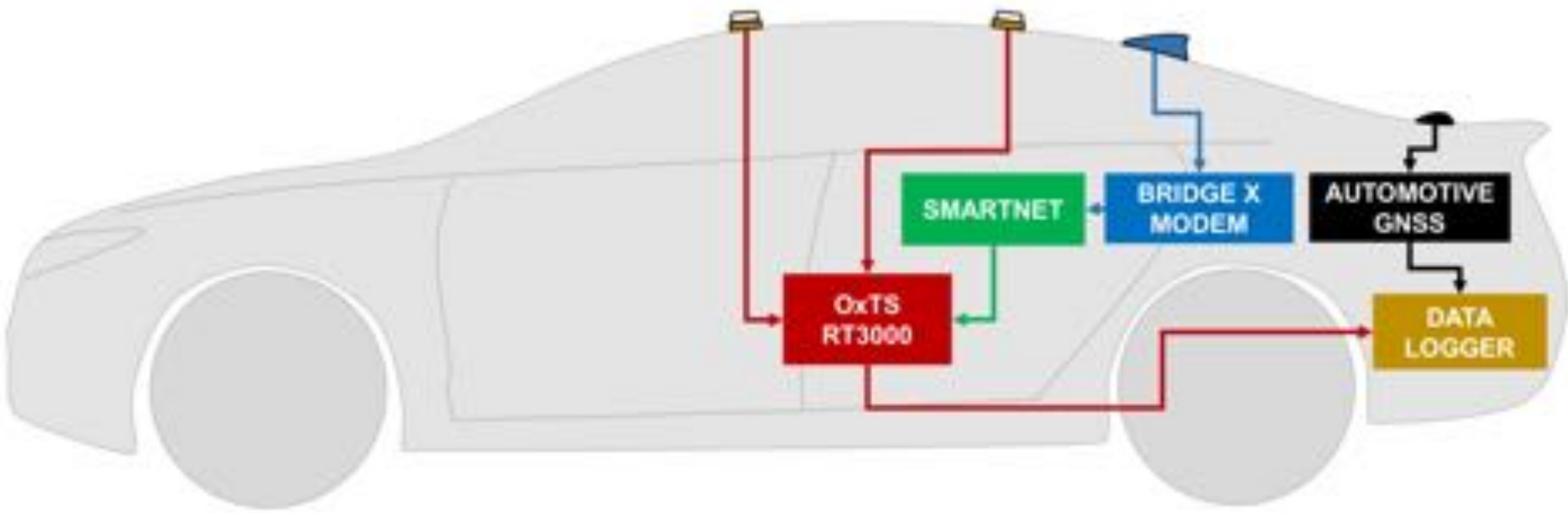
OxTS RT3000
L1 + L2
GPS + GLONASS
Two antenna
IMU Integration
Live RTK corrections

RTK

Hexagon SmartNet
Networked RTK
Delivery over cellular
RTK Bridge-X Modem

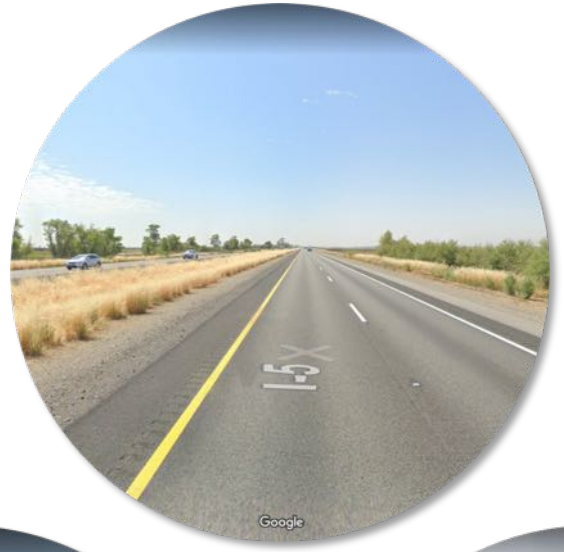
SmartNet North America
Any Constellation - Any Application - Open to All

Vehicle Setup



Data Collection Route – 27,500 km

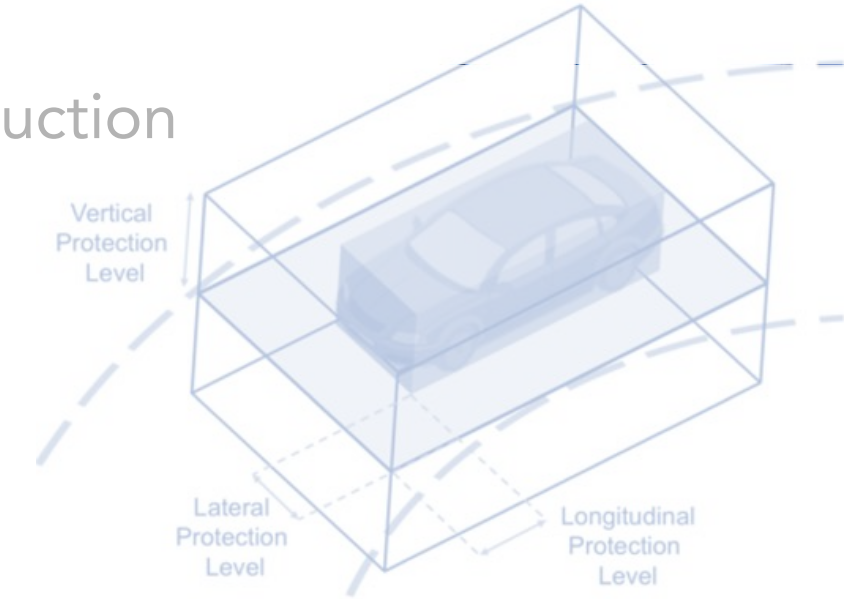
Highways – Open Sky



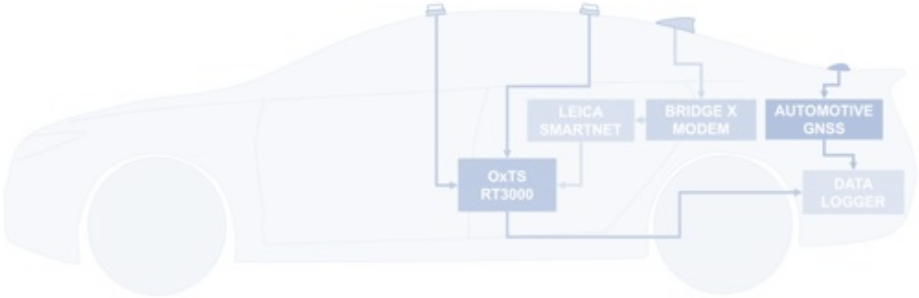
Highways – Less open sky

Outline

Introduction



GNSS Data Collection



Accuracy

Availability

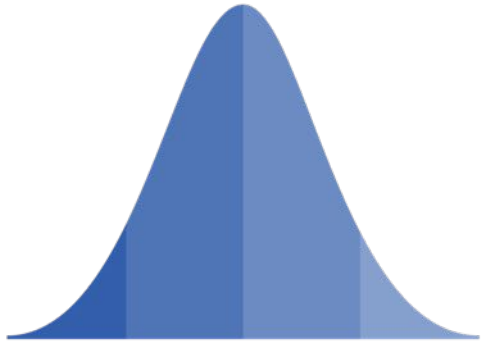
Continuity

RTK Performance

Evaluation

Accuracy

Position error distribution [m]

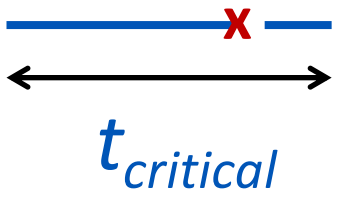


Availability

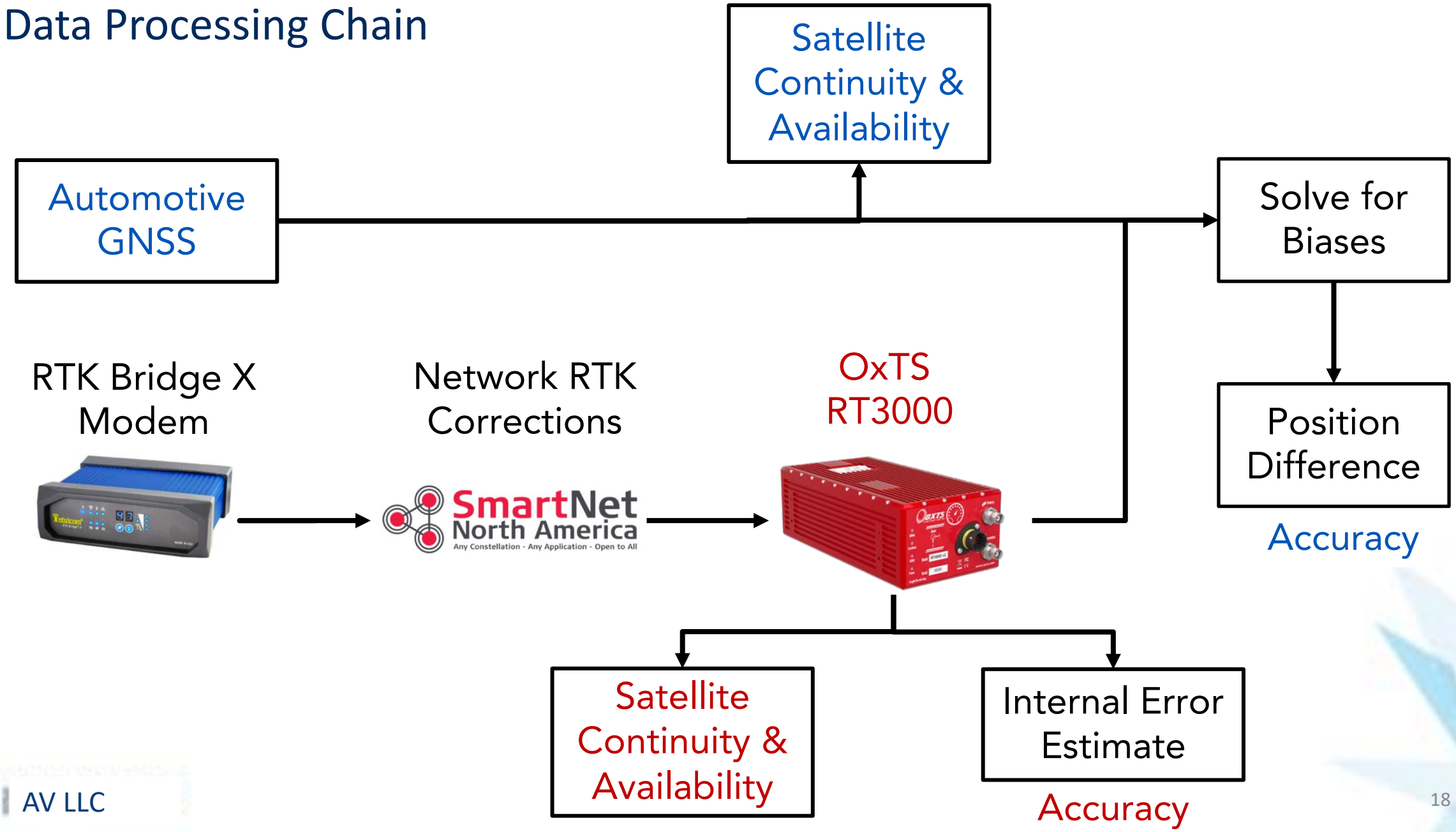
Fraction of time the service is available [%]

Continuity

Likelihood of losing service during a critical maneuver



Data Processing Chain



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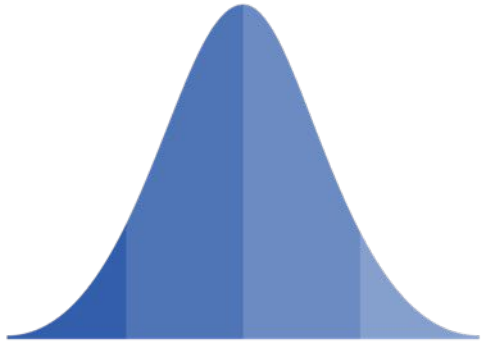
Accuracy

Position error distribution [m]



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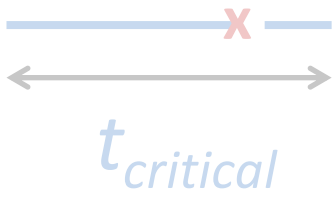
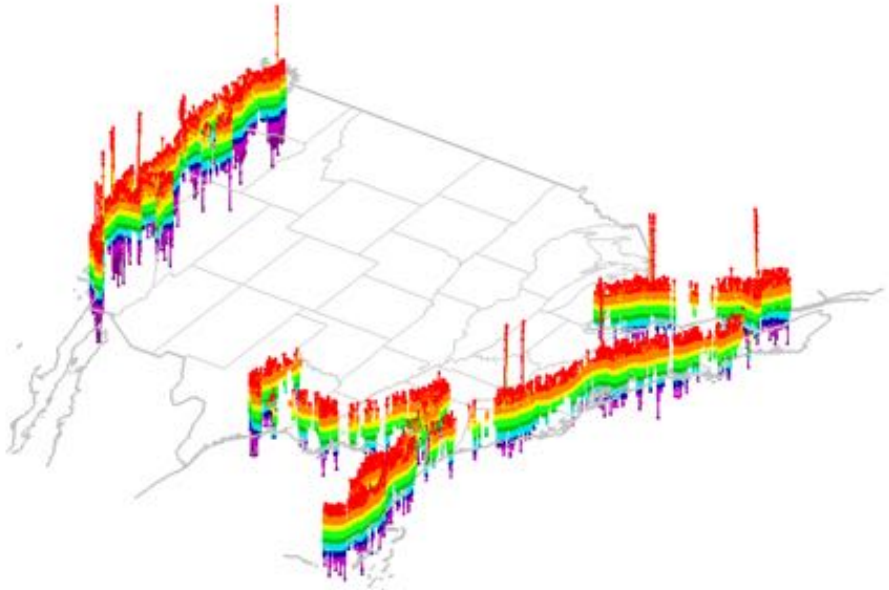


Accuracy

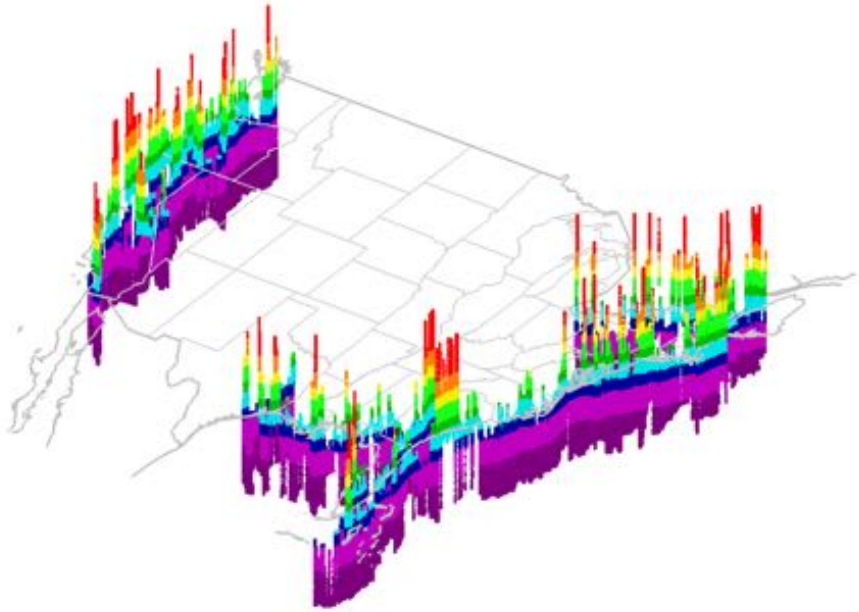
Positioning System	Lateral [m]			Longitudinal [m]			Horizontal [m]			Vertical [m]		
	68%	95%	99%	68%	95%	99%	68%	95%	99%	68%	95%	99%
Automotive GNSS	1.92	3.88	5.74	2.11	4.44	7.95	3.07	5.30	9.38	4.59	9.42	12.83
OxTS RT3000	0.18	0.73	2.60	0.18	0.75	2.88	0.26	1.05	3.91	0.31	1.34	2.56

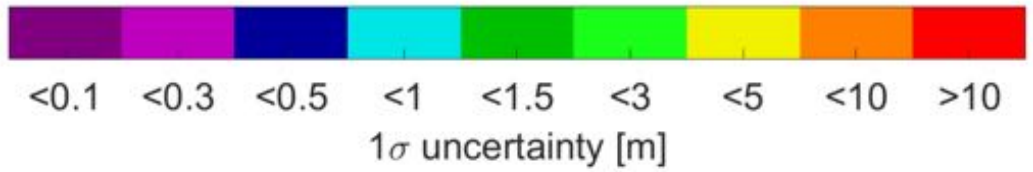
Accuracy – Geospatial Distribution

Automotive GNSS



RT 3000





Evaluation

Accuracy

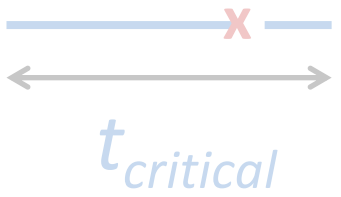
Position error distribution [m]

Availability

Fraction of time the service is available [%]

Continuity

Likelihood of losing service during a critical maneuver



Availability – Service Level

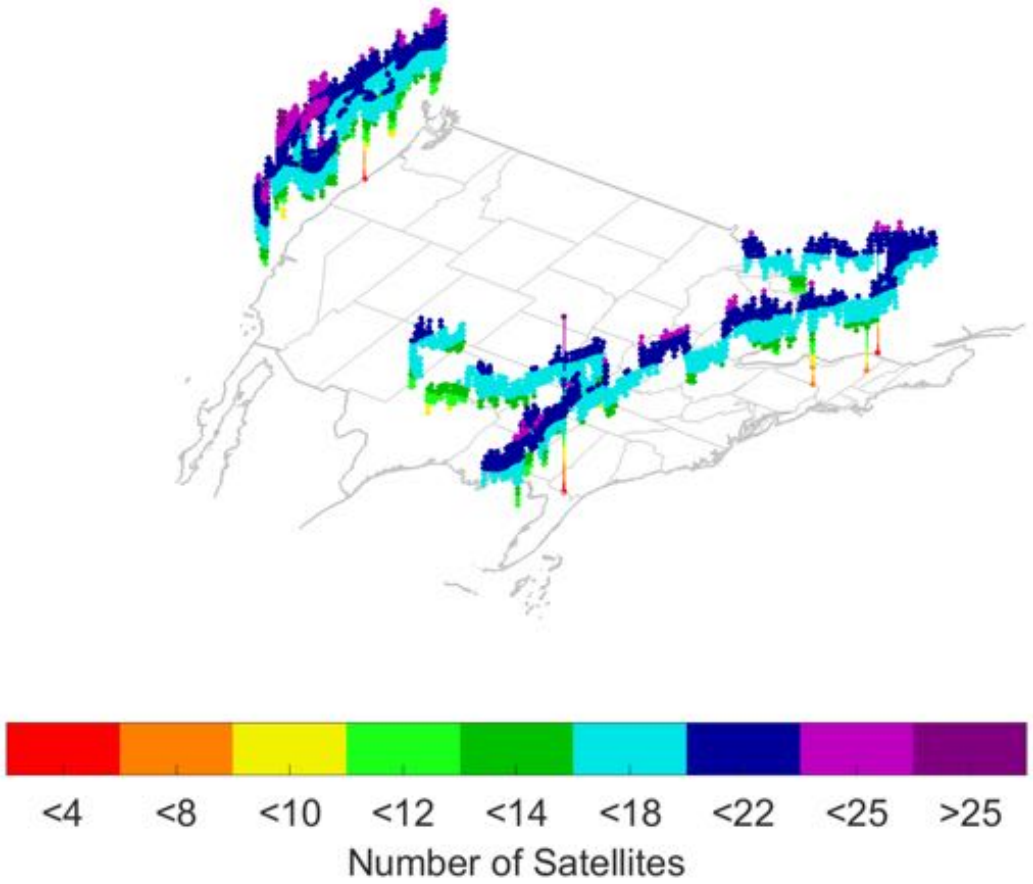
Position Service Level	Lateral Accuracy [m]	Availability [%]	
		Automotive GNSS	OxTS RT3000
Which Road	< 5	98.3	99.5
Which Lane	< 1.5	56.7	98.1
Where in Lane	< 0.5 (Highway)	21.0	91.1
	< 0.3 (Local Streets)	12.7	76.6

Availability – Satellite Visibility & Geometry

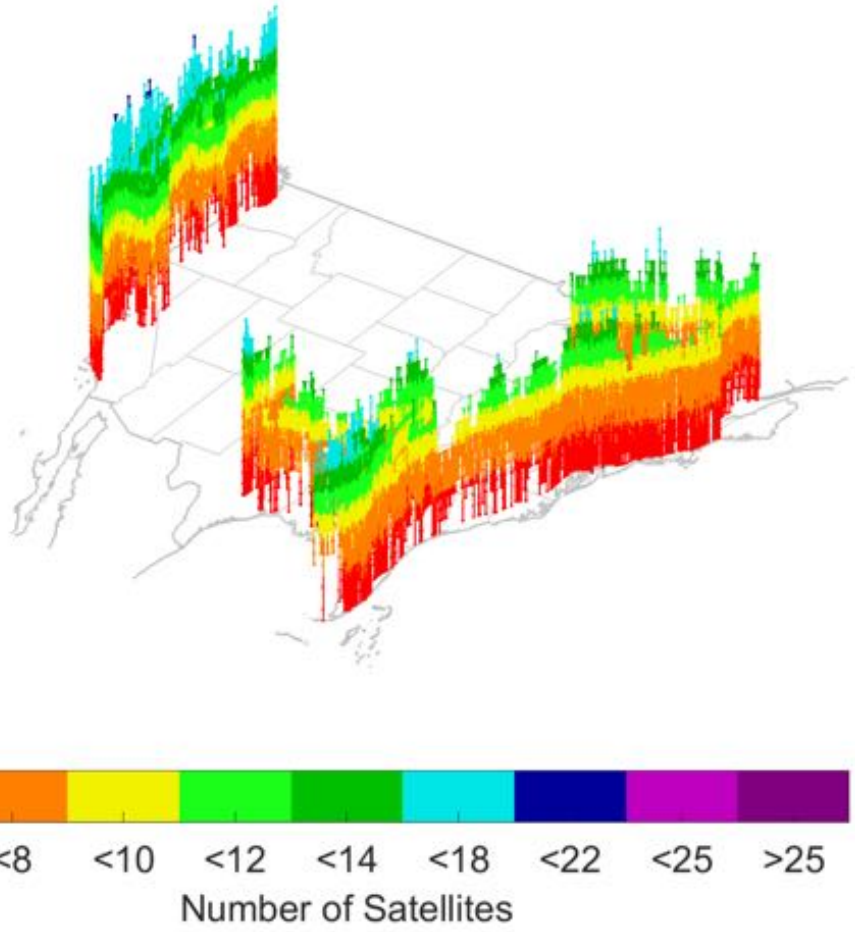
Positioning System	HDOP			Number of Satellites (Least)		
	68%	95%	99%	68%	95%	99%
Automotive GNSS	0.60	0.80	0.80	16	13	12
OxTS RT3000	1.30	3.70	11.20	8	4	0

Availability – Satellite Visibility

Automotive GNSS

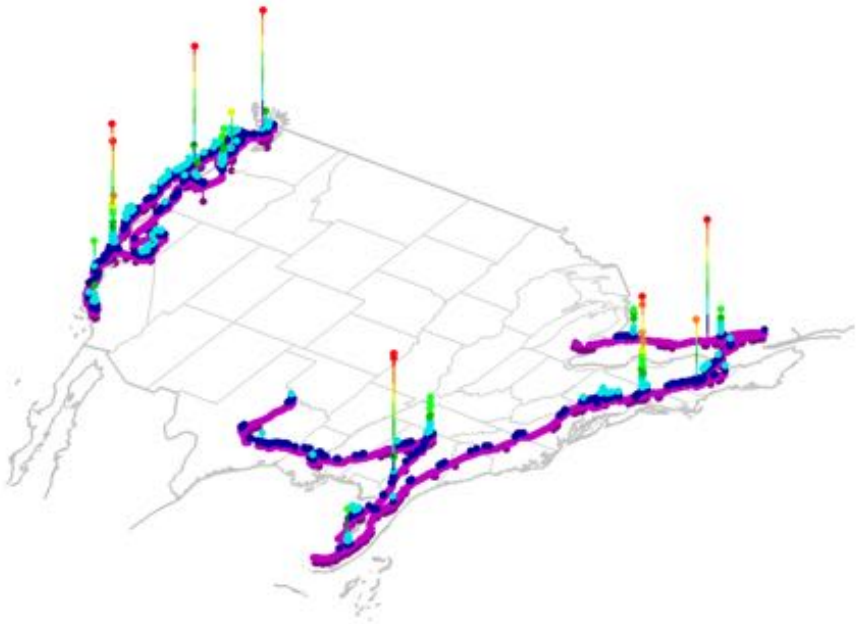


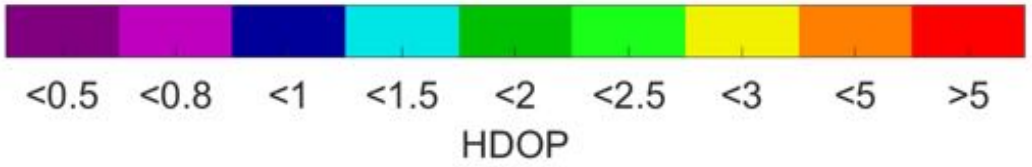
RT 3000



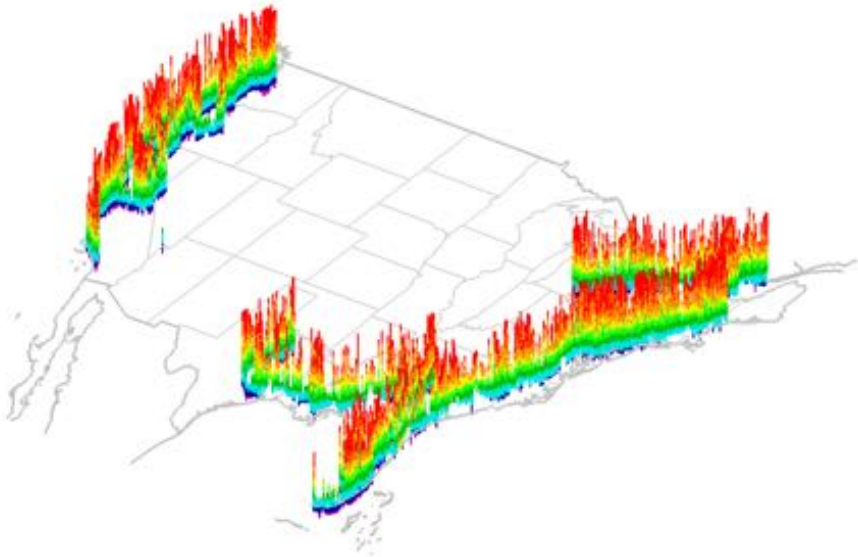
Availability – Satellite Geometry (HDOP)

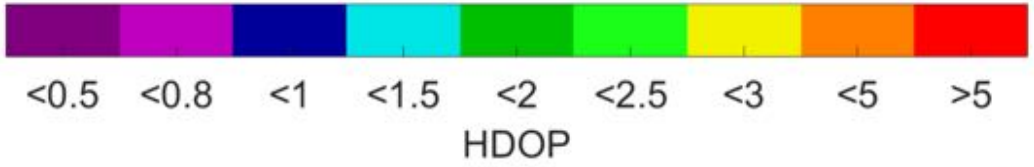
Automotive GNSS





RT 3000





Evaluation

Accuracy

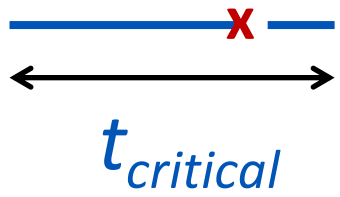
Position error distribution [m]

Availability

Fraction of time the service is available [%]

Continuity

Likelihood of losing service during a critical maneuver



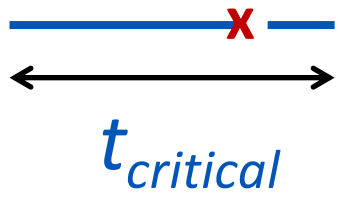
Evaluation

Critical Maneuver Timescales

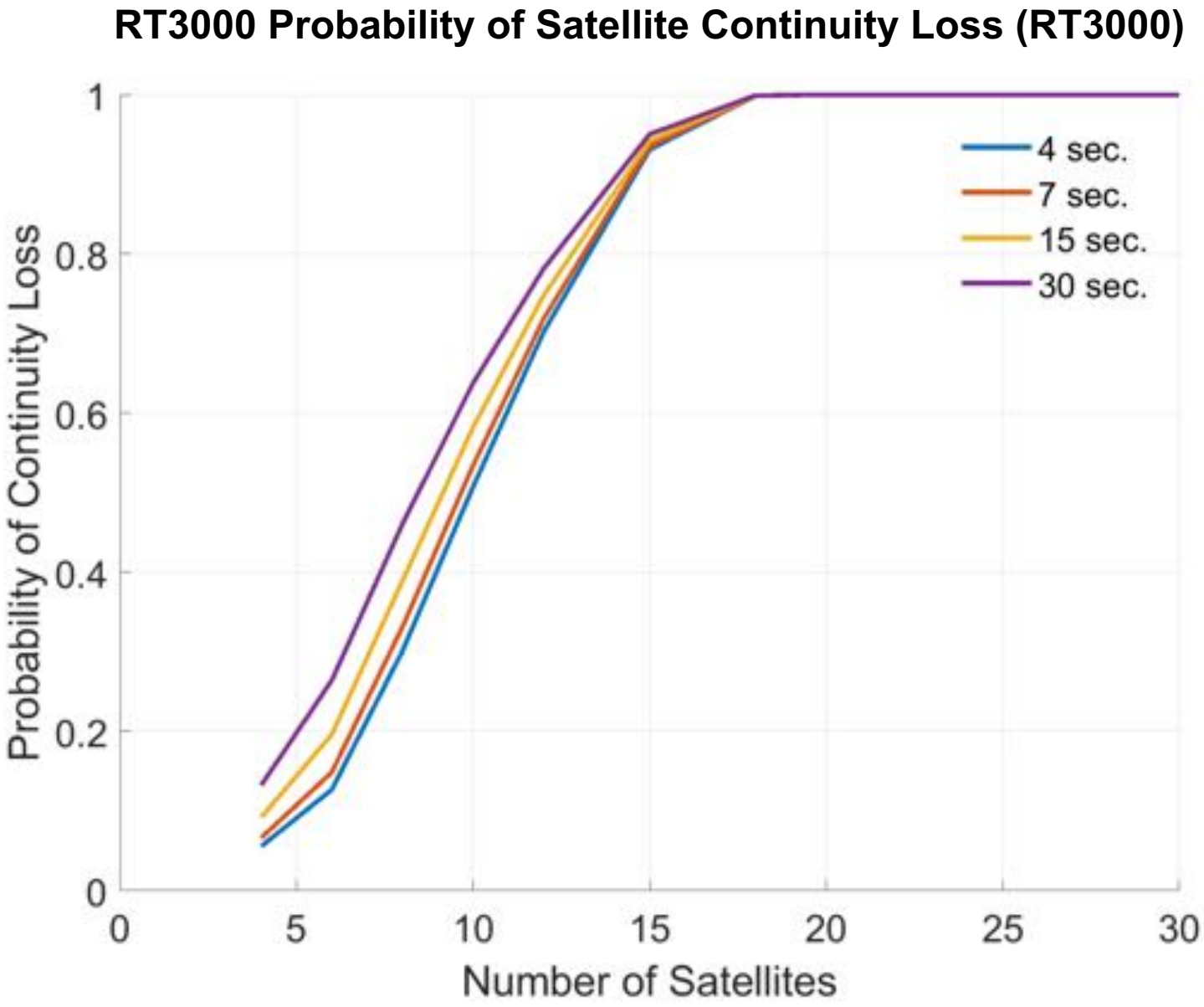
Type	Time [sec]
Lane Change	4 – 15
Overtaking	7 – 15
Automated to Manual Handover	23 – 30

Continuity

Likelihood of losing service during a critical maneuver



Continuity


RT3000 Probability of Satellite Continuity Loss (RT3000)
Probability of Continuity Loss
Number of Satellites
0
0.2
0.4
0.6
0.8
1
0
5
10
15
20
25
30
4 sec.
7 sec.
15 sec.
30 sec.

Outline

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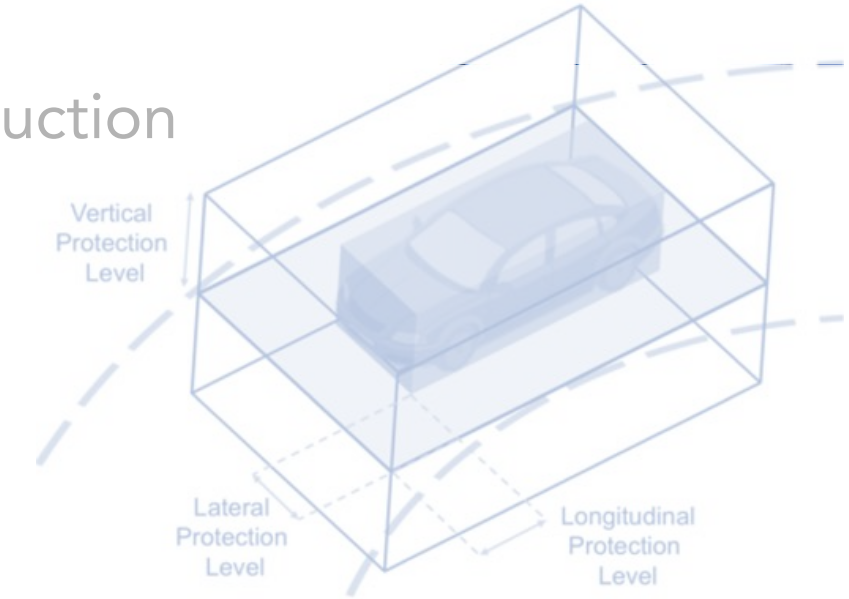

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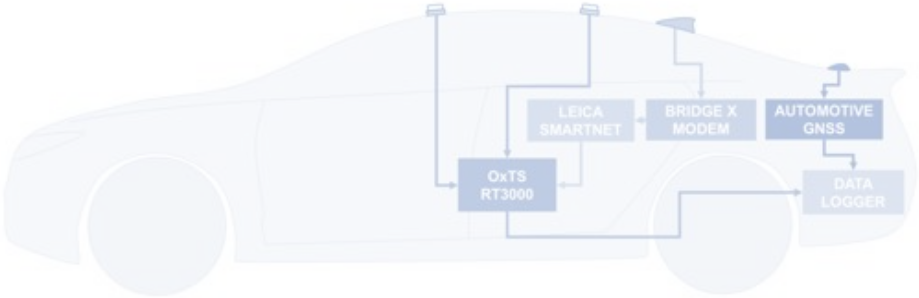

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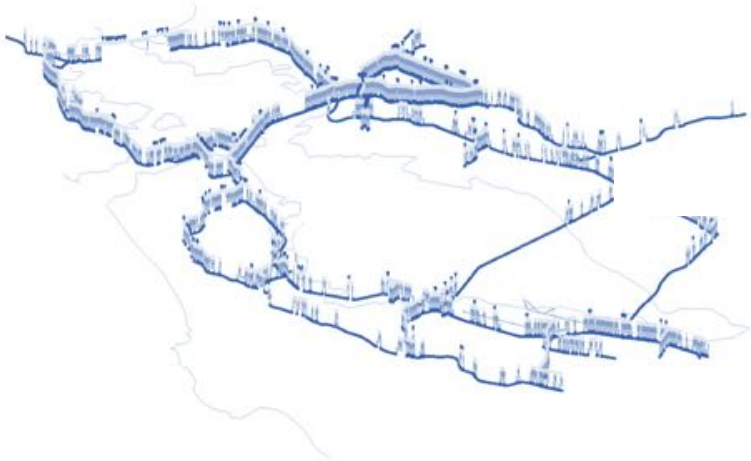


RTK Performance – Position Mode

Standard Position Service (SPS)

meters

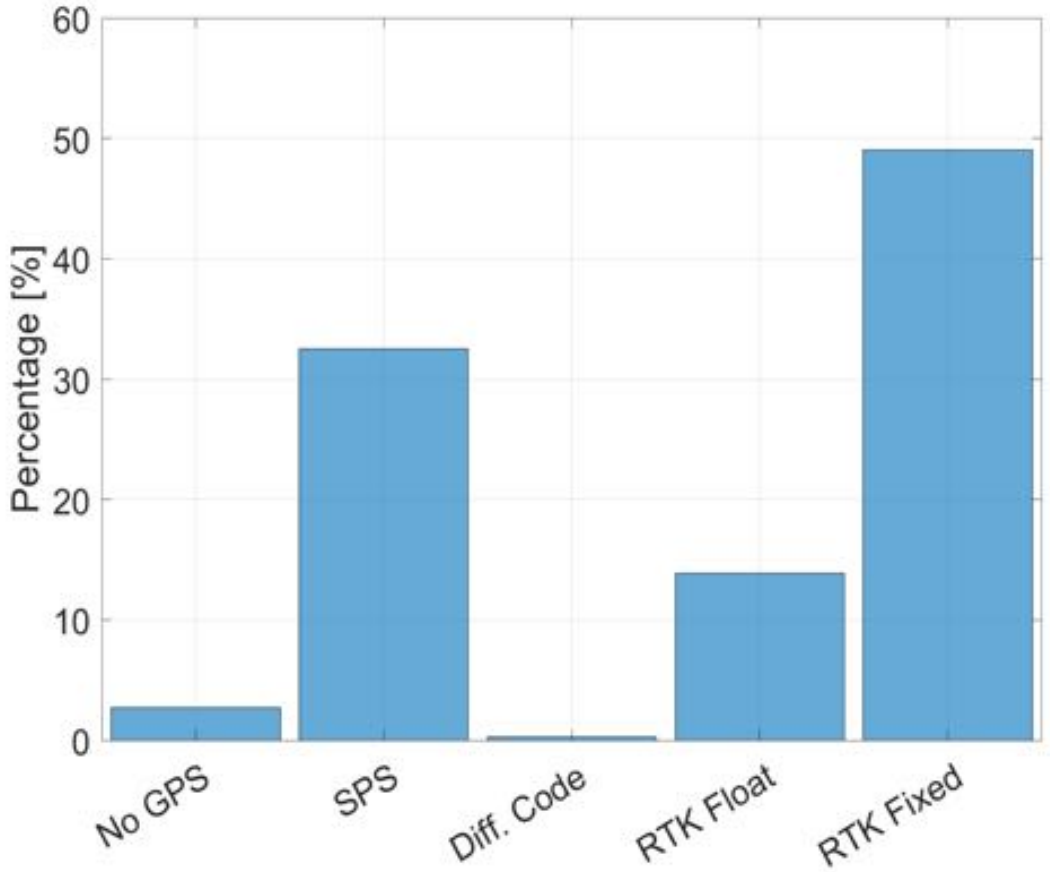
RTK-Float

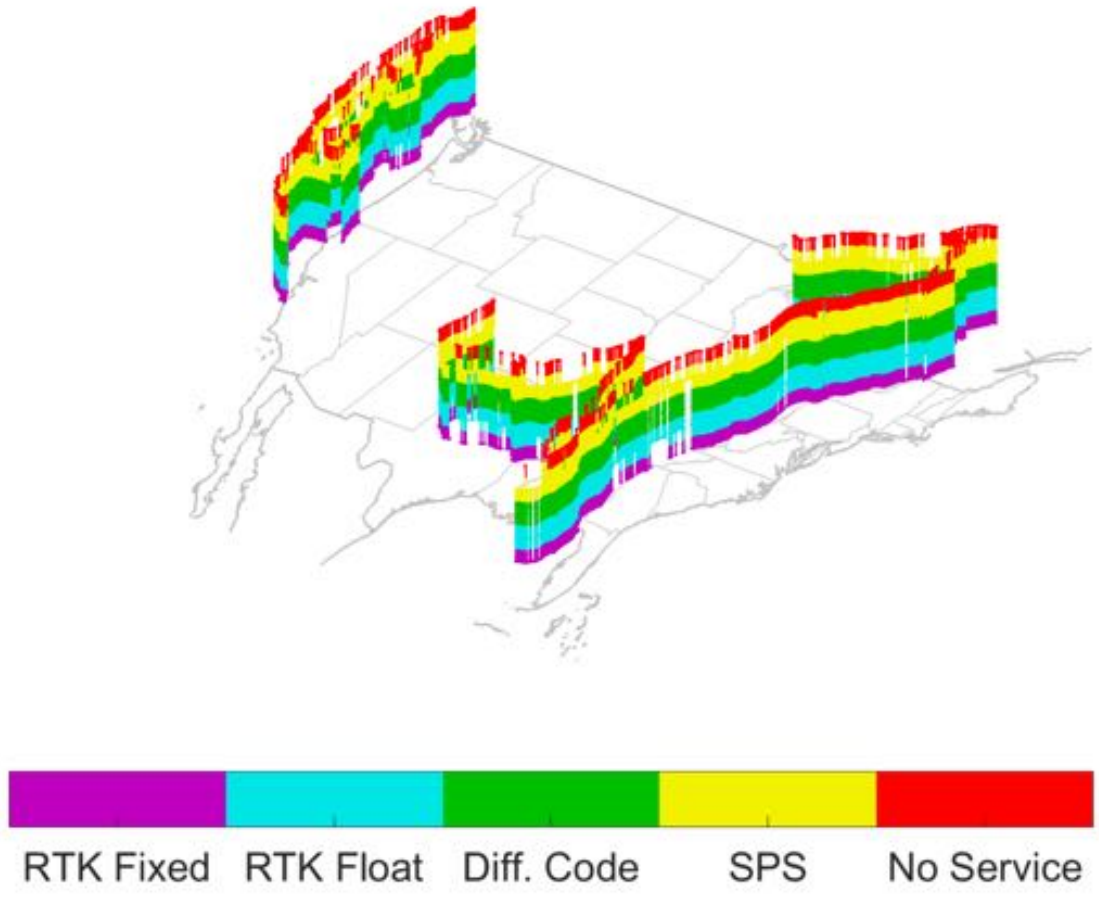
decimeters

RTK-Fixed

centimeters

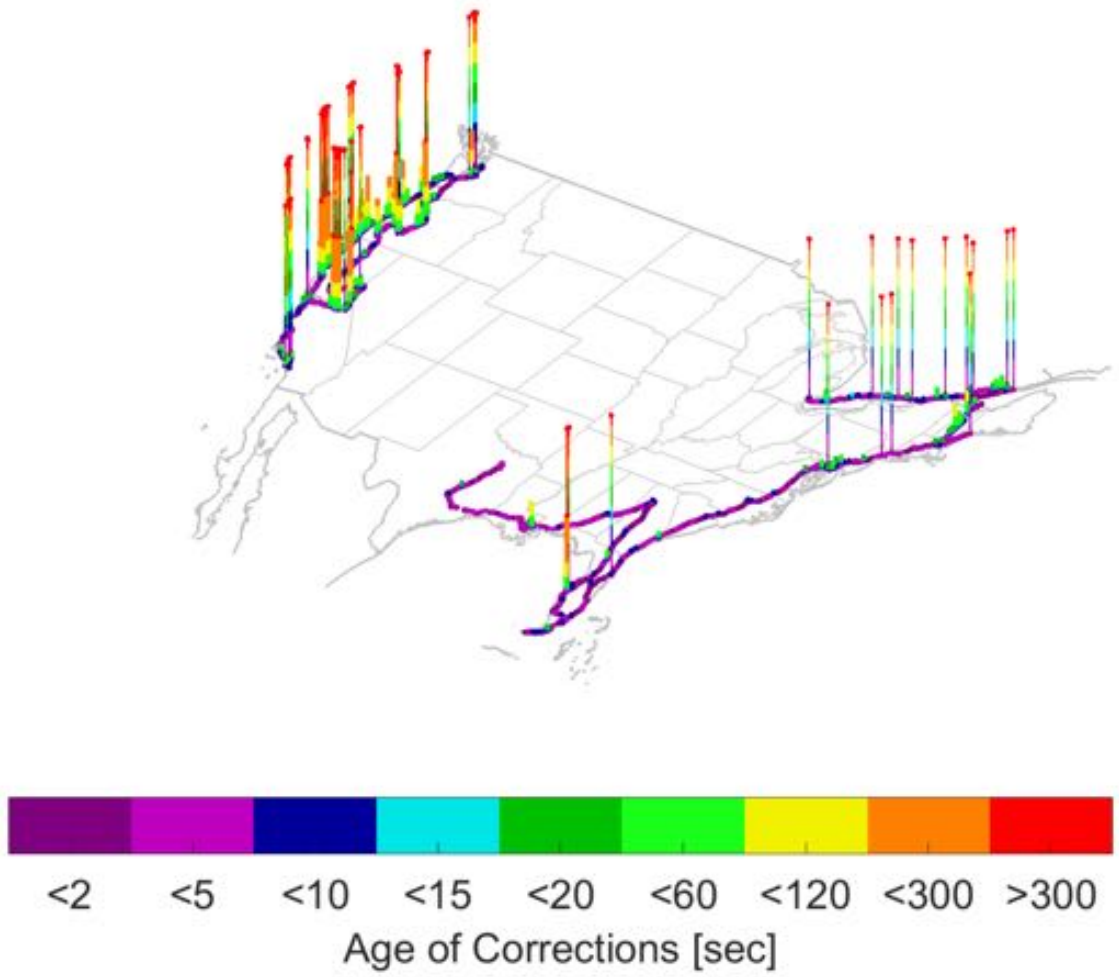
RT3000 Position Mode Availability



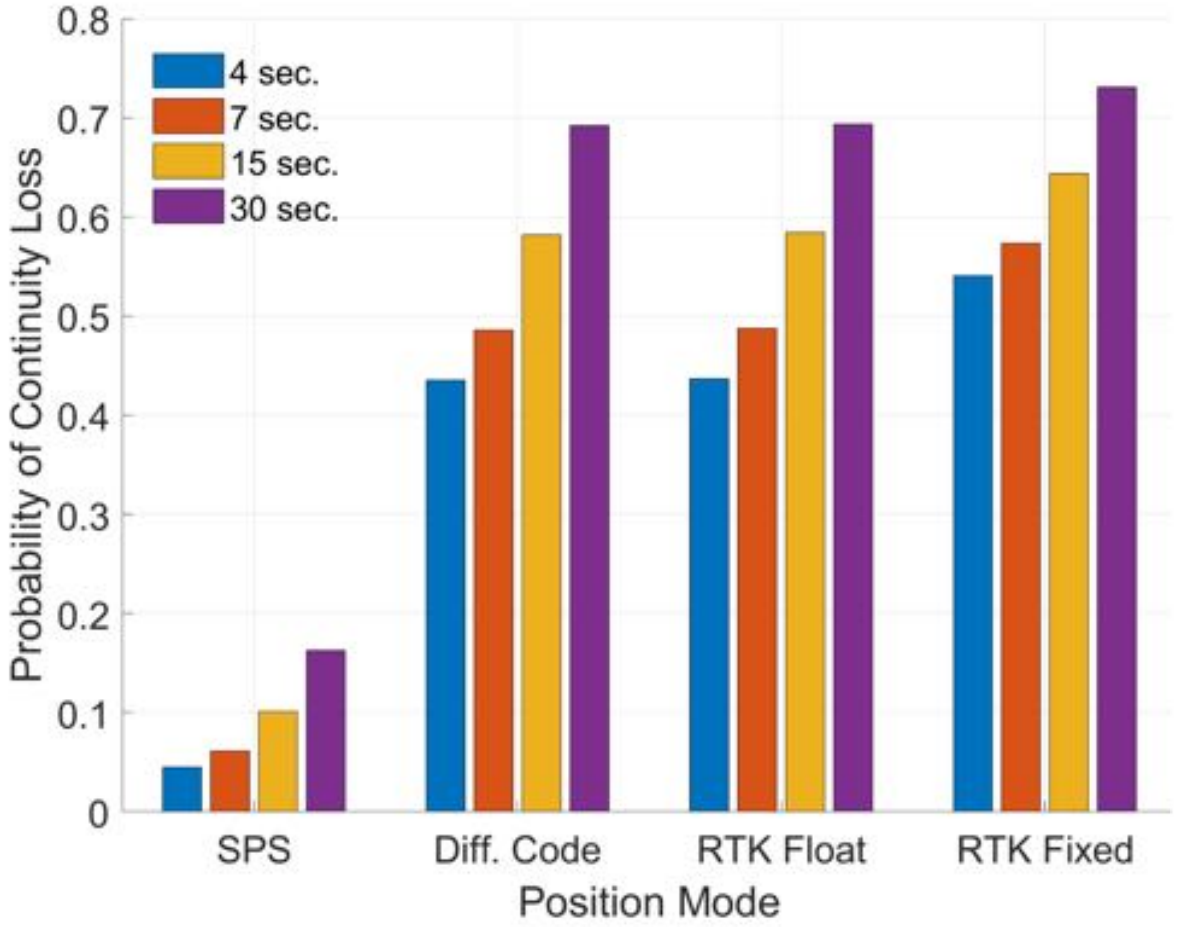


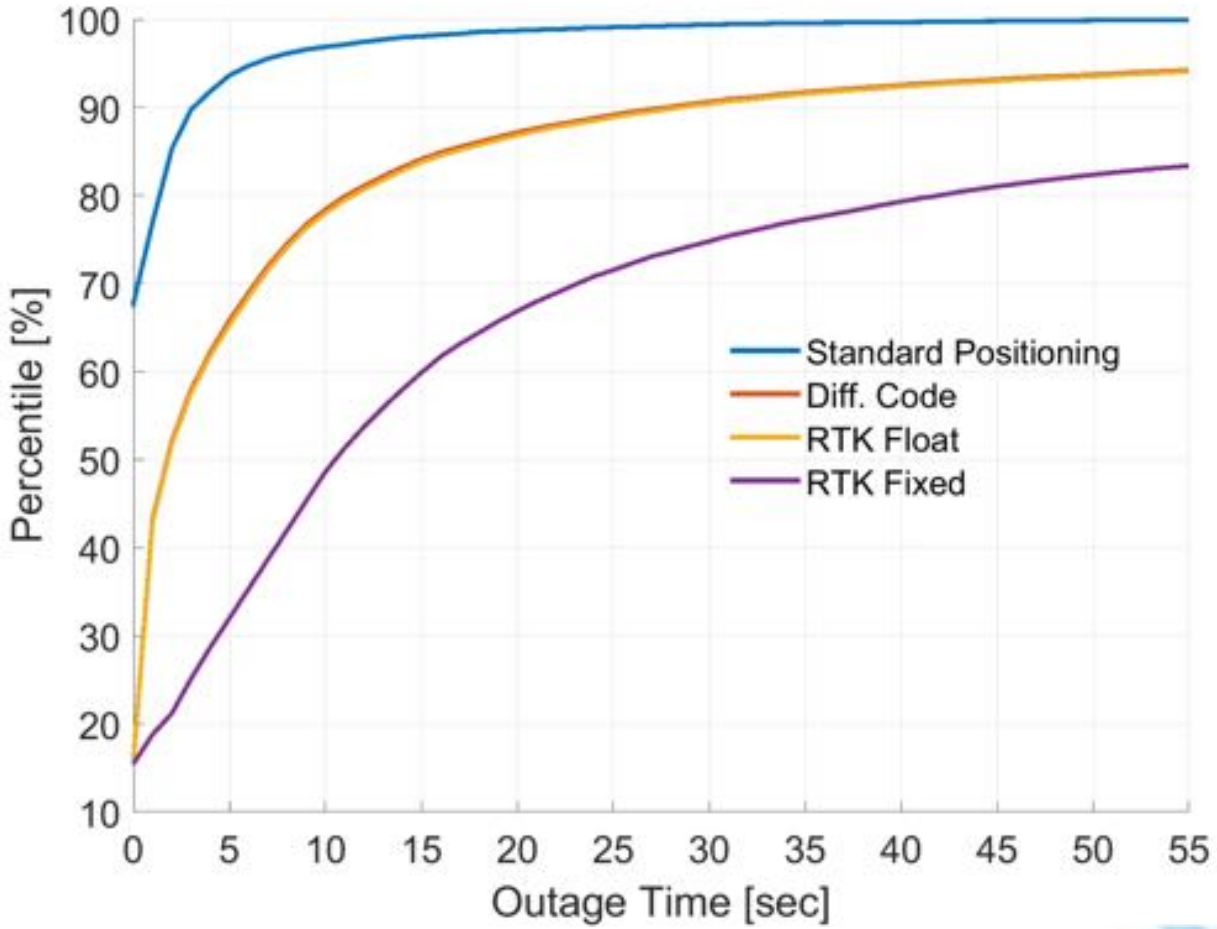
RTK Correction Latency

Age of Corrections		
< 2 sec	< 10 sec	< 120 sec
96.0%	97.3%	98.3%

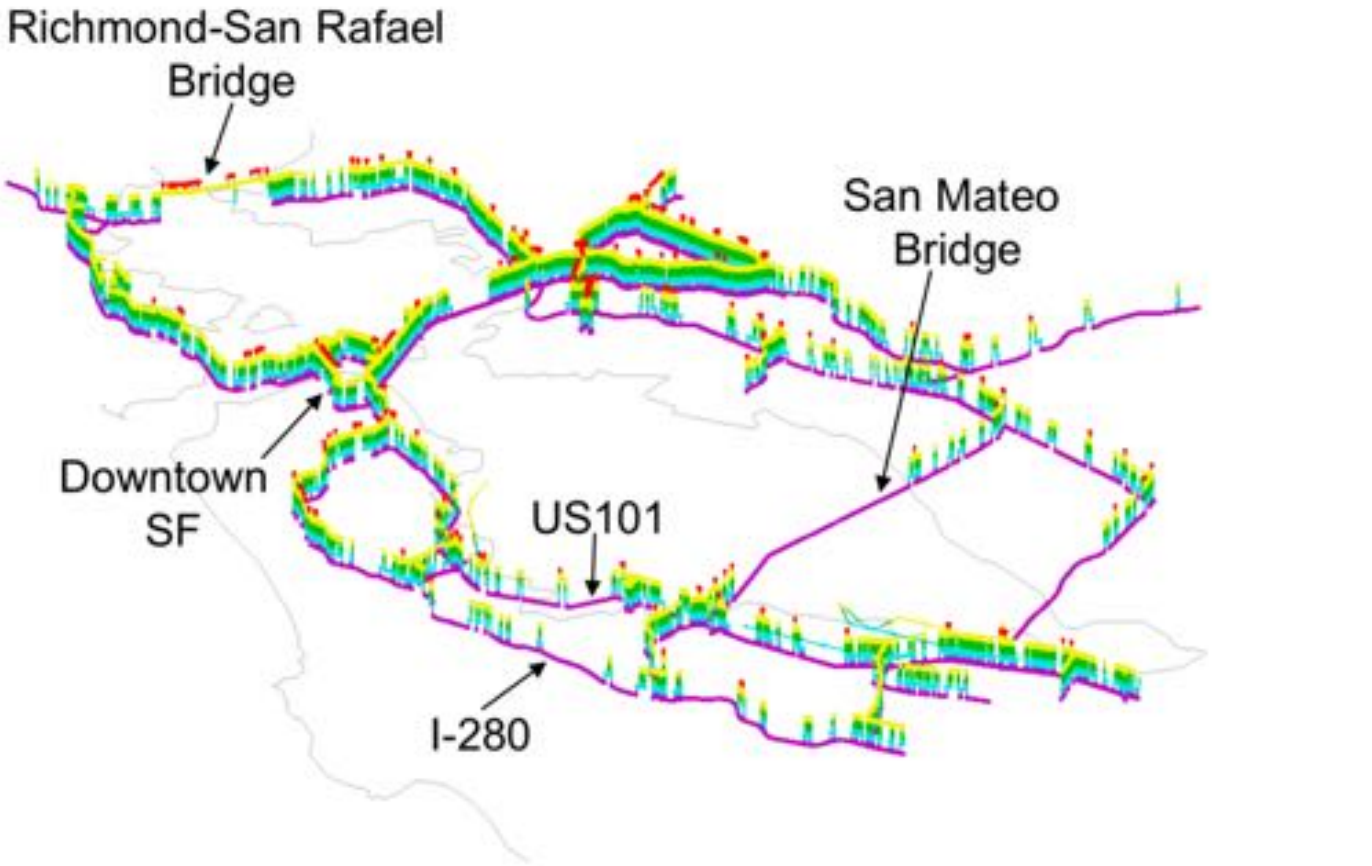


RTK Continuity & Outage Times

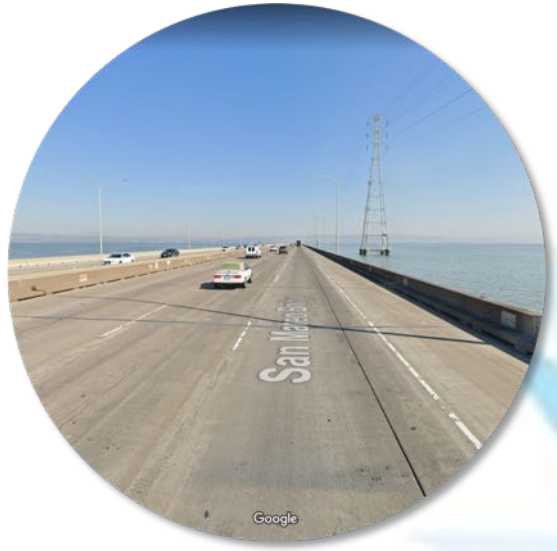




Case Study: Bay Area

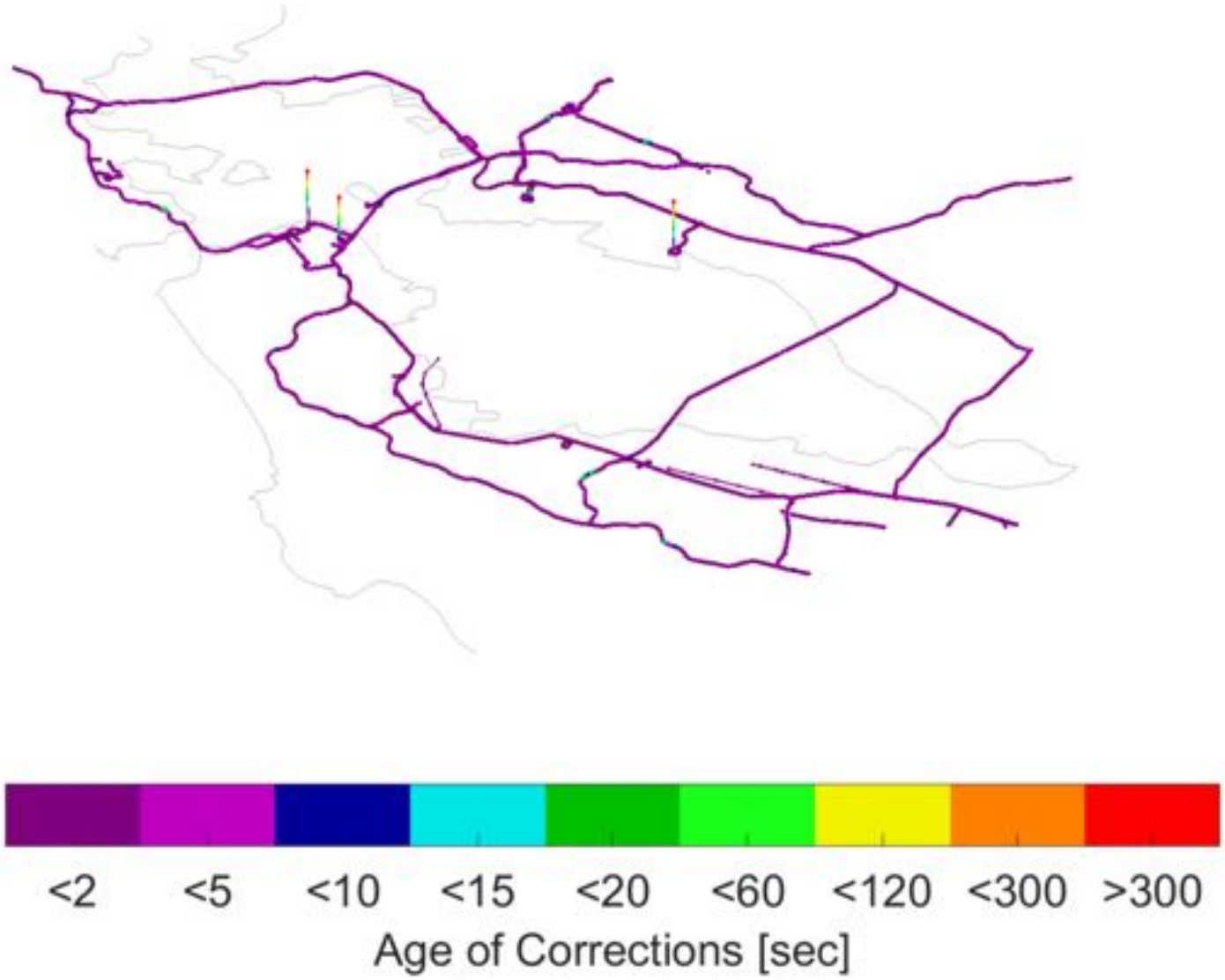


Richmond-San Rafael Bridge

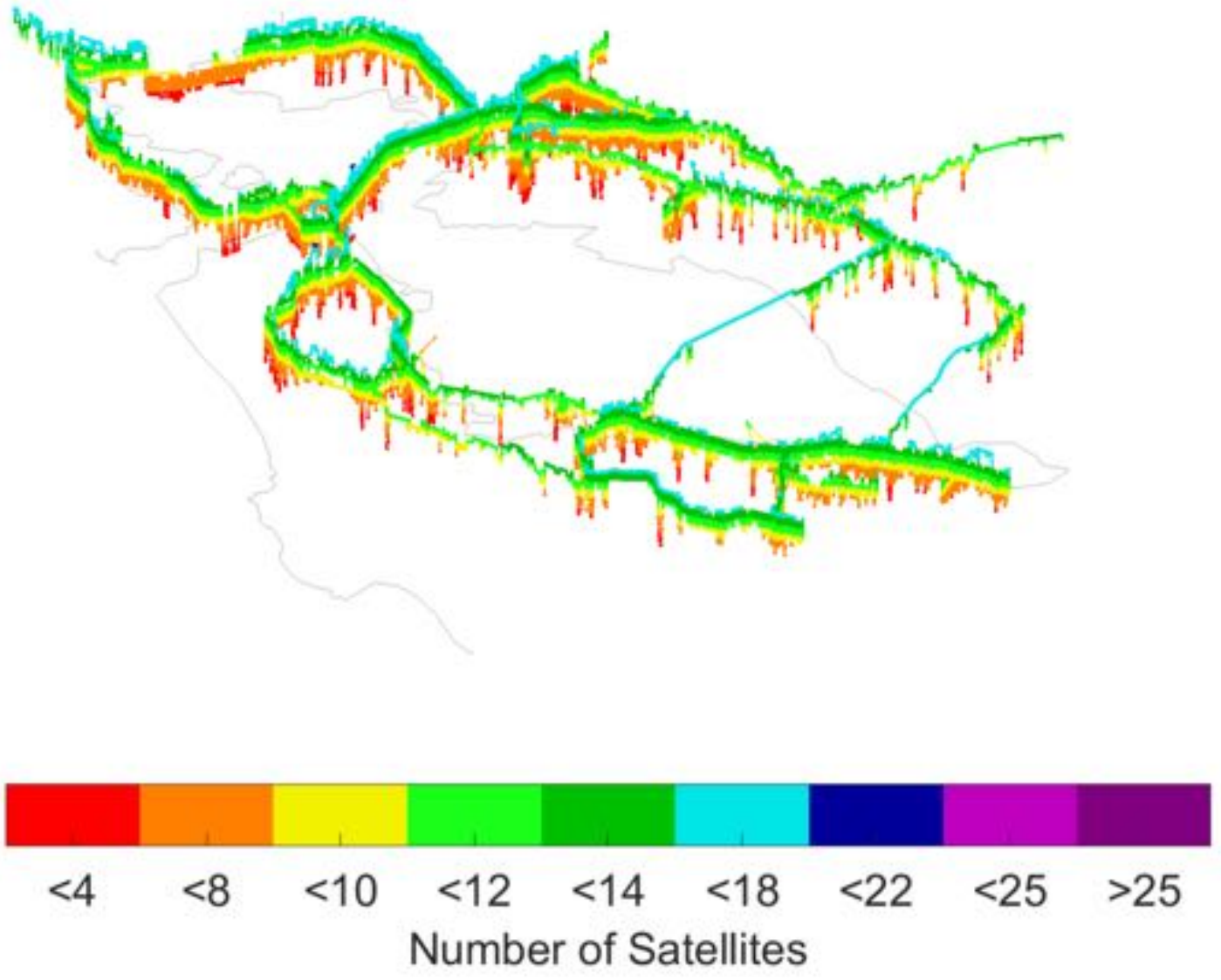


San Mateo Bridge

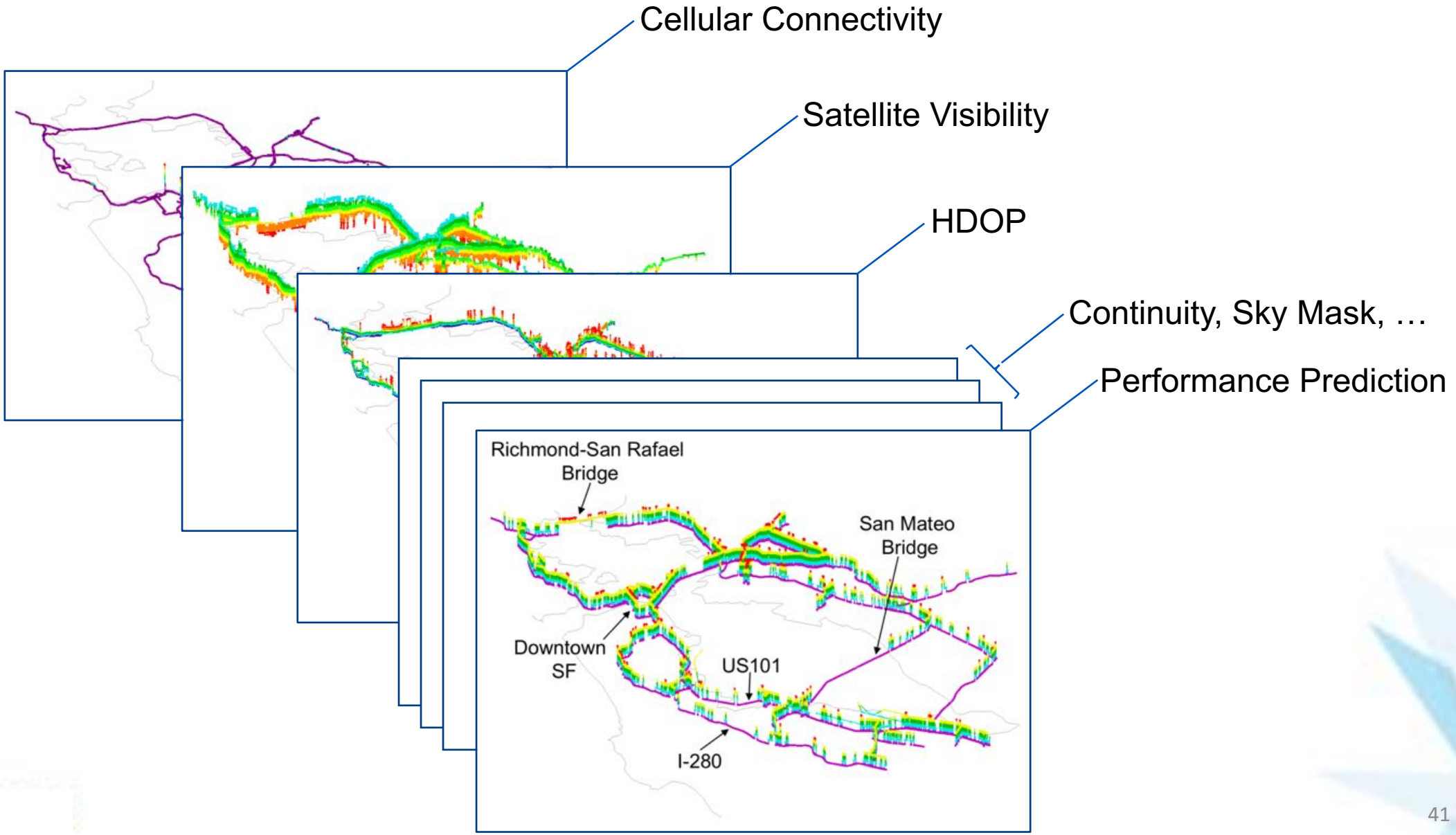
Case Study: Bay Area



Case Study: Bay Area



GNSS Performance Map



Summary & Conclusions

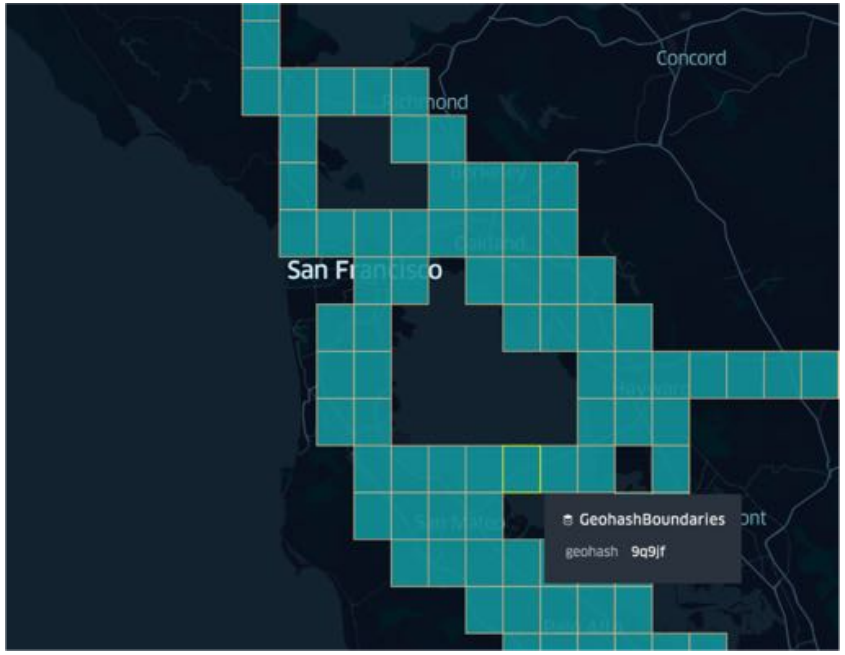
- Current standalone automotive GNSS seems best suited to road determination for convenience features at 98% availability.
- Looking forward, RTK corrections <10 seconds latency are available now over a large part of North America (>97%).
- RTK-fixed positioning was available 50% of the time, while RTK-float was available at 14%.
- Continuity in general can be problematic in some areas, motivating the concept of a GNSS performance to anticipate expected performance.
- Lane determination / lane departure have potential with RTK + inertial systems with 98% and 90% availability, respectively.

Dataset details

Location: http://ford-hdr-gnss.s3.amazonaws.com/ford-hdr-gnss.zip

Number of files: 3926

Total size: 1.3 GB



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Thank you