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Precise Point Positioning

Why is interoperability important?

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10th Multi-GNSS ASIA CONFERENCE, MELBOURNE, 24 October 2018
ICG WORKING GROUP D:
REFERENCE FRAMES, TIMING AND APPLICATIONS

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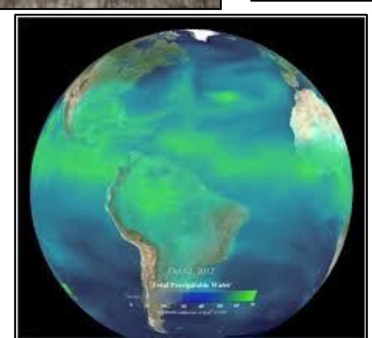
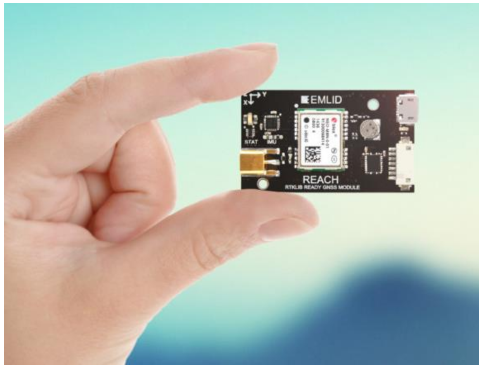
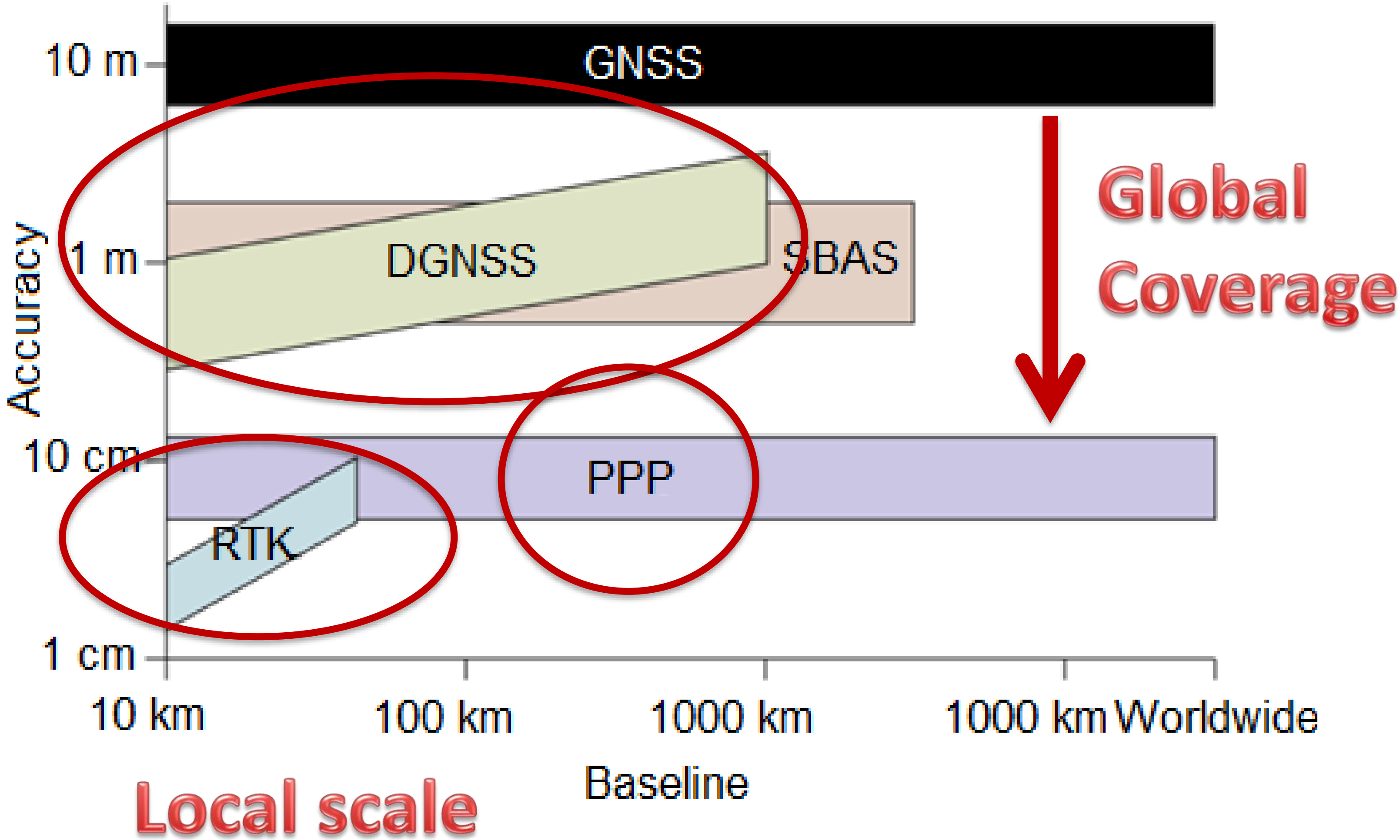
GNSS precise positioning enables a diverse array of applications



Mass-market users and innovative applications



Pushing the boundary of precise positioning



Source: NovAtel Inc (2015)

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Precise Point Positioning (PPP)

Precise Point Positioning (PPP) allows a single GNSS receiver user to determine position at the decimetre / centimetre error level in kinematic / static mode using precise satellite orbits and clocks.

Standard Positioning Service

Broadcast orbit and clock information

+

User satellite tracking information

=

m-level user position estimates

Precise Point Positioning

Precise orbit and clock information

+

User satellite tracking information

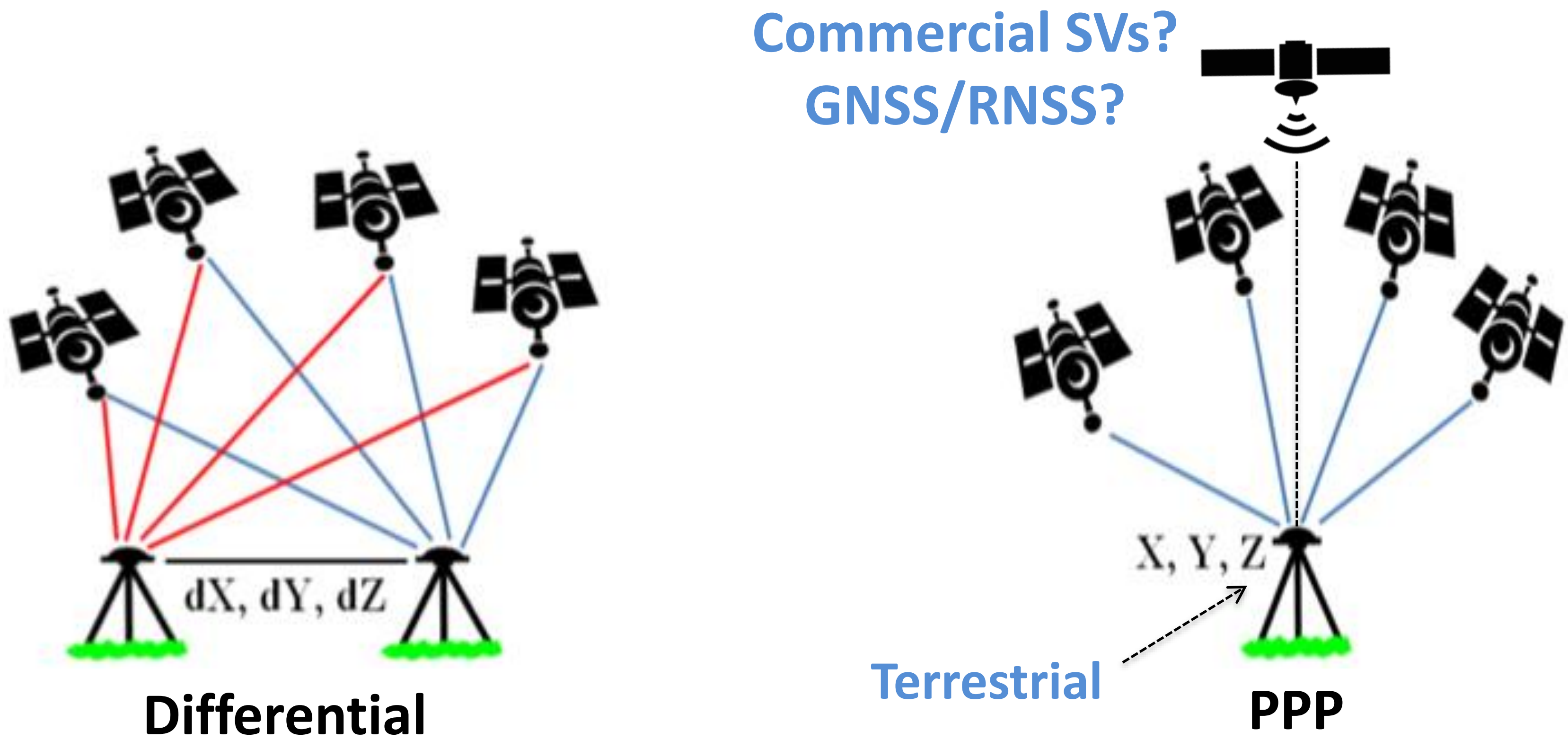
+

Additional error modelling

=

dm- to cm-level user position estimates

Precise Point Positioning (PPP)



PPP uses state space representation (SSR) correction products such as **precise satellite orbits**, **clocks** and **signal biases** from either *commercial or/and public providers* that are delivered to the user via *satellite and/or terrestrial comms*.

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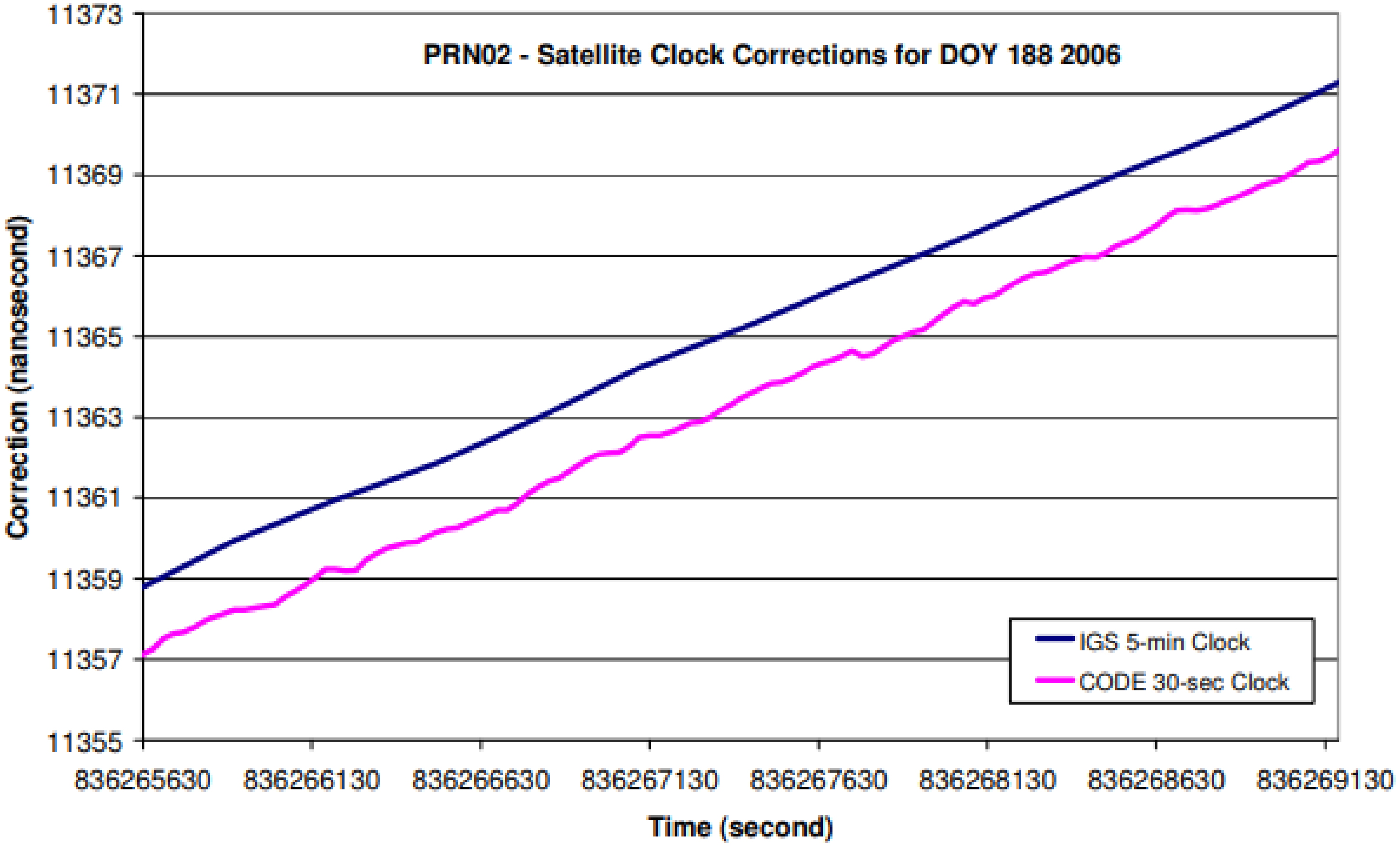
Reference Orbits (Frame)

The use of precise satellite orbits and clock corrections imply positioning, orientation and scale of a precise reference frame.

PPP positions are estimated in the same reference frame as the satellite orbits and clock corrections (e.g. the ITRF or the IGS reference frames) => globally consistent positions.

Reference Clocks



No mixing of clock and orbit corrections from different AC as the errors from the same AC (or combined solutions) are tightly correlated !

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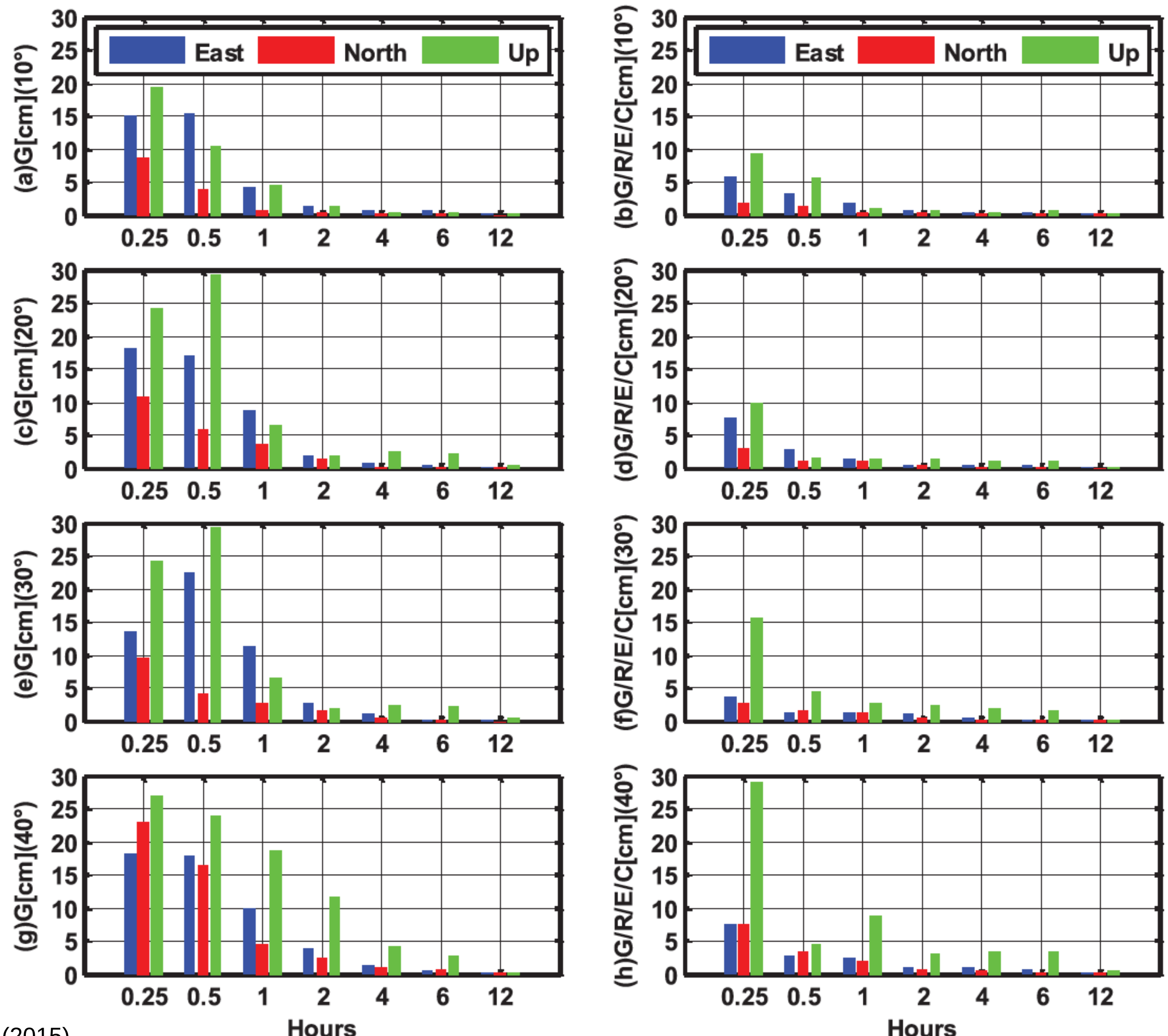
Single or multi-GNSS ?

GPS-only



Multi-GNSS

Source: Li et al (2015)

Which PPP Service ?

	PPP	PPP-AR	SSR-RTK*
Satellite orbits	✓	✓	✓
Satellite clocks	✓	✓	✓
Code biases	✗	✓	✓
Phase biases	✗	✓	✓
Ionospheric delay	✗	✗	✓
Tropospheric delay	✗	✗	✓

*Hybrid system of PPP and RTK, i.e. SSR-RTK/PPP-RTK/RTK-PPP

Single, dual- or multi-frequency PPP ?

Clarifying the Ambiguities

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$$C^s_{r,i} = \rho^s_r + T + \gamma_i I + dt_r + dt^s + d_{r,C_i} - d^s_{C_i} + \varepsilon_{C_i}$$

$$P^s_{r,i} = \rho^s_r + T + \gamma_i I + dt_r + dt^s + d_{r,P_i} - d^s_{P_i} + \varepsilon_{P_i}$$

$$\lambda_i\left(\phi^s_{r,i} + N^s_{r,i}\right) = \rho^s_r + T - \gamma_i I + dt_r + dt^s + \delta_{r,L_i} - \delta^s_{P_i} + \varepsilon_{L_i}$$

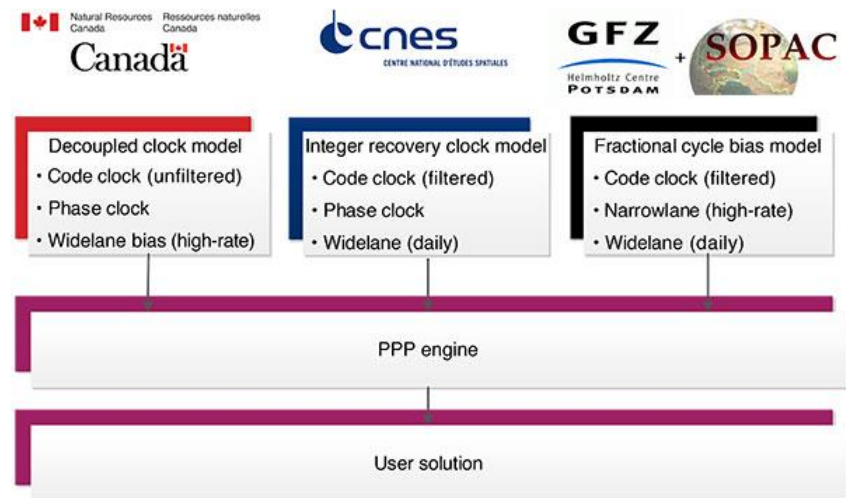
Geometric parameters | Time delay | Hardware delay

$$P^s_{r,i} = \rho^s_r + T + \gamma_i I + dt_{r,P_{IF}} + dt^s_{P_{IF}} + \varepsilon_{P_i}$$

$$\Phi^s_{r,i} = \rho^s_r + T - \gamma_i I + dt_{r,P_{IF}} + dt^s_{P_{IF}} - A^s_{r,i} + \varepsilon_{L_i}$$

where $A^s_{r,i} = \left(d_{r,IF} - d^s_{IF}\right) - \left(\delta_{r,IF} - \delta^s_{IF}\right) + \lambda_i N^s_{r,i}$

Real-valued ambiguity term | Code biases | Phase biases | Integer ambiguity term



	Float PPP	DC model	IRC model	FCB model
Observations	P3, L3	P3, L3, P6, L4	P3, L3, P6, L4	P3, L3, P6, L4
Clock terms	1	2 (Code and phase)	1	1
Data rate		δt^s_{IF} – 30 seconds dt^s_{IF} – 30 seconds δ^s_{WN} – 30 seconds	dt^s_{IF} – 30 seconds δ^s_i – 5 seconds d^s_i – daily	dt^s_{IF} – 5 seconds a^s_1 – 1 seconds a^s_{WN} – 2 days
P_i			d^s_i	
L_i			δ^s_i	
Narrowlane				a^s_1
Widelane		δ^s_{WN}		a^s_{WN}
Estimated ambiguities	Real	Integer	Integer	Real (FCB applied to estimated ambiguity)

Source: Seepersad and Bisnath (2016)

Commercial PPP Service

Company	Services	Company	Services
OmniSTAR	OmniSTAR HP	NavCom	StarFire
	OmniSTAR G2	C-Nav	C-NavC2
	OmniSTAR XP		C-NavC1
Trimble	CenterPoint RTX	Veripos	Apex 2
	RangePoint RTX		Apex
	ViewPoint RTX		Ultra 2
Fugro	Starfix.G2+		Ultra
	Starfix.G4	TerraStar	TerraStar-C
	Starfix.G2		TerraStar-D
	Starfix.XP2	Novatel	CORRECT (PPP)
	Starfix.HP	Hemisphere	Atlas

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Commercial PPP Service

Company	Augmentation/Communication Satellite
OmniSTAR	ASAT, MSV, AORW, AORE, ESAT, IOR, PORL
Fugro	ASAT, MSV, AORW, AORE, ESAT, IOR, AUSAT, POR
Fugro Starfix.HP	Inmarsat, SpotBeam
NavCom	IND-W (25°E), PAC-E (98°W), IND-E (109°E)
C-Nav	Inmarsat 4-F3, Inmarsat 4-F1, Inmarsat 3-F5, Inmarsat 3-F4, Inmarsat 3-F3, Inmarsat 3-F2, Inmarsat 3-F1
Veripos	Inmarsat 25°E, 98°W, 143.5°E, AORE, AORW, IOR, POR
TerraStar	Inmarsat 25°E, 98°W, 143.5°E, AORE, AORW, IOR, POR

All (if not most) GEO communication satellites !

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Augmentation Signals Frequency

Example of a commercial service providing global coverage

Region	Frequency (MHz)	Baud rate
Western North America (RTXWN)	1557.8615	600
Central North America (RTXCN)	1557.8150	2400
Eastern North America (RTXEN)	1557.8590	600
Latin America (RTXSA)	1539.8325	600
Europe / Africa (RTXEA)	1539.9525	600
Europe	1523.7250	2400
Asia / Pacific	1539.8325	600

PPP Augmentation Signals by GNSS and RNSS

System	SV Orbit	Augmentation Signal for PPP	Frequency (MHz)	Bandwidth (bps)
Galileo/ EGNOS	MEO GEO	E6 E5b	1278.75 1207.14	500 250
GLONASS/ SDCM	MEO GEO	L1 or L3? L1 or L5?	1207.14 (L3) ?	?
BeiDou-3	GEO	B2b	1207.14	1000
QZSS	IGSO and GEO	L6D, L6E	1278.75	2000

Australia ?

Combination of GEO, MEO and IGSO satellites !

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Service Coverage

Regional ?

Global ?

Standards

Open ?

Proprietary ?

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Consideration

- High precision GNSS, is it a commodity? Or high-tech?
- Would it constitute to “Selective unavailability”?
- Intended market, business model?
- Must ensure compatibility and interoperability to maximize benefit to all GNSS users.