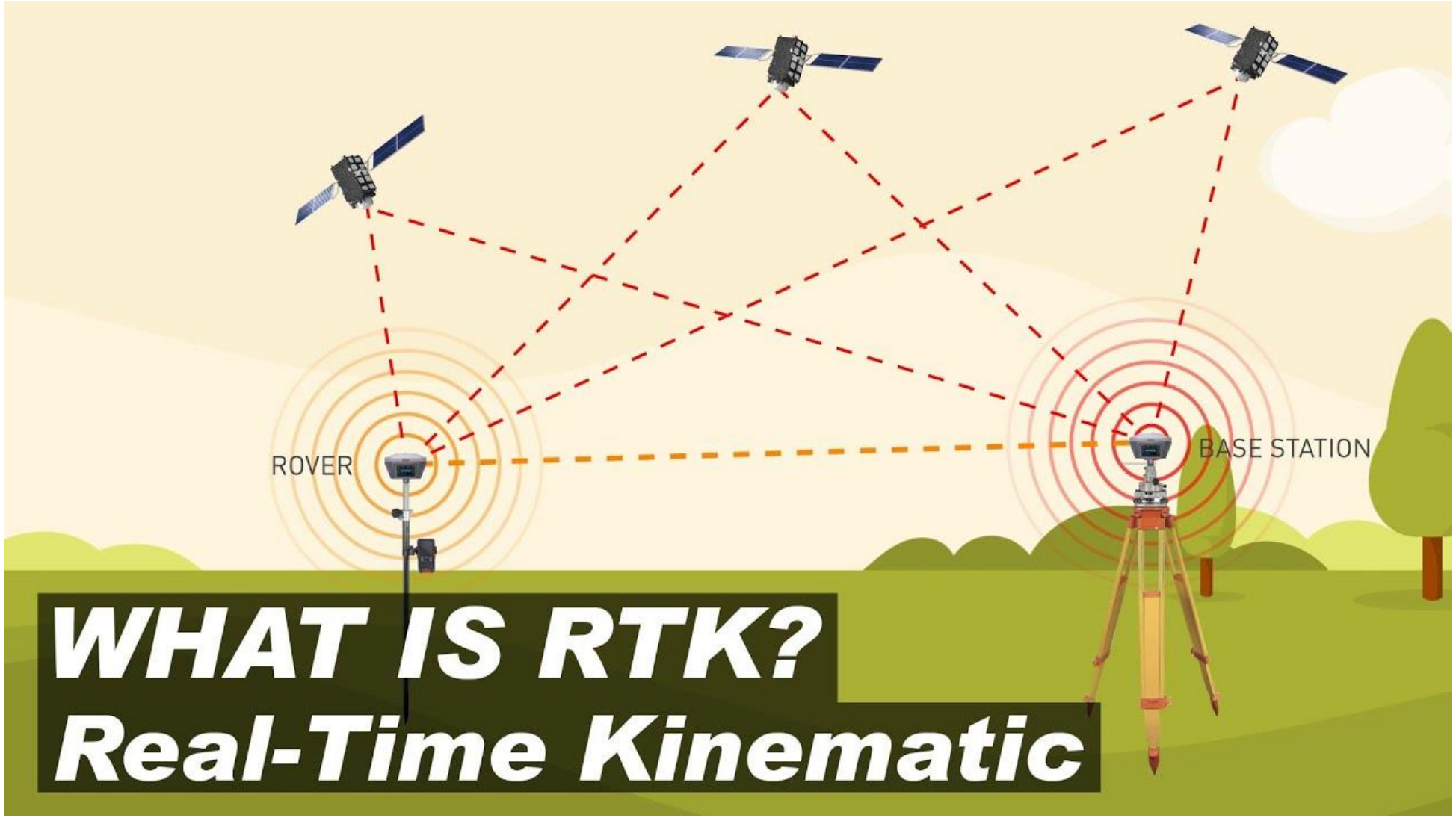
RTK/PPP and QZSS correction service

GNSS training on January 20, 2021 @ICG

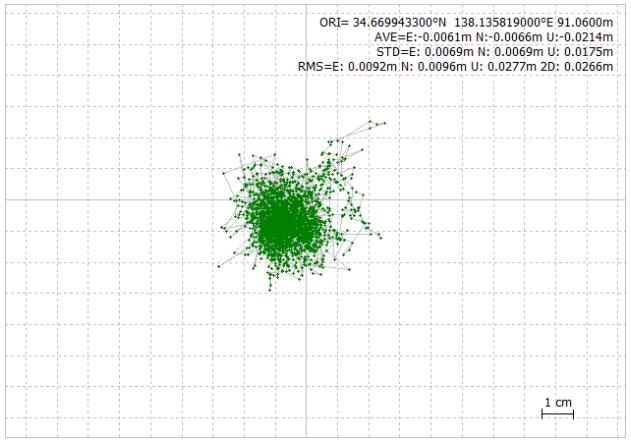
Nobuaki Kubo

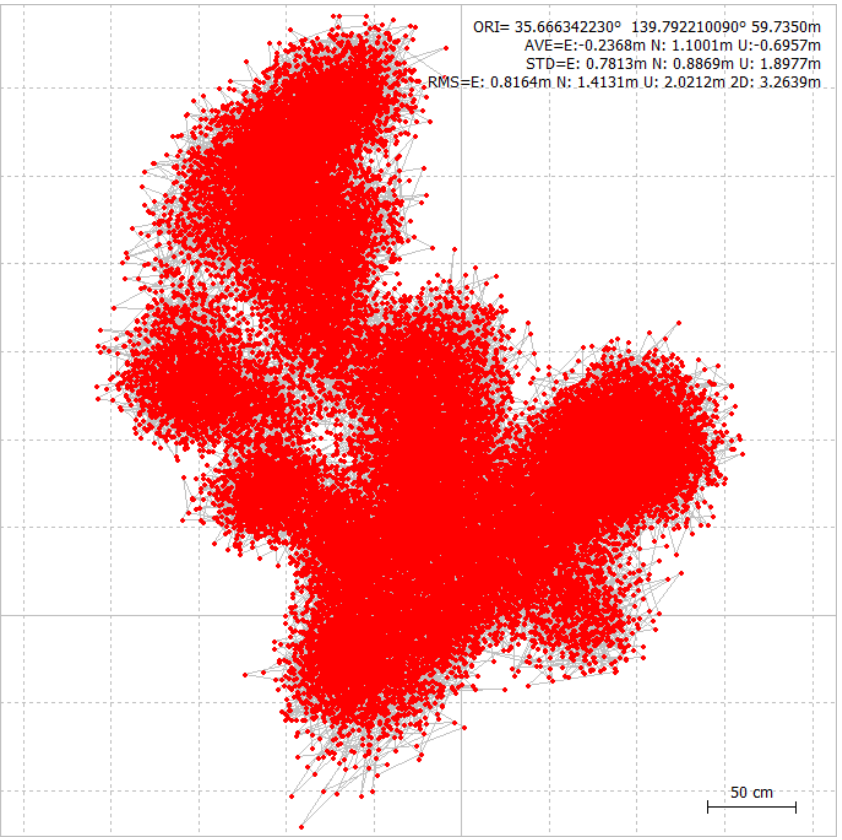
Tokyo University of Marine Science and Technology, Japan



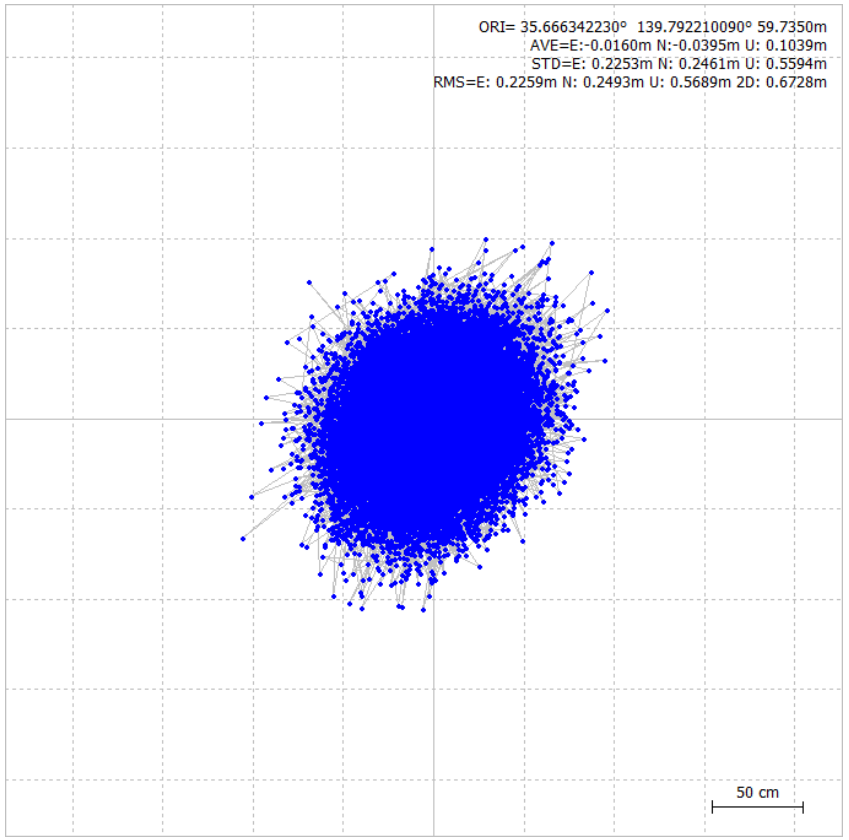
Real-Time Kinematic (RTK) is a technique used to enhance the precision of position data derived from satellite-based positioning systems (global navigation satellite systems, GNSS) such as GPS, GLONASS, Galileo, NavIC and BeiDou. It uses measurements of the phase of the signal's carrier wave in addition to the information content of the signal and relies on a single reference station or interpolated virtual station to provide real-time corrections, providing up to centimeter-level accuracy.

Accuracy is different.

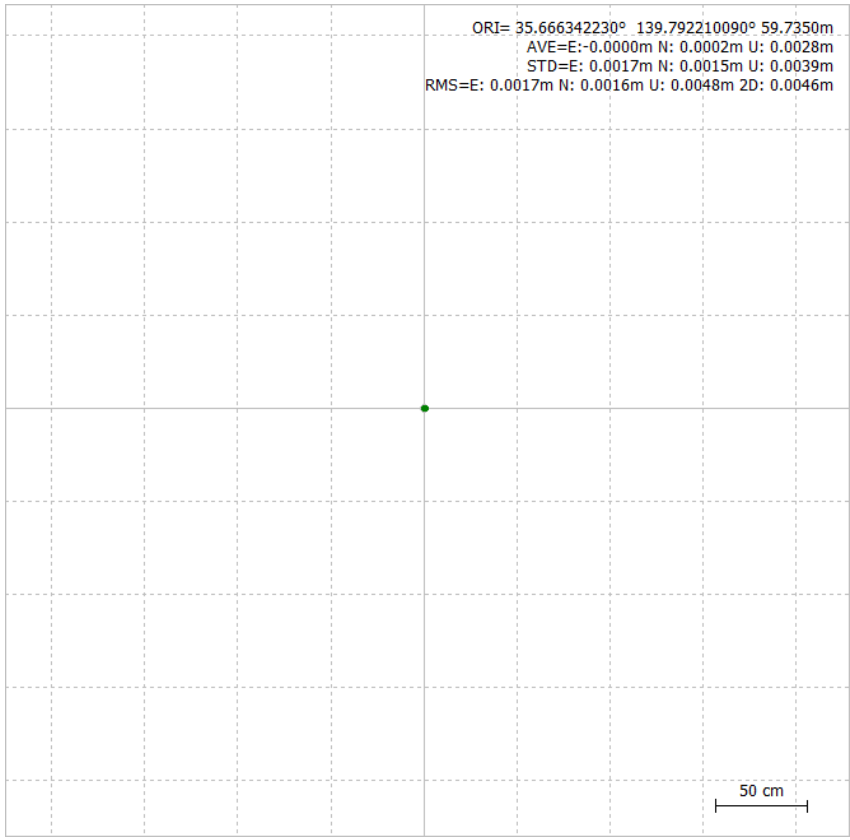




SPP



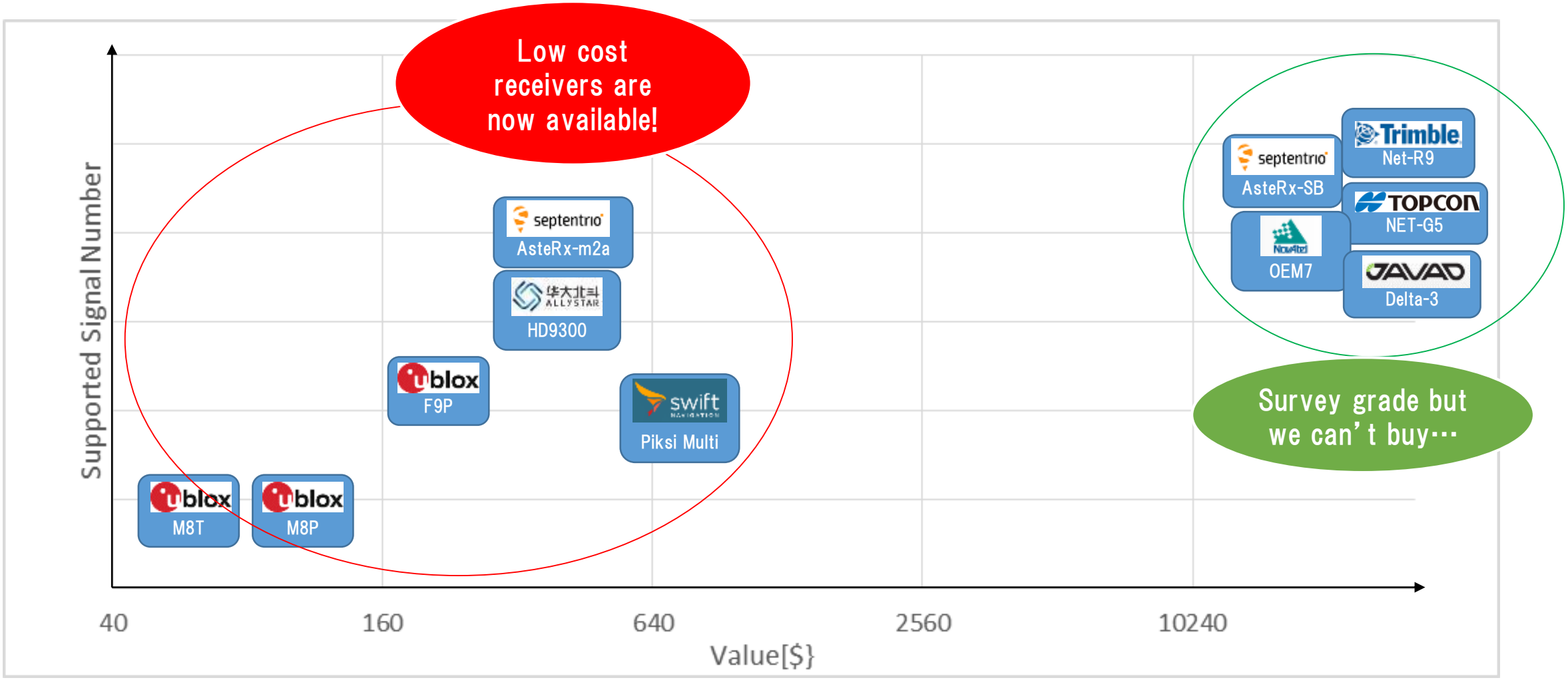
DGNSS



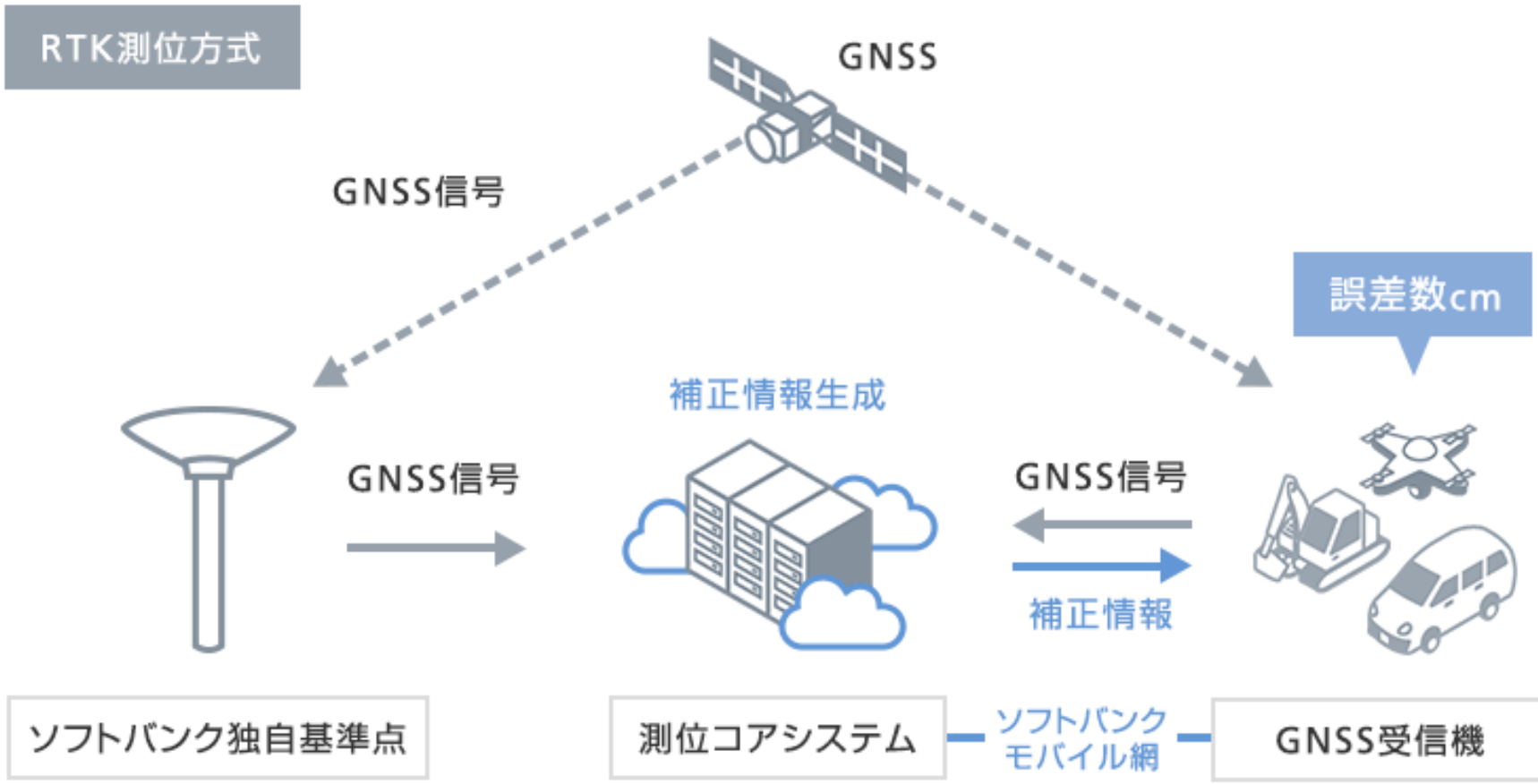
RTK

Receiver selection

Low-cost and excellent performance receivers are ready.



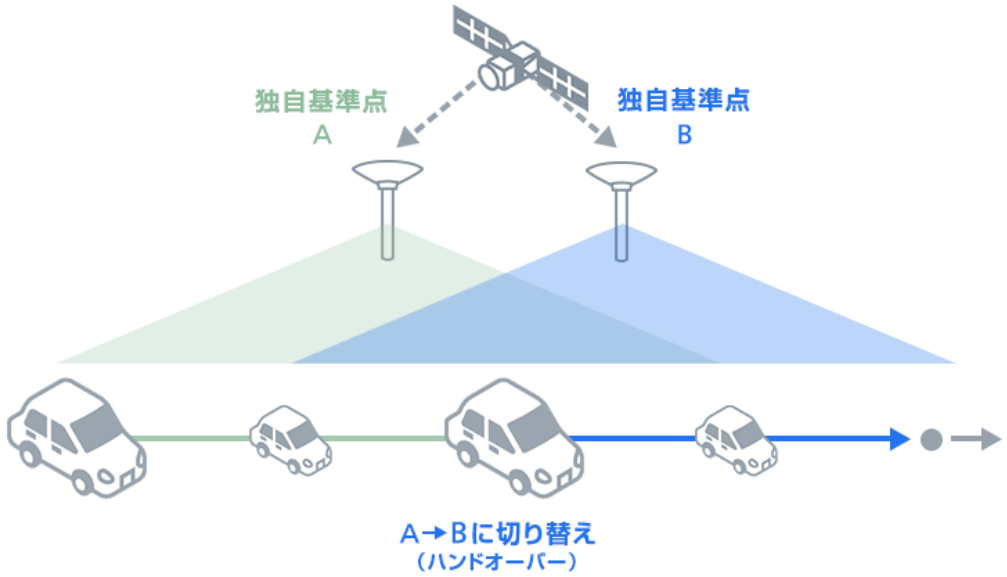
Ichimill (SoftBank starts RTK service in 2019)



GNSS + LTE + internal Ant.
All you need is switching on…

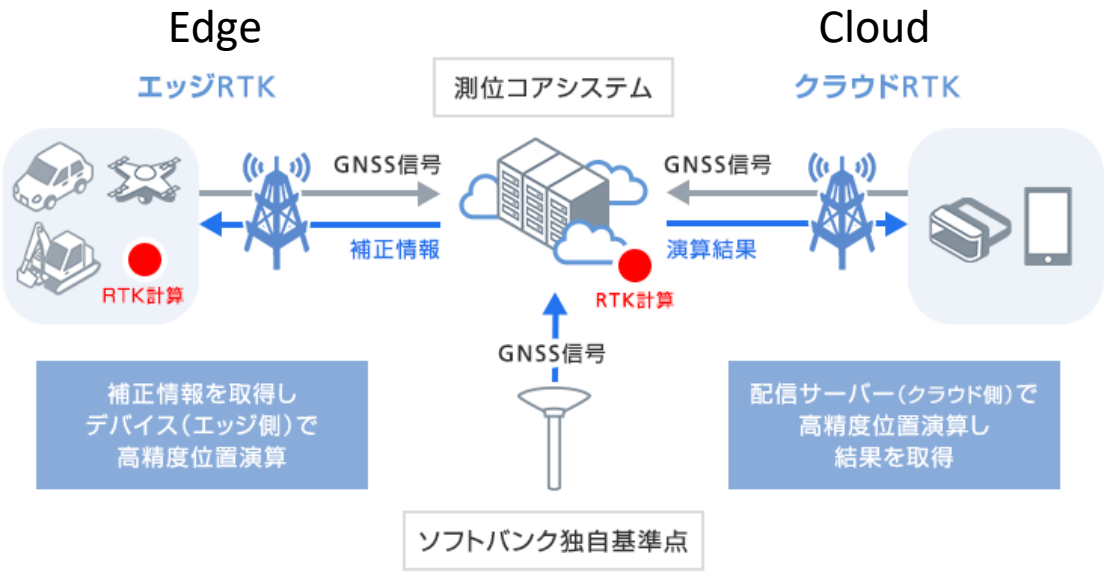
About $50/month. We can use RTK in everywhere in Japan as long as Softbank LTE is available.

The advent of very good low-cost multi-GNSS dual-frequency GNSS receiver. Strong RTK engine !



※ソフトバンク独自基準点の座標特定に国土地理院の電子基準点を活用

Japanese territory (land) : 378,000 km^2
378,000/3,300 = 114 km^2
Very dense



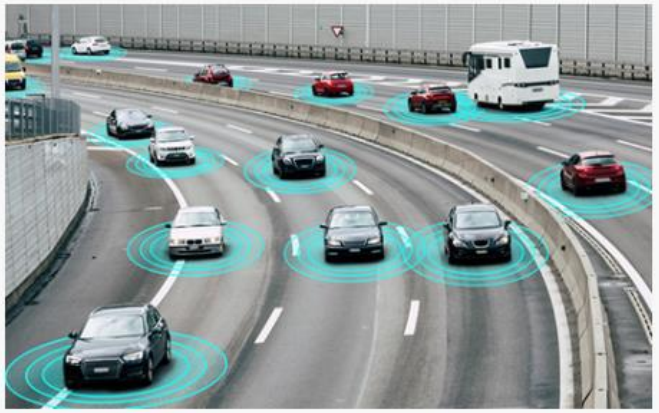
Varieties of applications！

農業

農業の自動化

建設

建設の自動化



交通

自動運転やMaaSへの活用

ドローン

飛行経路の自動制御

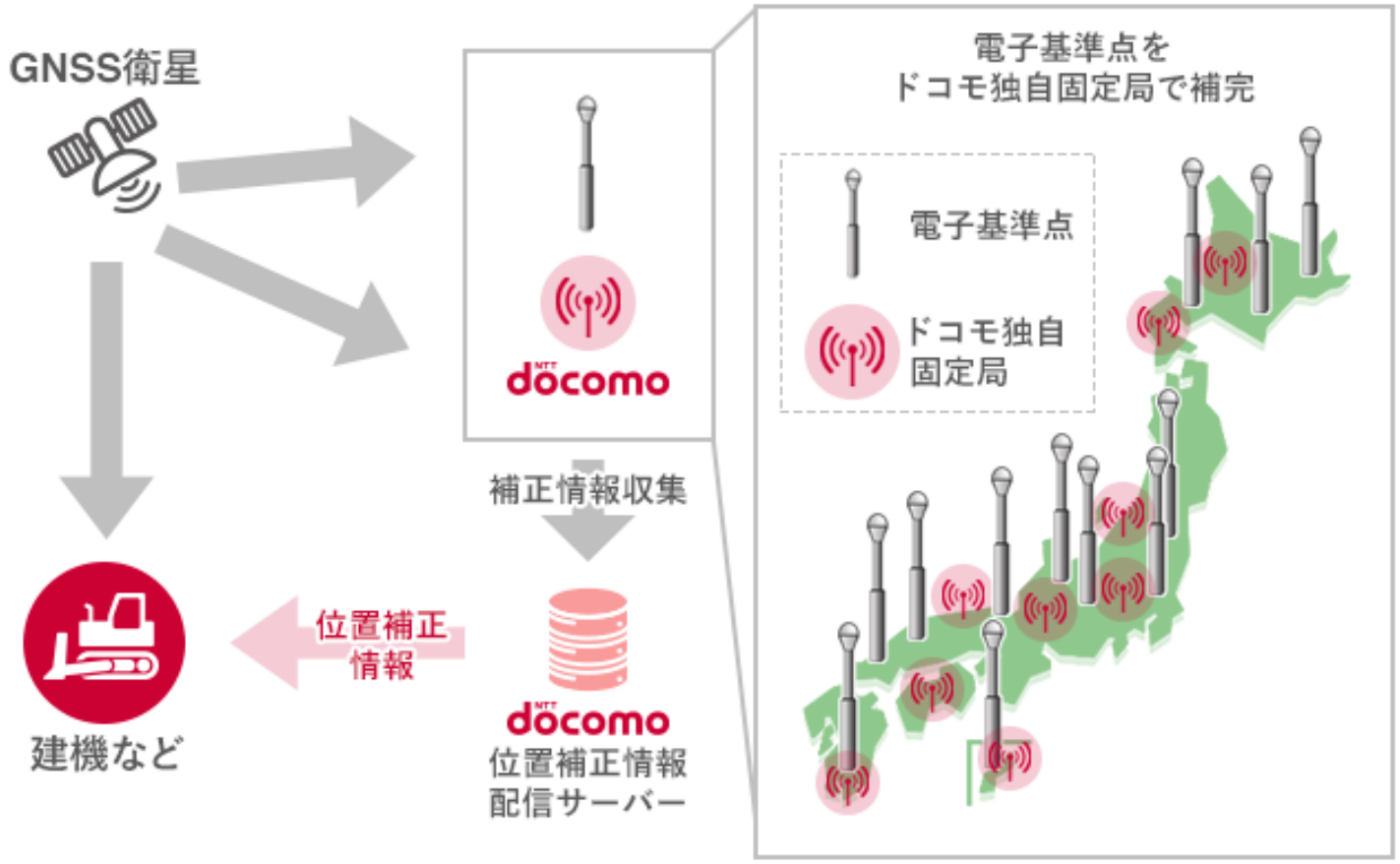
ウエアラブル

スポーツ等への様々な分野への活用

インフラ監視

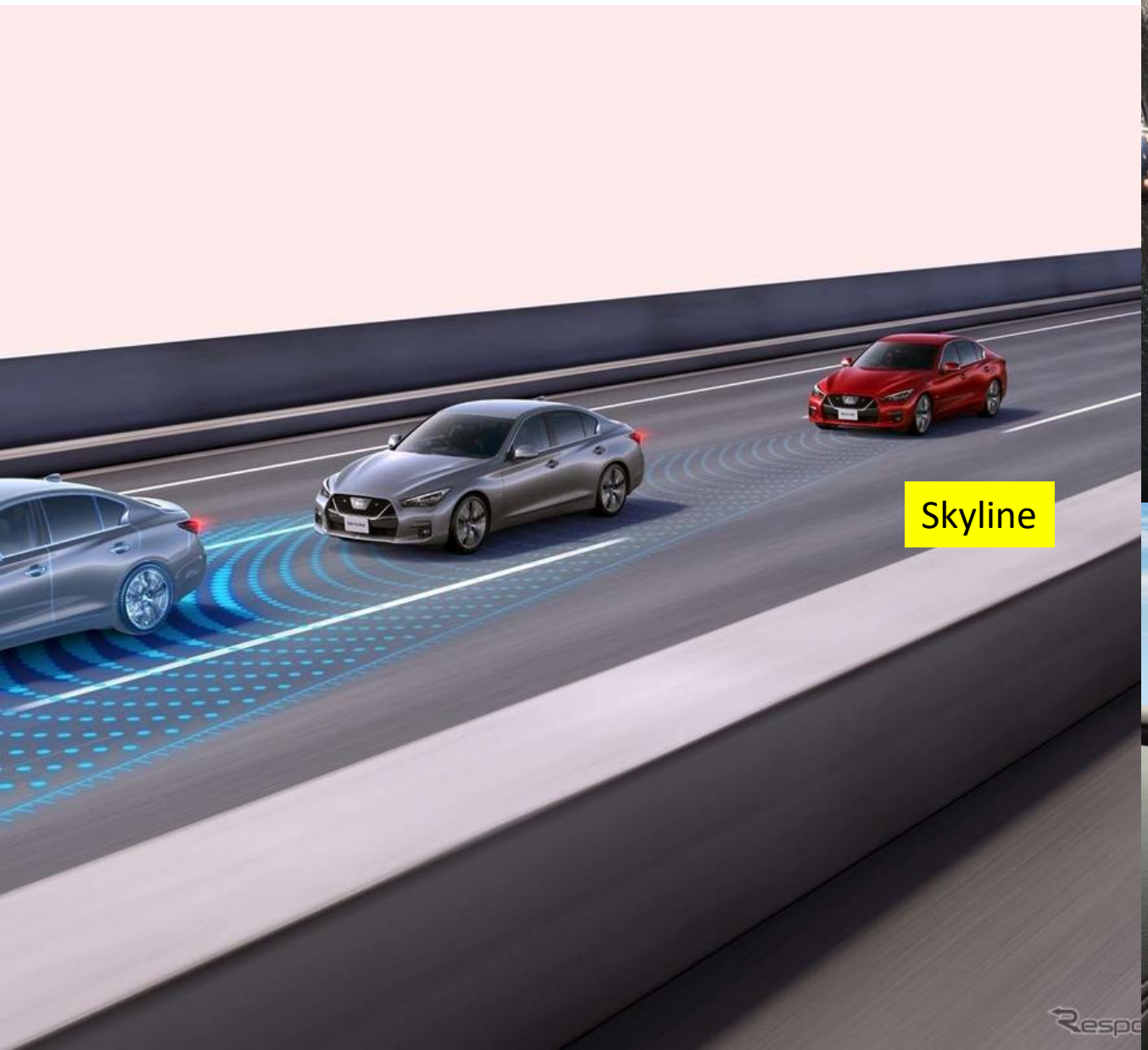
インフラ保全の効率化

NTT DOCOMO also starts in 2019



- 1,300 GEONETS and local base stations added by NTT DOCOMO.
- NTT starts the could RTK service.
- NTT DOCOMO is a subsidiary of NTT.

Hands free driving

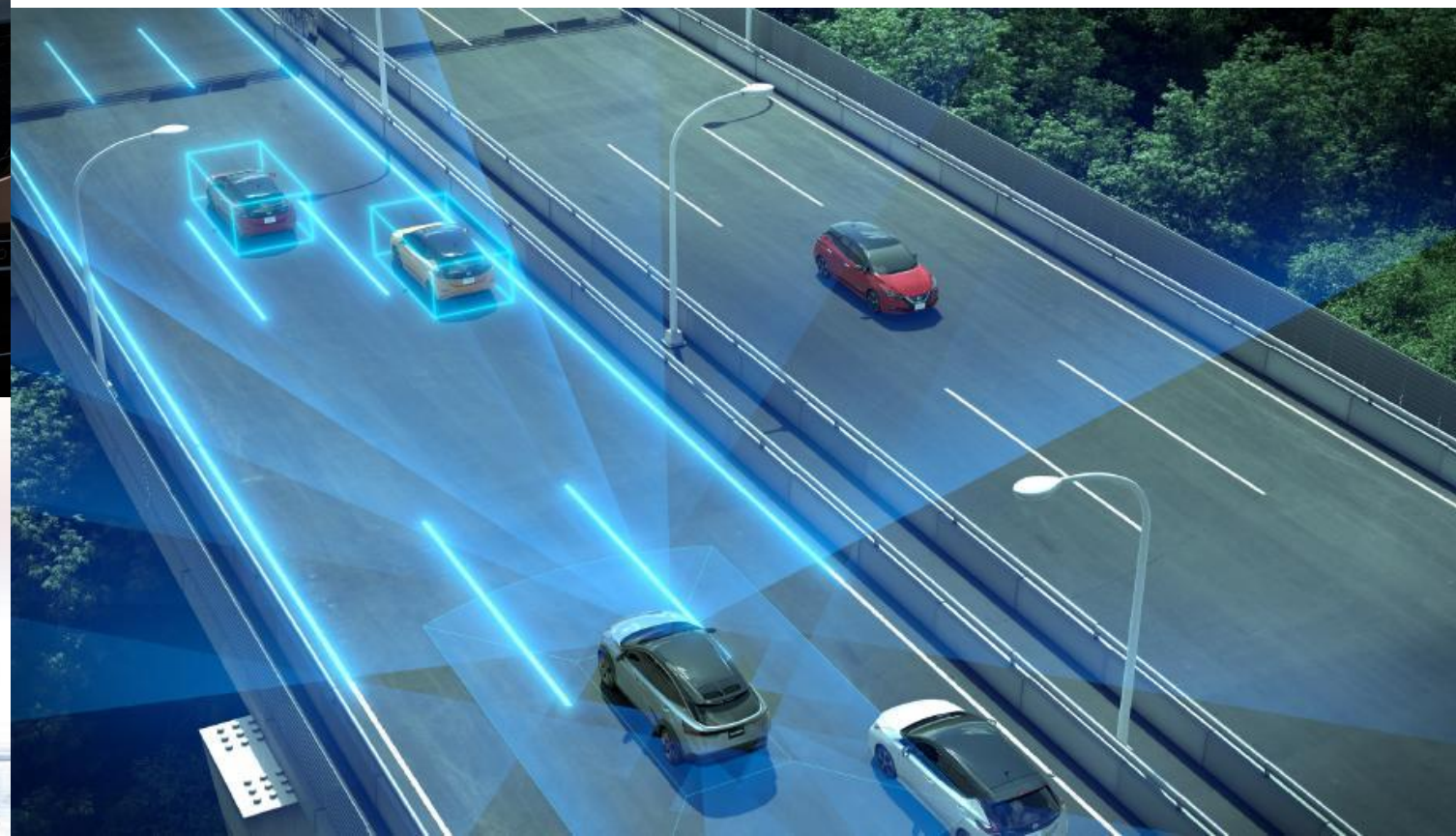


Pro Pilot 2.0 and Eyesight X

ARIYA


LEVORG

- Nissan and Subaru for now.
- CLAS service is used.
- Precise 3D MAP is used.
- This map has been generated using RTK.



Difference between RTK and PPP

- The big difference is the time to get cm accuracy.
- RTK is instantaneous.
- PPP takes about 5-30 min (depends on ionospheric correction).
- Therefore, PPP is not suitable for moving platform with issues of cycle slips (carrier phase is not tracked continuously)
- The difference will become small in the future.
- RTK can be used for local area but CLAS/PPP will be more suitable for wide area.

RTK/CLAS/PPP

Error sources	RTK	CLAS (Wide area RTK)	PPP
Satellite position	Not separated	○	○
Satellite clock		○	○
Ionosphere		○	?
Troposphere		○	
Coverage	Within about 50 km	Japan : 2kbps	No limitation

FCB : PPP-AR enables

High Accuracy positioning service has come.
RTK/PPP are those core techniques.

QZSS correction services (CLAS and PPP)

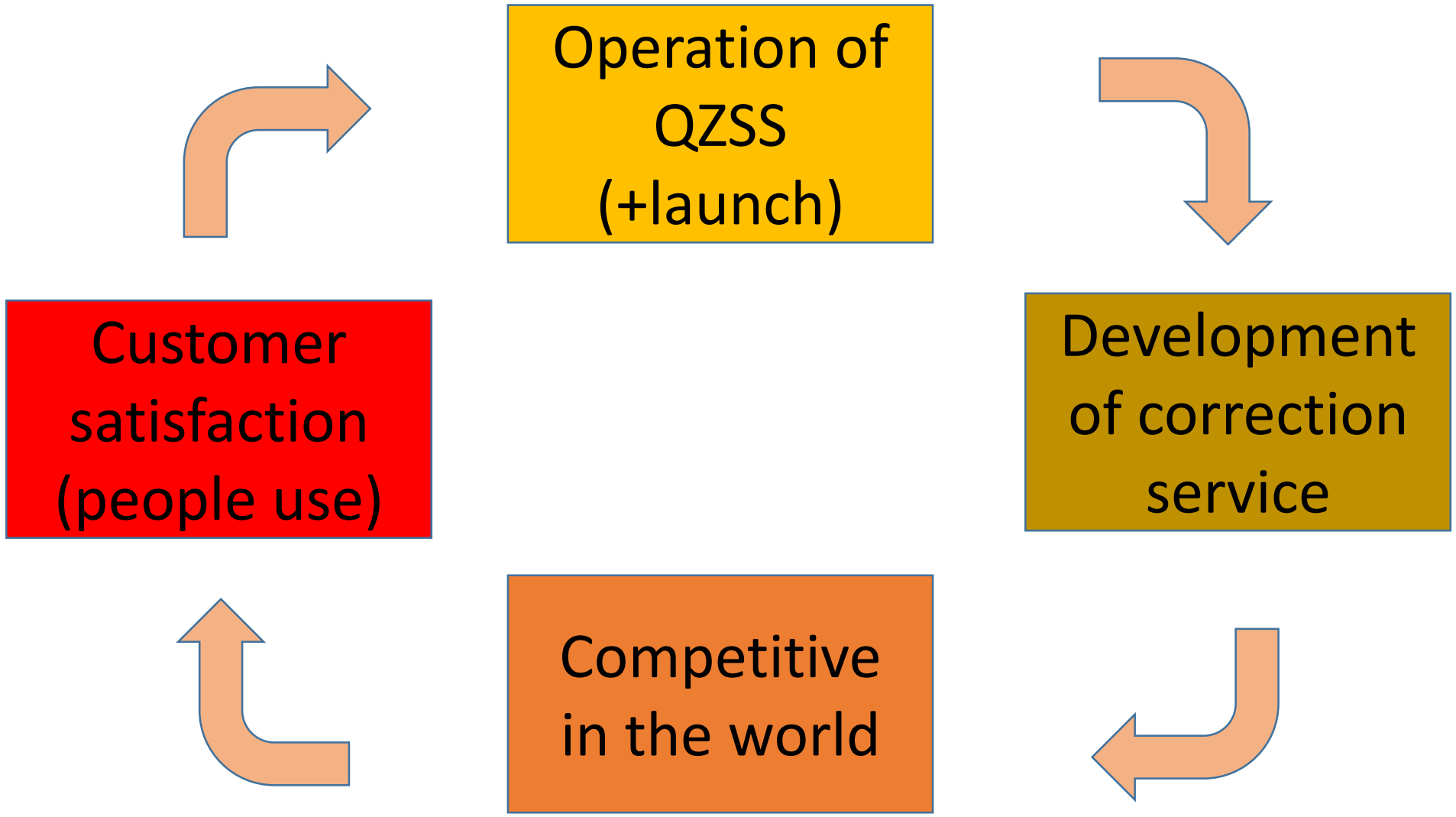
Other countries consider the similar correction service.
RTK is not free but CLAS/PPP are **free if you have L6 reception**.

CLAS provider (L6D) : Mitsubishi
PPP provider (L6E) : GPAS

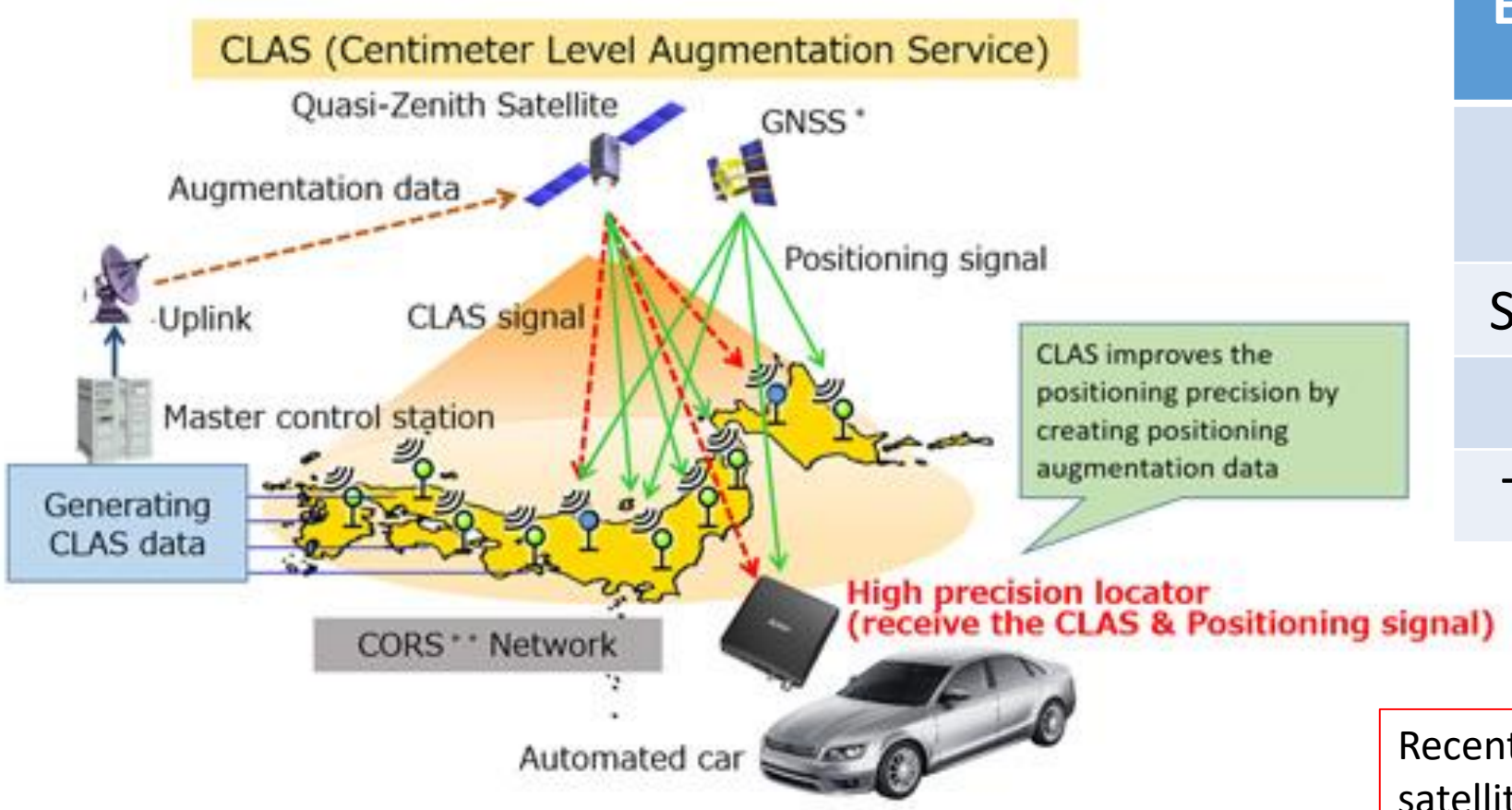
Table of Correction Services

	Accuracy (95%)	coverage
SLAS	1.0 m	Japanese islands +
CLAS	6.0 cm	Japanese islands
MSAS	1-2 m	Japanese islands +
MADOCA PPP	10 cm (no AR)	Asia, Oceania

Good cycle


Operation of QZSS (+launch)
Development of correction service
Competitive in the world
Customer satisfaction (people use)

CLAS : Centimeter Level Augmentation Service



Error sources	Intervals
Satellite position	30 sec
Satellite clock	5 sec
Ionosphere	30 sec
Troposphere	30 sec

CLAS is like wide area RTK

Recently, the number of maximum satellites used for CLAS was increased to 17. Galileo can be used now. GPS/QZSS/GALILEO

Typical accuracy

Recent Test results (kinematic use)

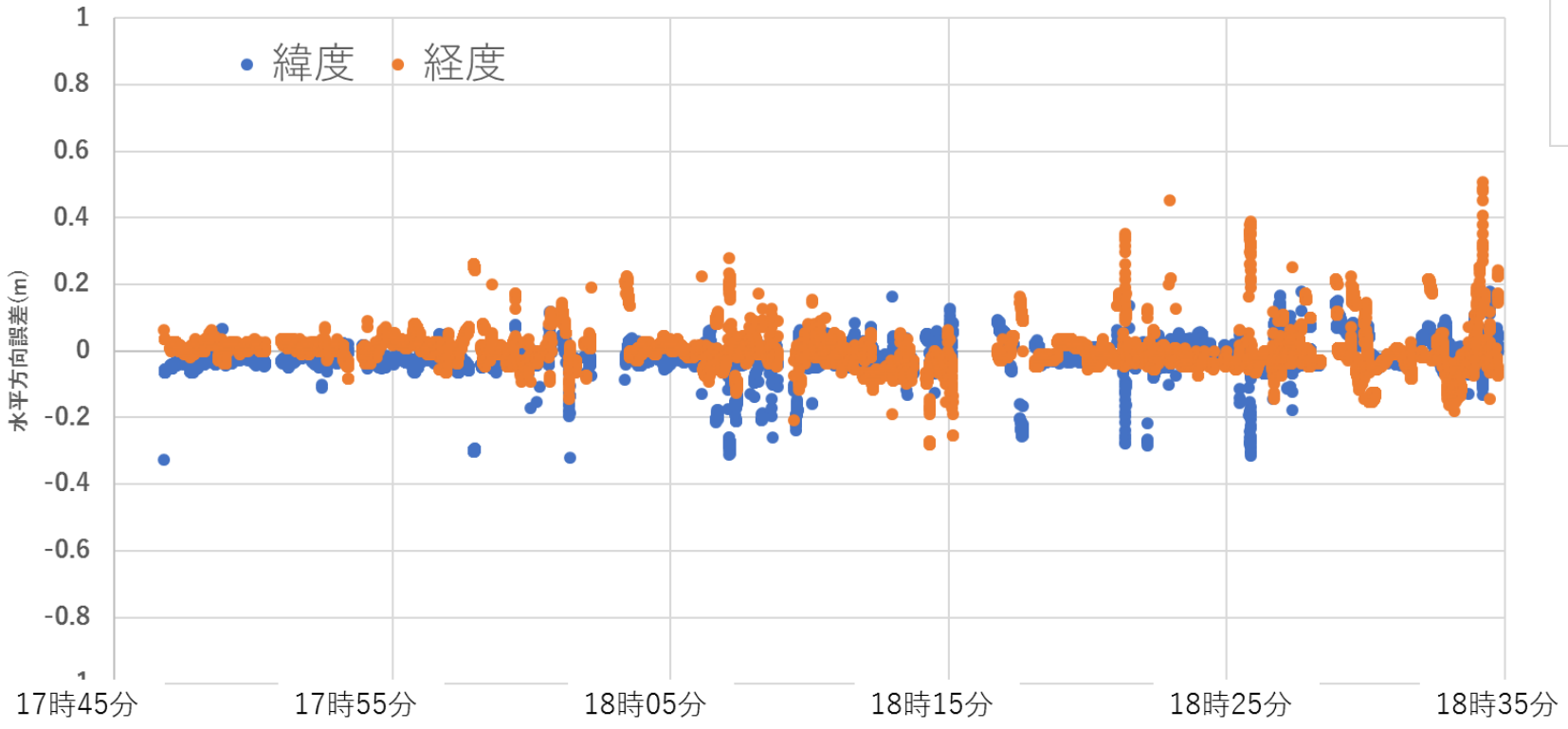
- Evaluated from positioning results of vehicle mounting both RTK and CLAS receivers in open-sky condition.
- Difference between CLAS positioning results and RTK positioning results are evaluated.

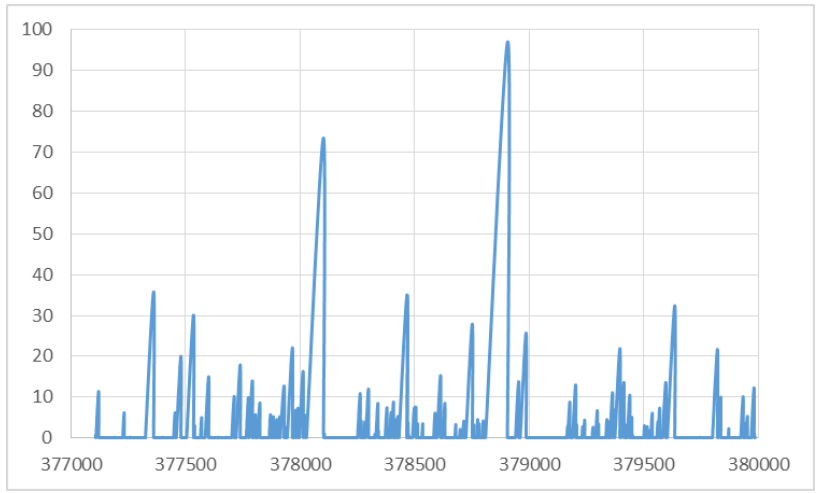
3D Error	cm (rms)
East-West	2.0
North-South	1.8
Vertical	4.2

CLAS performance at highway in Tokyo

Date : January 2018
Receiver : AQLOC (Mitsubishi)
Duration : 50 min.
Reference positions : RTK

Horizontal positions errors (CLAS)





Time to fix (s)

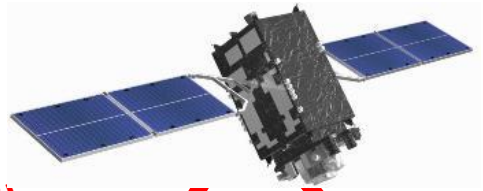
CLAS FIX rate	**76.85%**
RTK FIX rate	**90.32%**

絶対誤差	水平誤差（m）
標準偏差	0.047
90%	0.088
95%	0.139

MADOCA PPP (JAXA -> GPAS)

PPP correction service（operation in the near future）

Precise orbit and clock



LEX signal (L6) broadcasting

Upload to QZSS

Control station

Product

Users

MADOCA

MADOCA

After 15 min., we can get 10 cm accuracy. With new method, we can shorten the time and PPP-AR is possible

Product(LEX signal)

GPS・GLONASS・QZSS

Precise orbit and clock

Conventional → Now

Conventional

decode

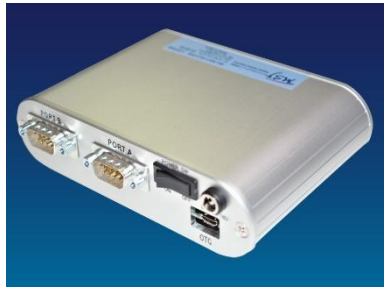
LEX

PPP

Software receiver

High-end receiver

Now



PPP

Low-cost small receiver is available for PPP.
F9P+L6D kit is coming.
(Dr. Dinesh)

MADOCA-PPP/CLAS対応

All you need is to connect antenna.

Issues in sea and undeveloped area

It is difficult to use cm-level accuracy on the sea and undeveloped areas without controlled base stations.

PPP is possible through the satellite

No limitation in baseline

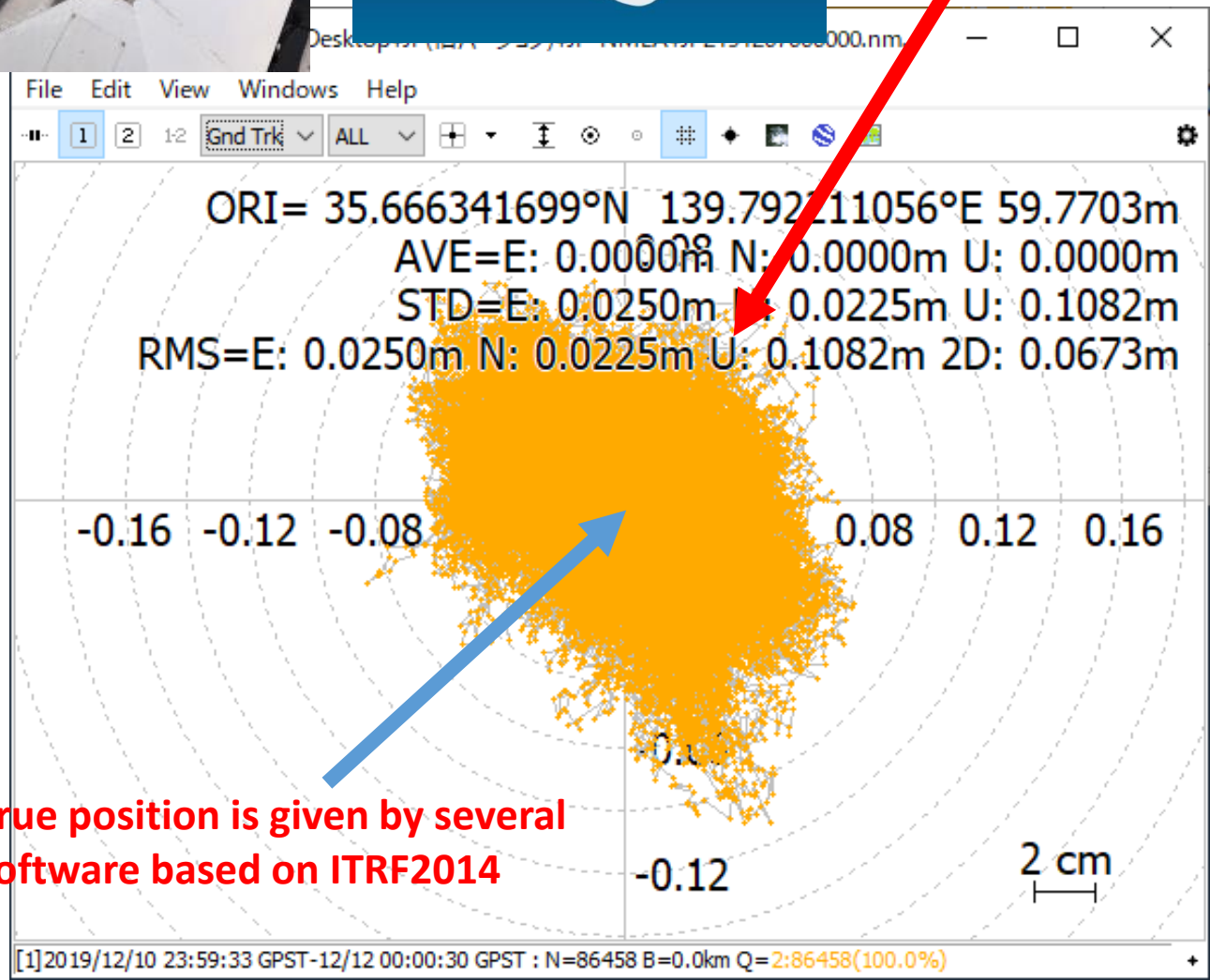
20km~30km (RTK)

基地局

Evaluation campaign

- Receiver is multi-GNSS receiver manufactured by Magellan Systems Japan.
- Locations are 1 in Japan and 7 in foreign countries in east Asia.
- Errors in each station are evaluated based on true position (ITRF2014)→**suitable for moving platform in global (ship and airplane…)**

NMEA (PPP)

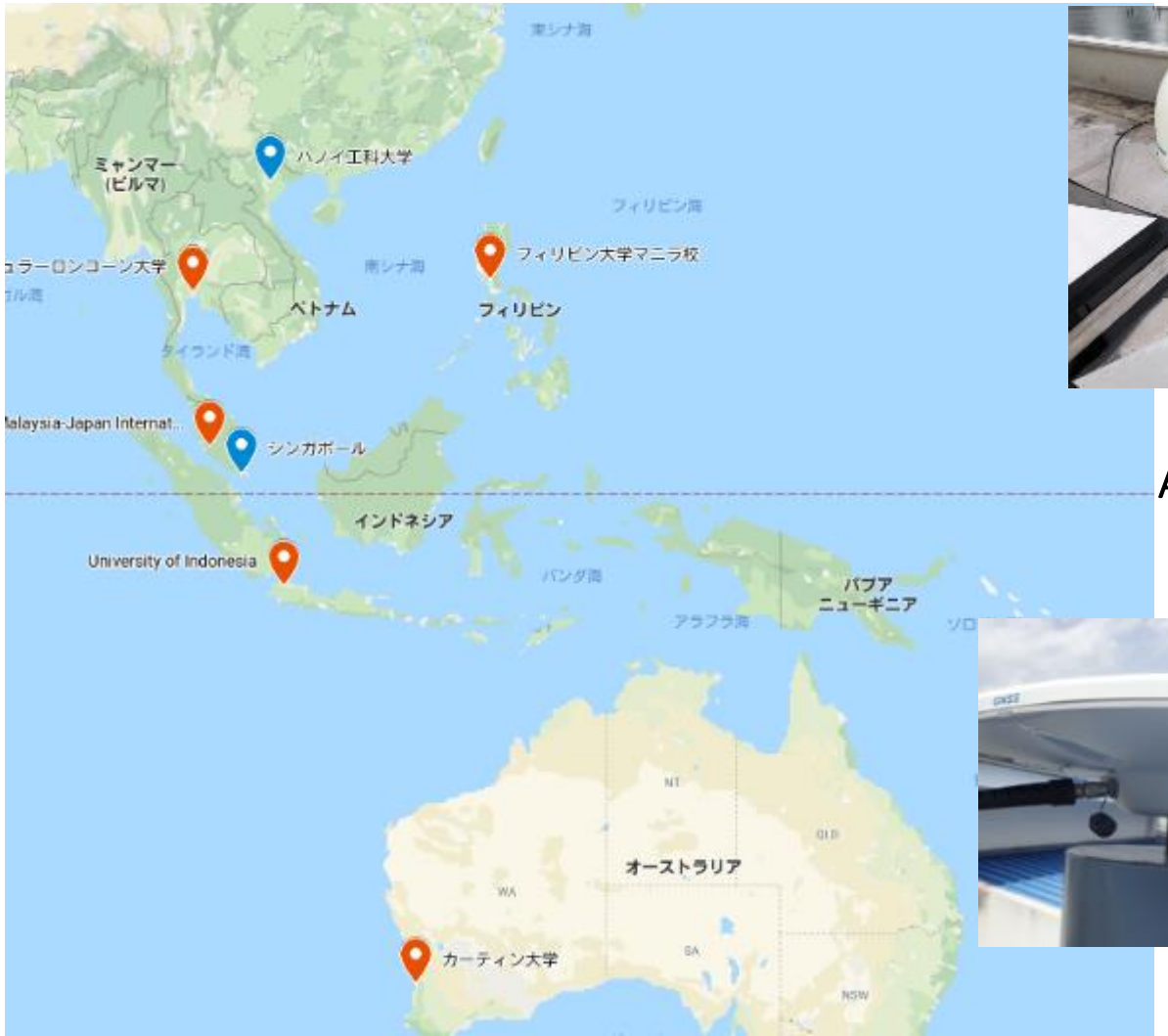


True position is given by several software based on ITRF2014

Outline of locations

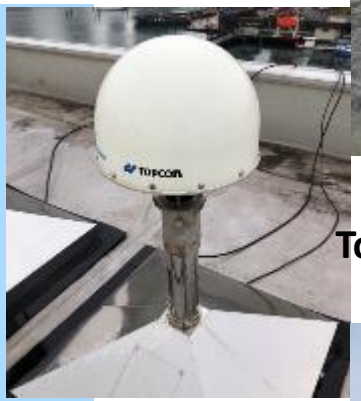
Locations (Time)

TUMSAT JAPAN（2019 August）
Chula Thailand（2019 August）
UOP Philippine（2019 August）
MJIIT Malaysia（2019 Nov.）
Curtin Australia（2019 Nov.）
UOI Indonesia（2019 Dec.）
Singapore：（2020 Oct.）
Vietnam：（2021…）



Thailand

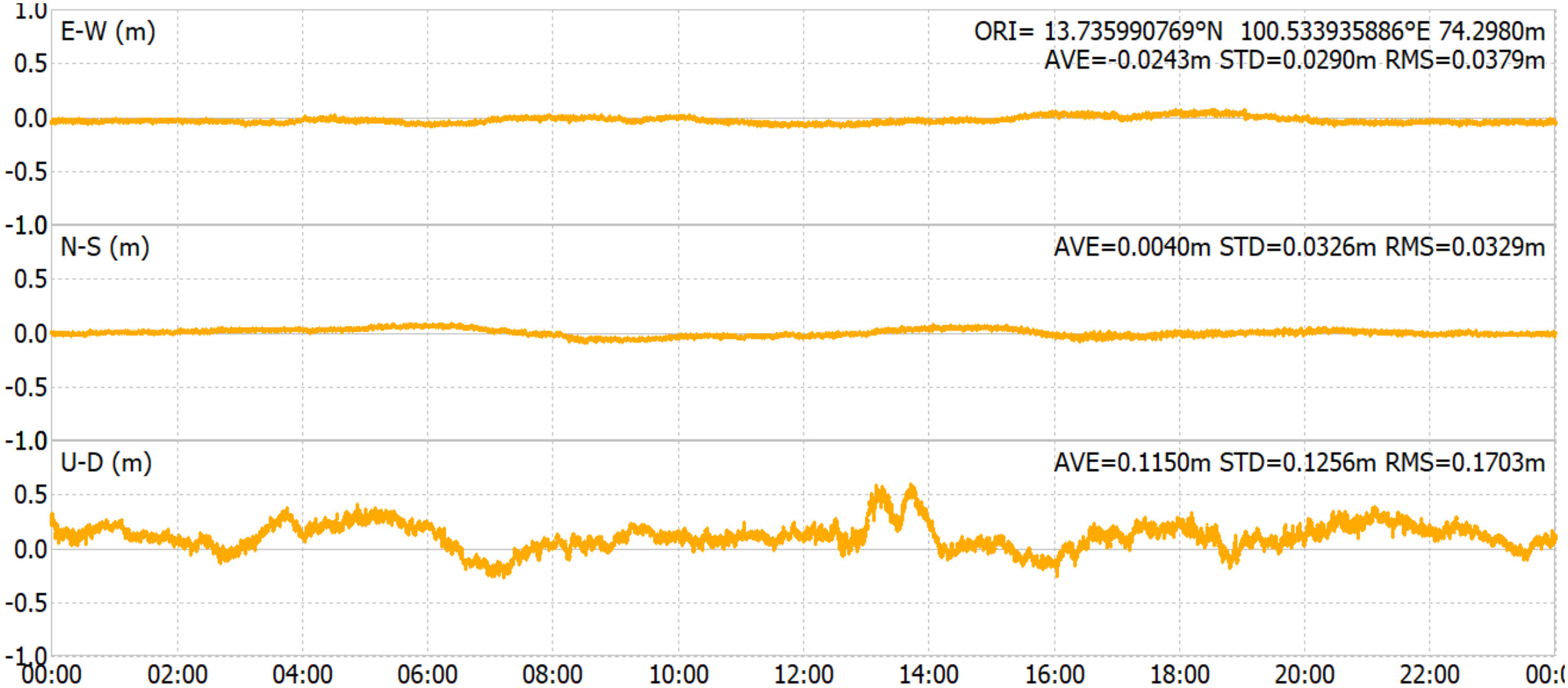
Tokyo



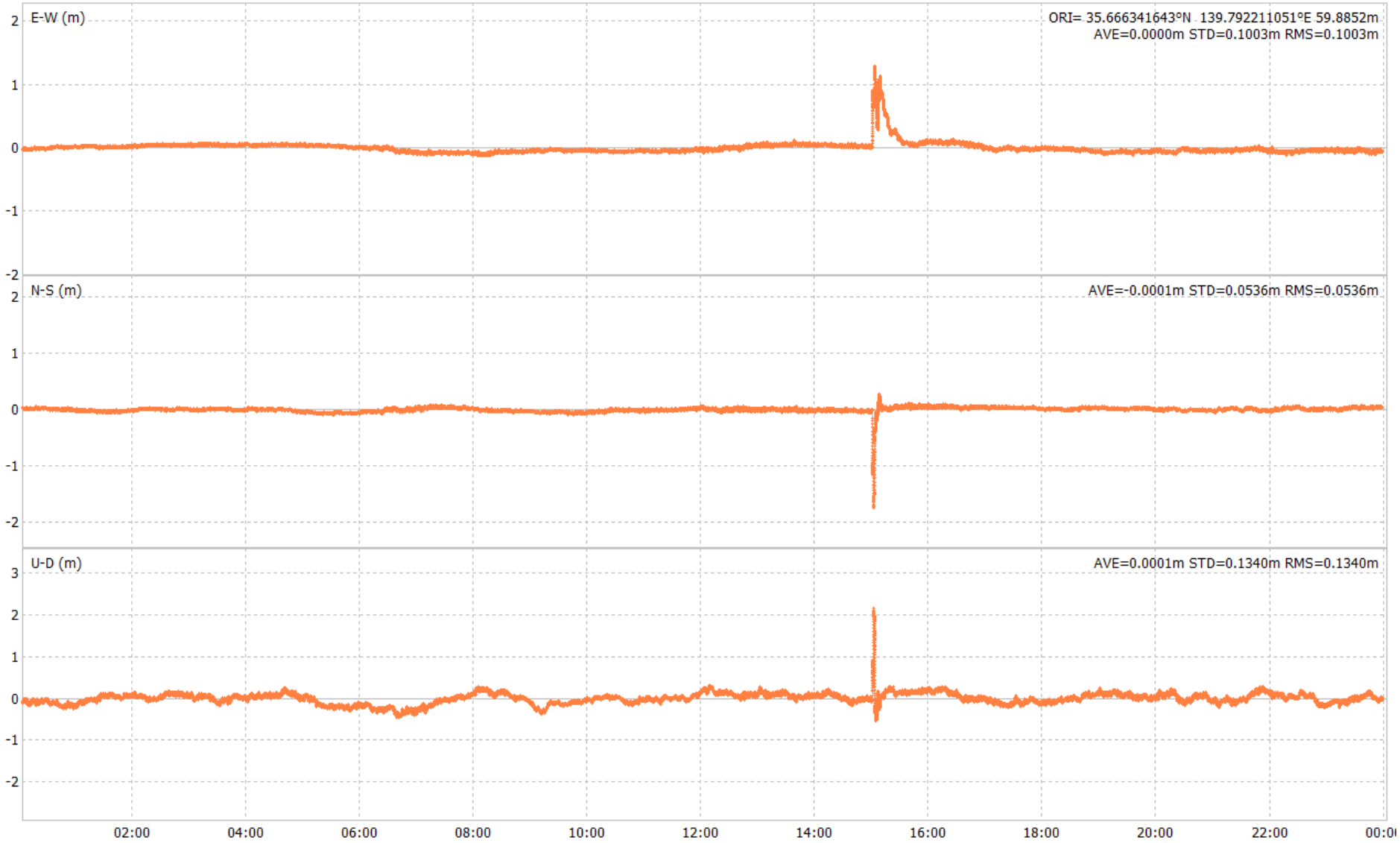
Australia→

←Malaysia

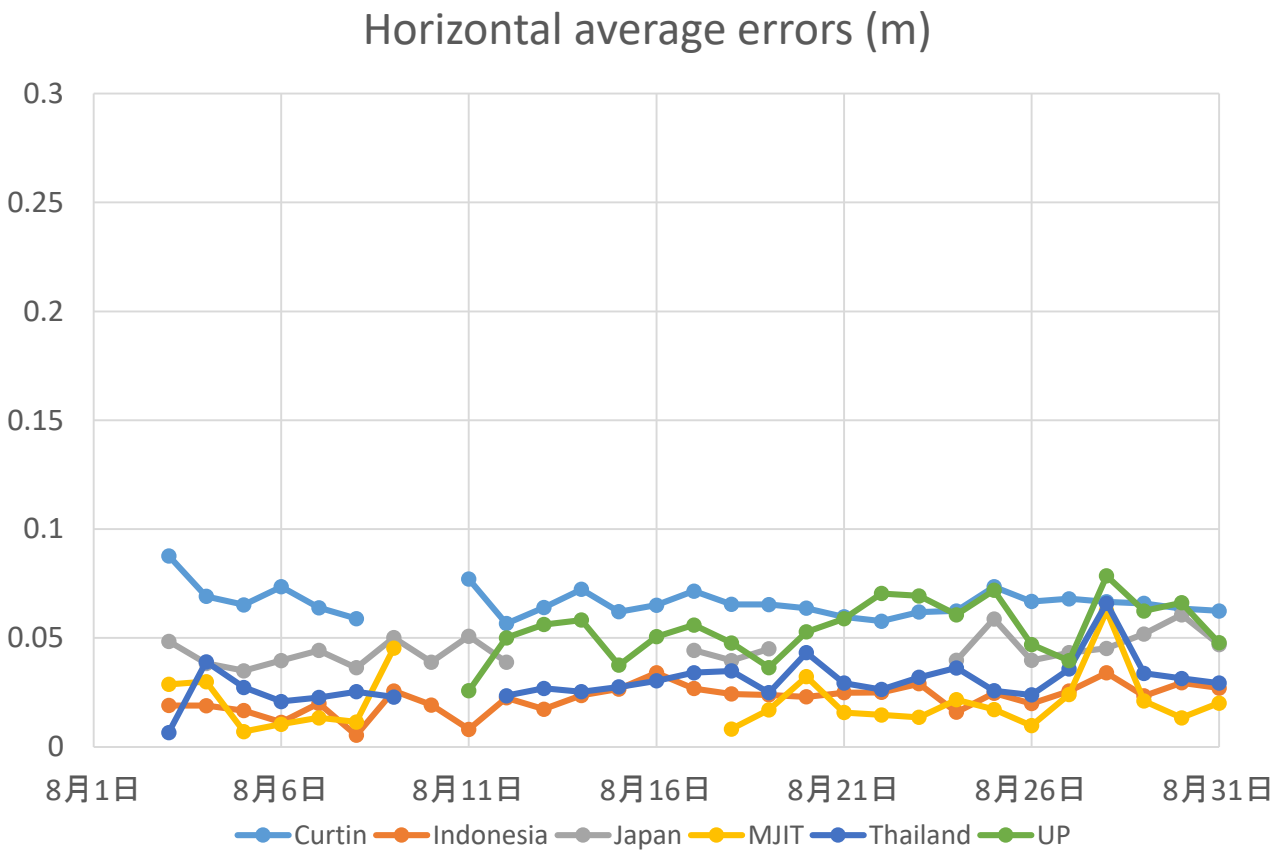
Apr 1 2020 (real time at Chula)

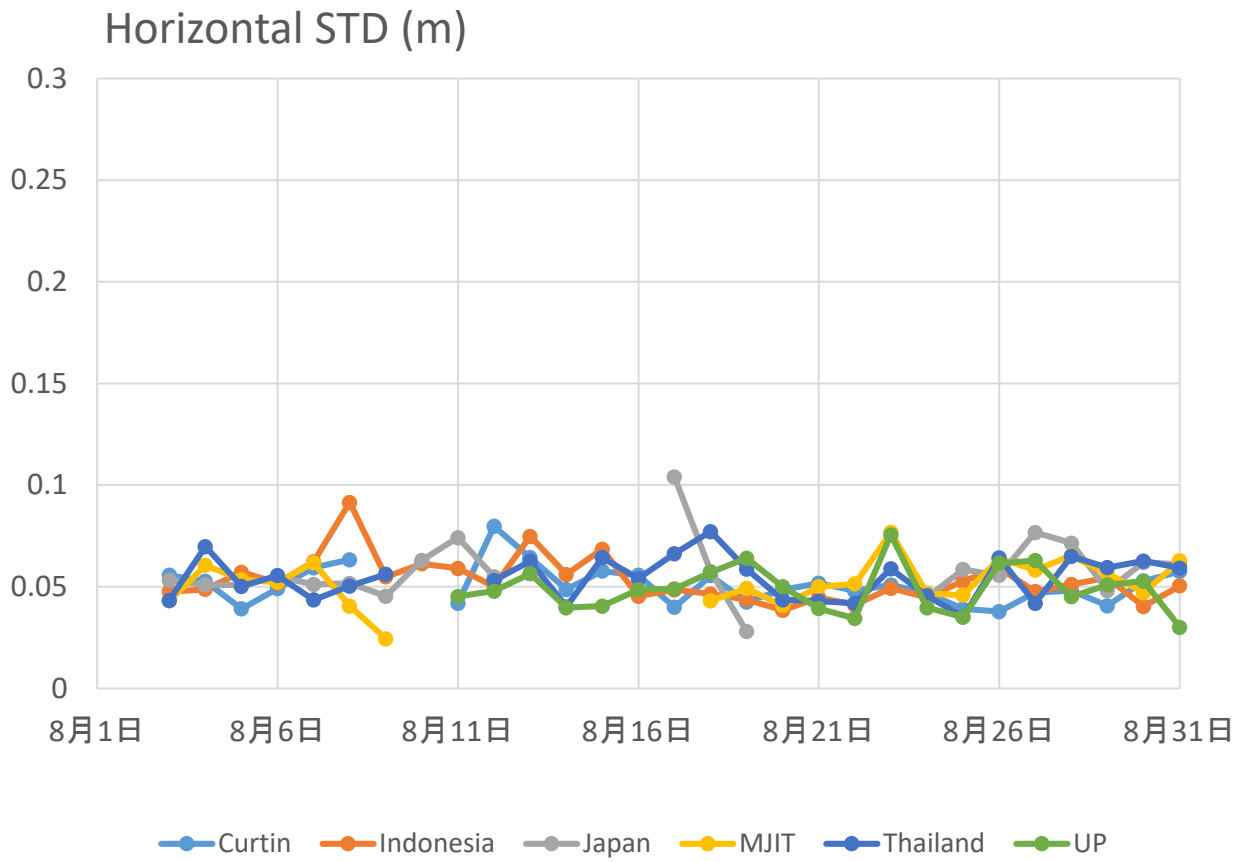


June 30 2020 (real time at TUMSAT)



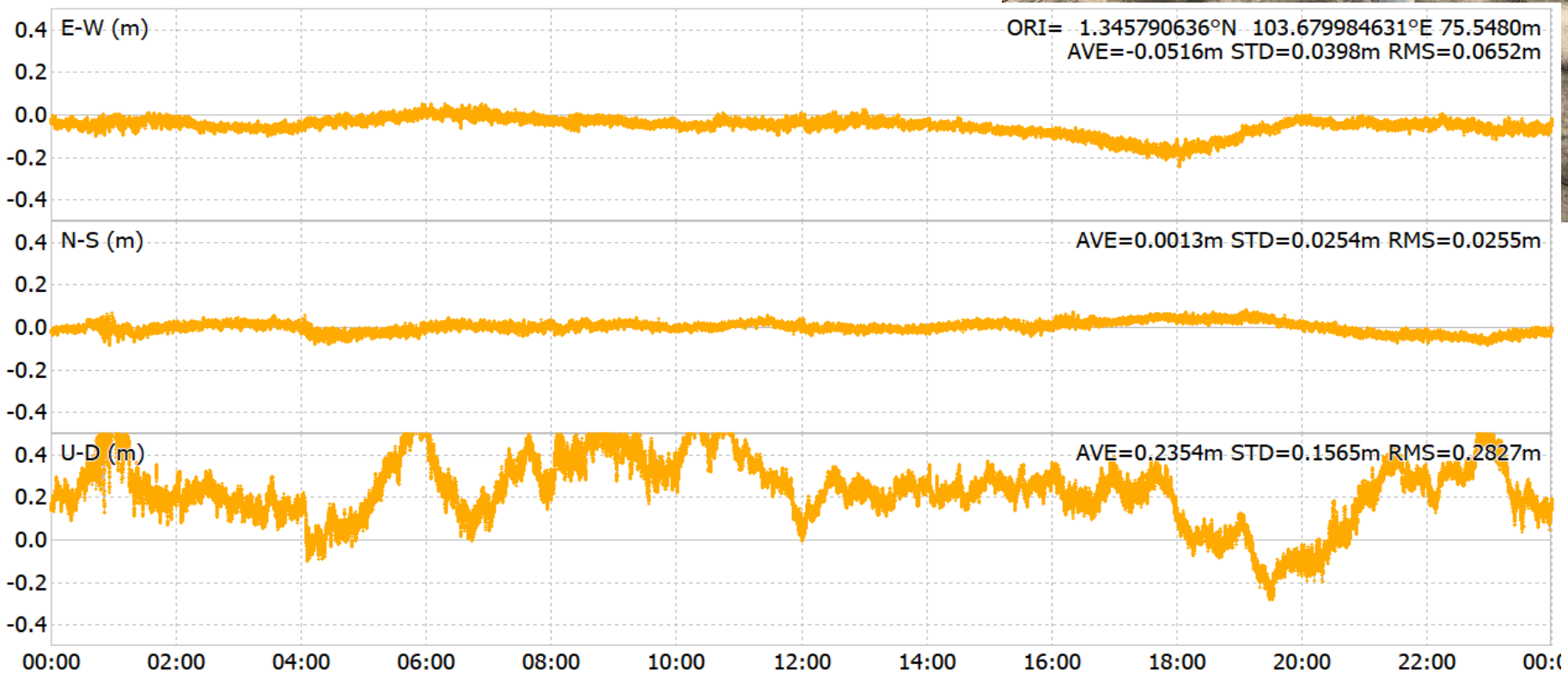
August 2020 in 6 countries (real time)





Nanyang Technological University (Singapore)

2020/9/19



Updates of PPP via QZSS in the near future

- PPP-AR will be enabled.
- GALILEO will be added in the precise orbit/clock.
- Shorten the time to fix, which means providing the ionosphere correction information via QZSS.
- We can use CLAS or PPP according to the requests of users.

Application of GNSS using QZSS correction service

Test has just started in march 2019.
Snow removal work on roads in Hokkaido.

i-Snow

Smart 賢い、機敏な
nice 魅力的な、快適な
Operation 操作、運転
Work 除雪作業
（for snow removal work）

Automate snow removal with GNSS

CLAS was used in this test.

<u>* Excellent skill is covered by the technology</u>
<u>* Labor saving</u>

1. **Where we are**
2. **Operation of the machine**
3. **Safety confirmation**

We are sure to face

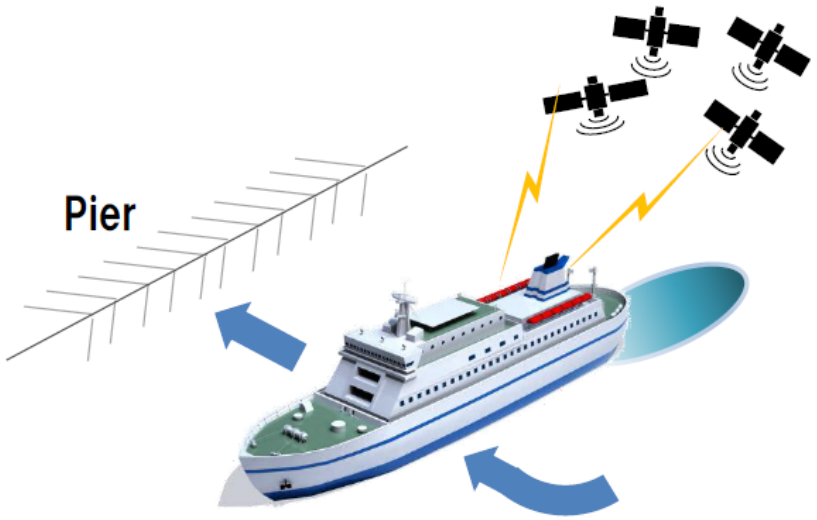
1. Aging society
2. Decreasing the population

Auto Berthing/Un-berthing

Auto Berthing/Un-berthing System with QZSS

High precision positioning is required for berthing/un-berthing.

→R&D activity on Auto Berthing/Un-berthing system with QZSS is starting.



Wide Area RTK / PPP can be used

Support for surveying at construction sites etc.

- Ground subsidence monitoring by the tunnel
- Cost effective
- Safety management

朝日新聞（夕刊） 2017年(平成29年)8月3日(木)

住宅街 最大13センチ沈下

横浜の首都高工事 百数十メートル四方 影響

首都高速道路・横浜北線の「馬場出入り口」（横浜市鶴見区）を造るための地下工事の影響で、現場から数百メートル離れた同市神奈川区内で地盤沈下が起き、住宅にひび割れなどの被害が出たことがわかった。首都高速道路株式会社（東京）が住民への補償を進めている。

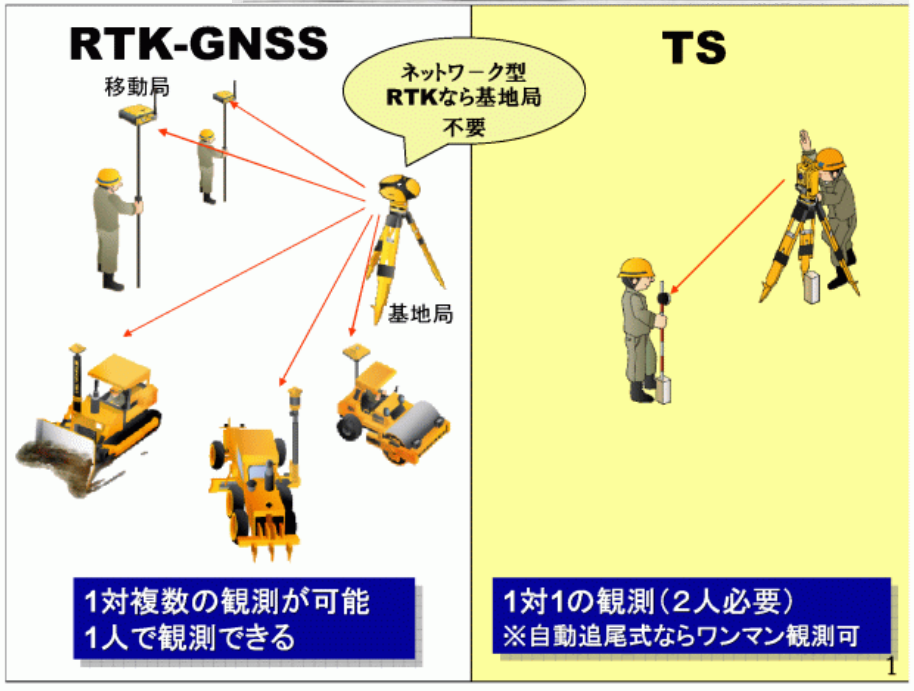
同社によると、地盤沈下が確認されたのは、地下トンネルと地上をつなぐ「馬場出入り口」の工事現場周辺。2015年1月に住民から「建物と道路の間に隙間ができた」と苦情が寄せられ、調査したところ、住宅の塀や基礎部分にひび割れなどが見つかった。現場付近を通るJR横浜線の擁壁にも亀裂が入ったという。

同社は被害区域や戸数などを明かしていないが、朝日新聞が入手した住民向け資料によると、今年4月時点で工事現場から400メートルほど南の神奈川区の住宅街では最大13・7センチ沈んでいた。一帯では百数十メートル四方ほどのエリアで沈下したことなどが記されている。

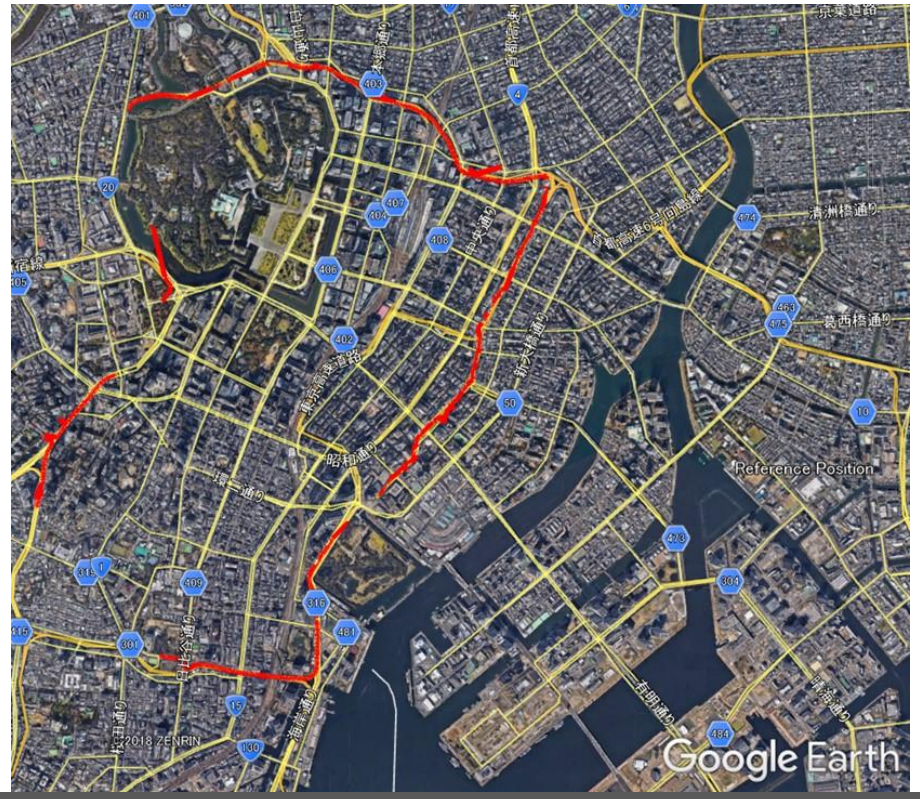
原因について同社は、工事に伴い地下水位が低下したと説明。昨年7月に出水量を抑える対策を取ったという。今年1月に再び沈下が起きたが、現在は収まっているという。過去に地盤が軟弱なことが沈下後の調査で判明。工事前の地盤調査の対象外だったという。

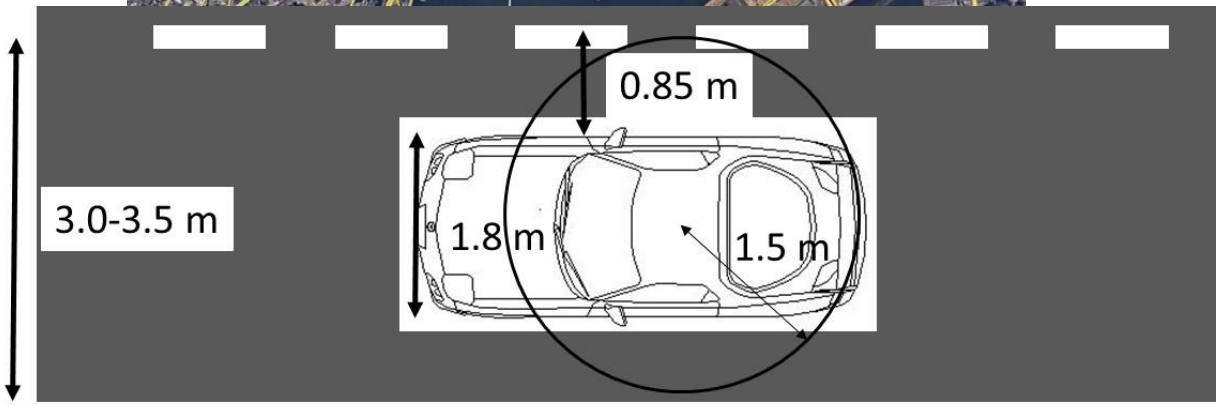
同社は取材に、「引き続き慎重に工事を進めるとともに、住宅被害の把握に努め、補修費用を負担する」としている。

（古田寛也）



Lane recognition



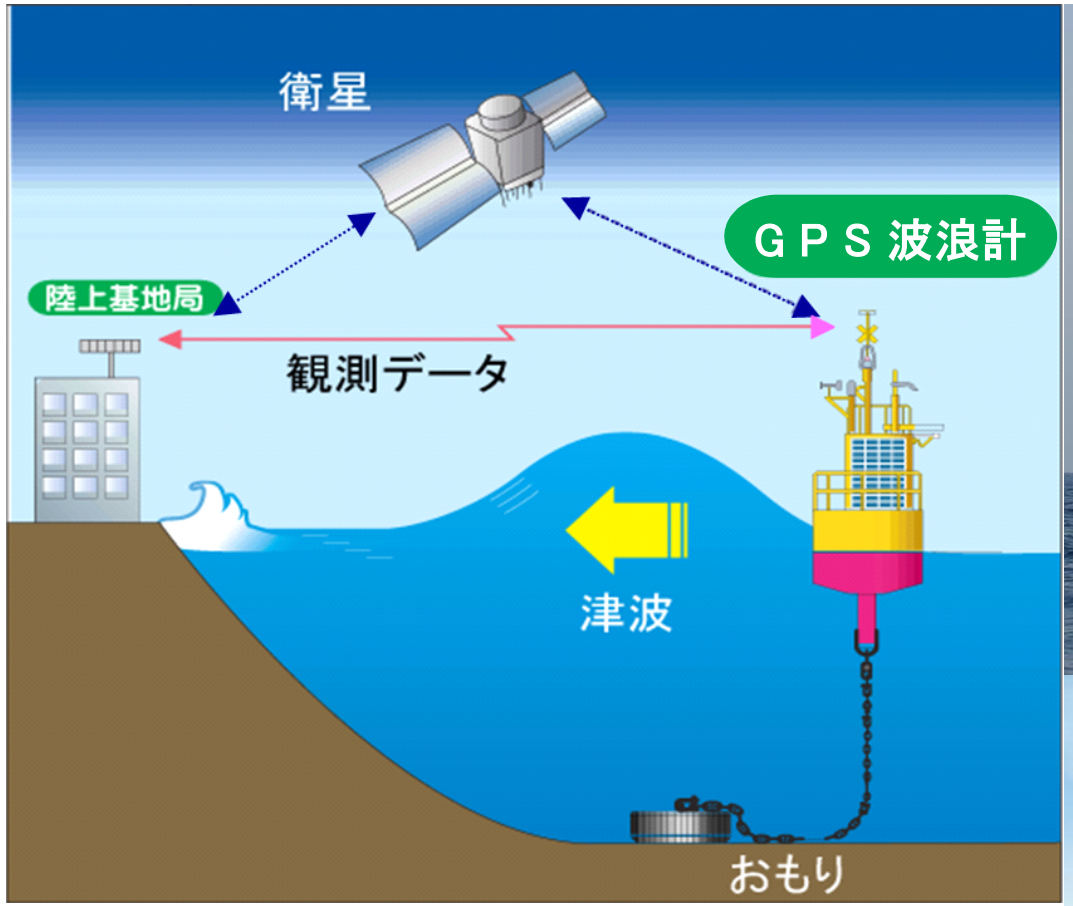


- Many requests in the expressway (Lane recognition)
- Case that can not be handled by the Camera or Lidar
- Generation of the precise dynamic map
- **Maximum Horizontal Error < 1.5 m**

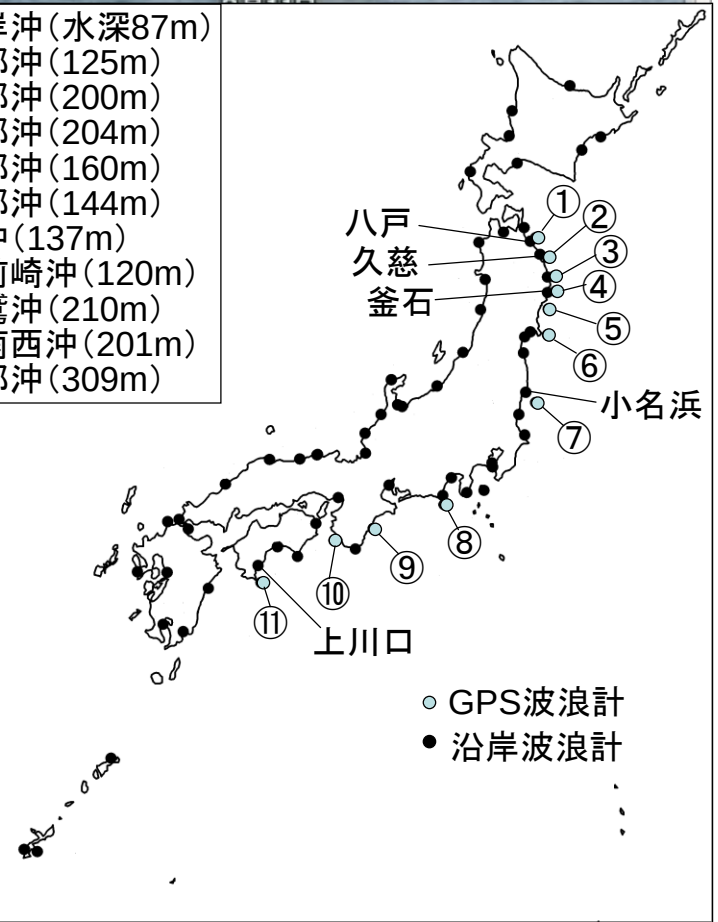
→Except for tunnel ○

→Much more severe condition

Tsunami Detection



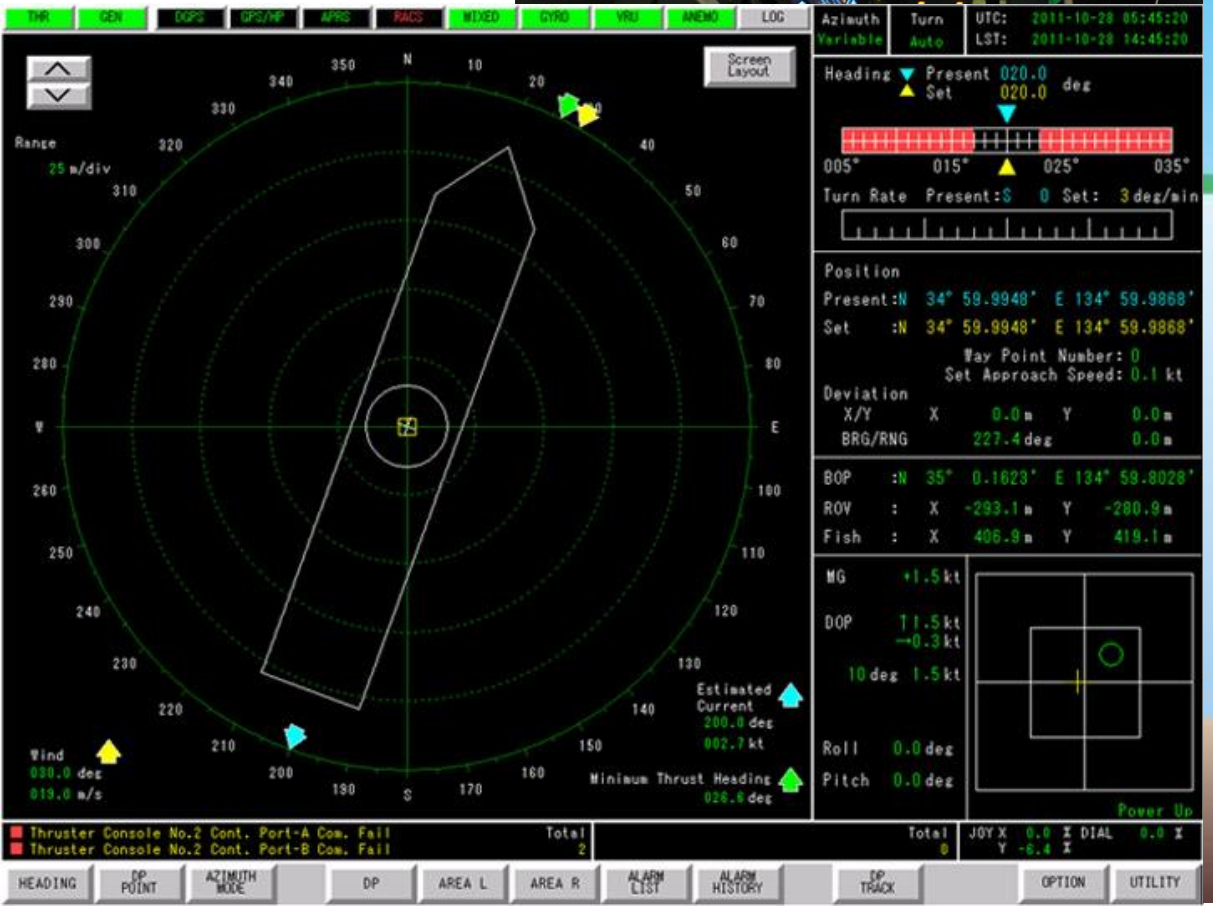
①青森東岸沖(水深87m)
②岩手北部沖(125m)
③岩手中部沖(200m)
④岩手南部沖(204m)
⑤宮城北部沖(160m)
⑥宮城中部沖(144m)
⑦福島県沖(137m)
⑧静岡御前崎沖(120m)
⑨三重尾鷲沖(210m)
⑩和歌山南西沖(201m)
⑪高知西部沖(309m)

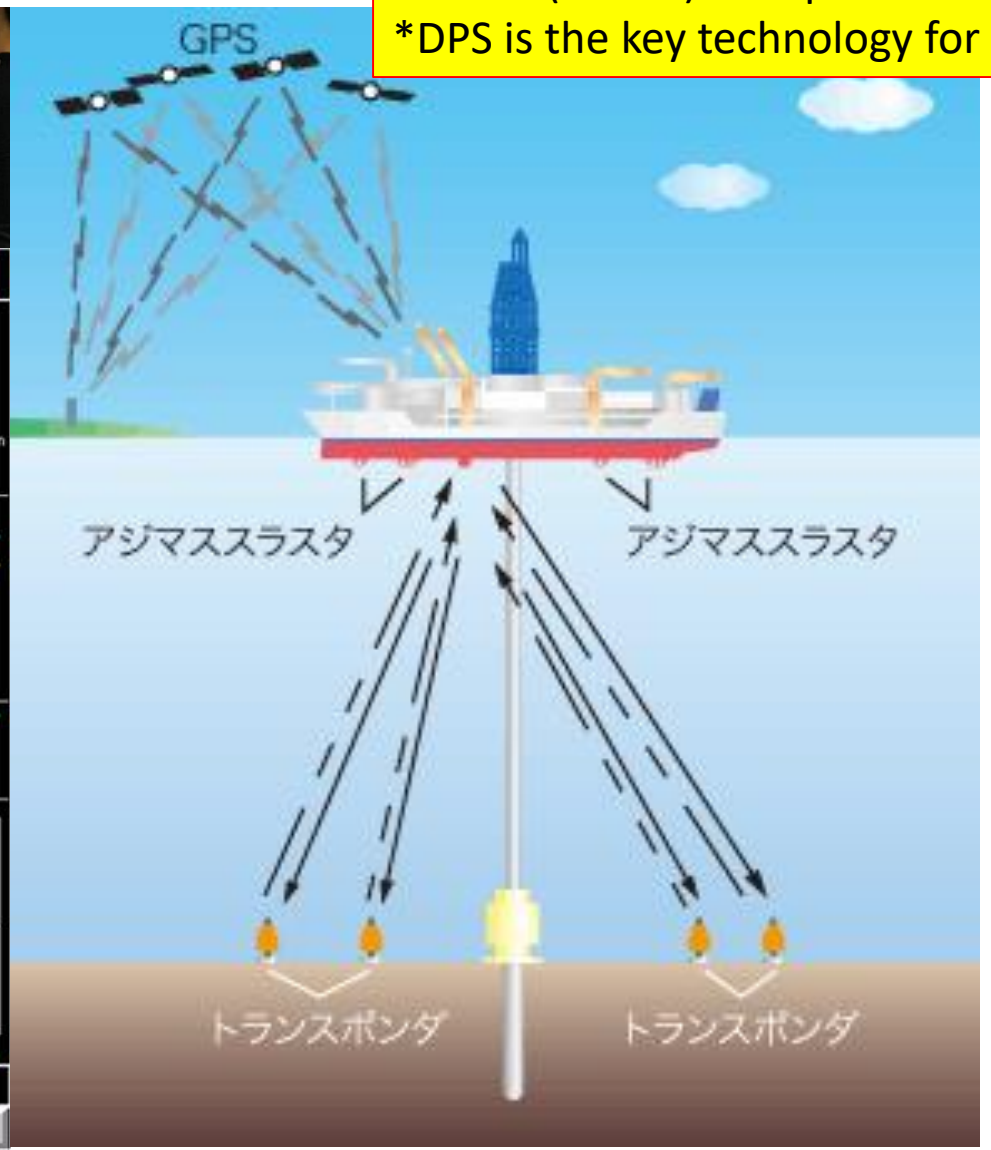


Wide Area RTK / PPP can be used

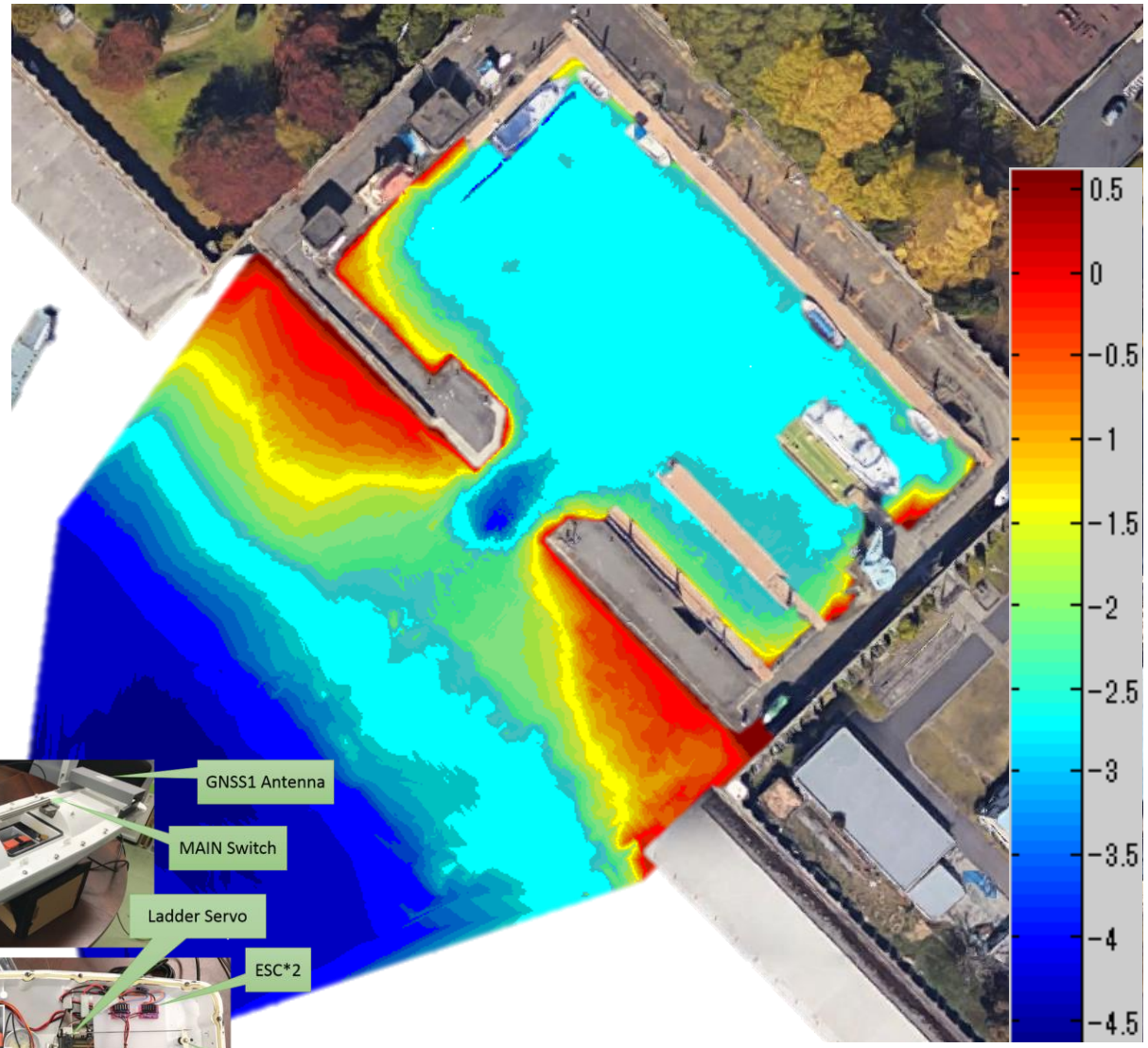
DPS (Dynamic Positioning System)

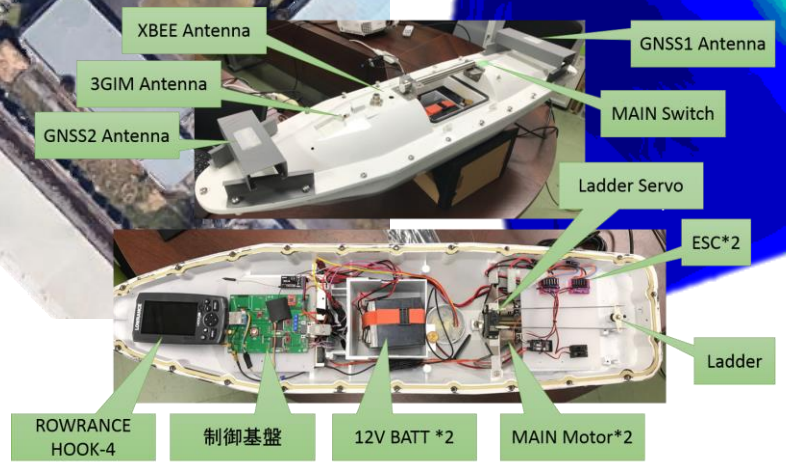
*Wide Area RTK / PPP / DFMC SBAS can be used
*50 cm (2drms) is required.
*DPS is the key technology for autonomous Ship





Measuring the depth in the river/sea





Summary

- High accuracy society has already come.
- We can choose RTK/CLAS/PPP.
- Various applications are assumed in the future.
- Lack of manpower -> some sort of automation
- **Instantaneous centimeter / decimeter level** positioning is definitely attractive.
- **Integrity / reliability** issues will be emerge (spoofing/interference).
- One of the motivation to promote future QZSS (5^{th},6^{th} and 7^{th} and more) is the "**realization of QZSS use for some applications**".