Impact of SLR tracking on QZSS

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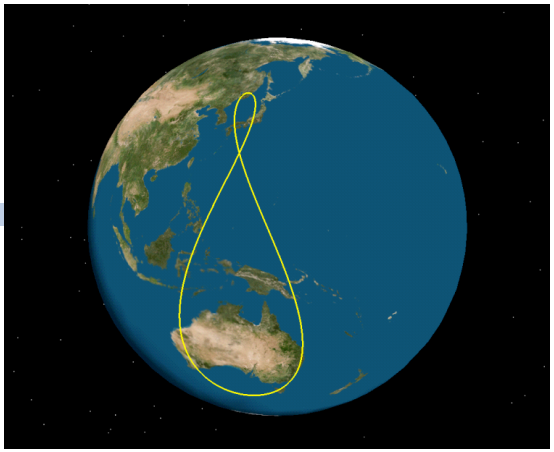
QZS as SLR Target



Semimajor axis
42164 km → Same as GEO

Inclination
43 deg → QZS flies the sky dynamically

→ Slant Range is longer than GEO

Except Luna ranging, QZS is farthest target.

QZS is not stay same position.

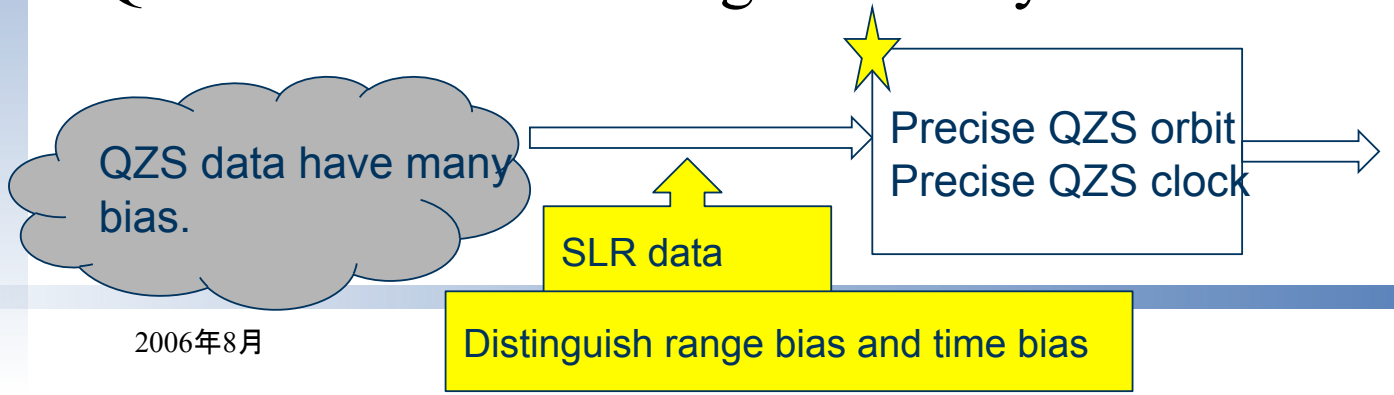
→ QZS is challenging target.

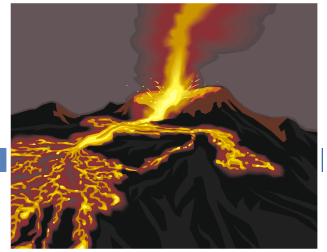
Role of SLR on QZSS operation

In order to contribute to geodesy and earth science, JAXA distributes precise orbit of QZS (QZS final orbit), which is similar to the final orbit of GPS.

In order to calculate QZS final orbit, JAXA needs to determine QZS clock bias and orbit simultaneously.

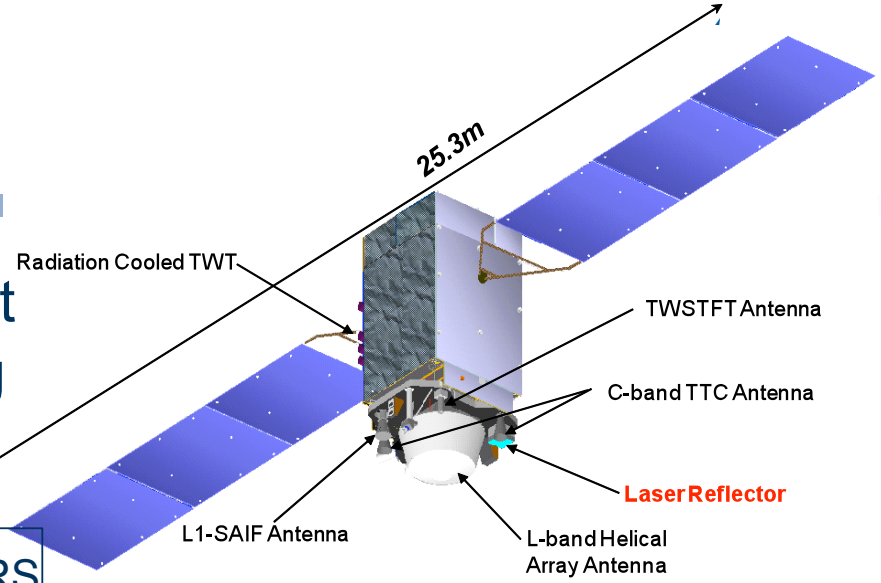
As well known, since SLR data helps to eliminate the error (bias) from observed data, JAXA estimates QZS final orbit with high accuracy.





LRA on QZSS s/c

In order to perform precise orbit determination, QZS mounts big letro reflector array (LRA).



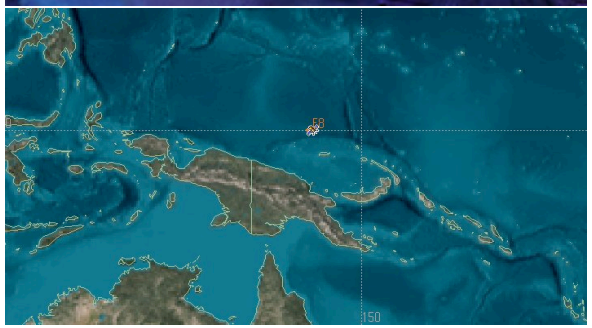
Satellite Configuration on Orbit

JAXA has experiment that, thanks of ILRS support, ETS-8 tracking is successful.

JAXA has experiment that, thanks of ILRS support, ETS-8 tracking is successful.

JAXA/HTSI developed new LRA.
- using heritage during ETS-8 LRA
- but, taking account of effect of QZS orbit

What is ETS-VIII ?

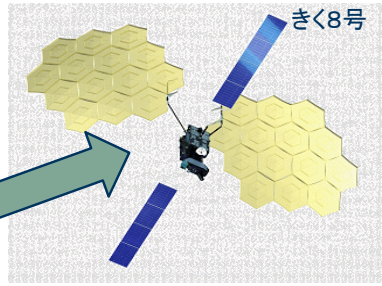


- Engineering Test Satellite
- Launched 2006/12/18
- Geostationary Satellite
- Located 146 deg Longitude

Remarkable characters

- Two Large Deployable Antenna Reflectors and two Solar Array paddles.

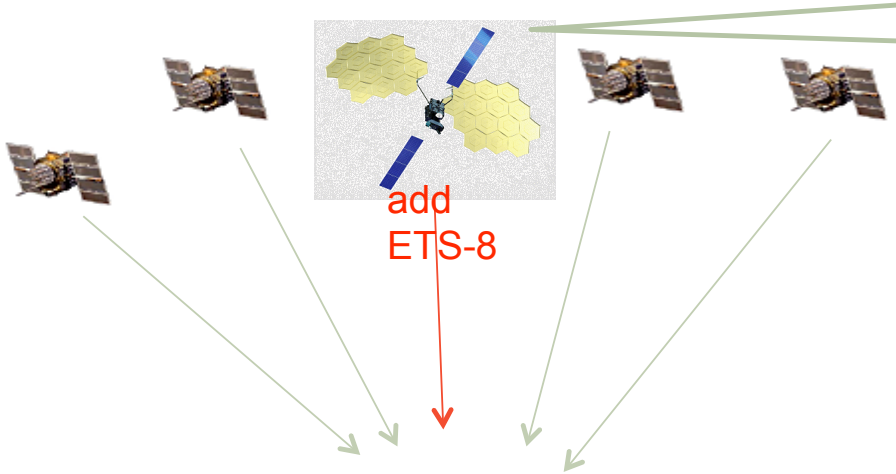
The main purpose of dealing with the increasing demand for digital communications, such as mobile phones and other mobile devices.



50～100 bps(↑)

超小型携帯端末

ETS-8 Experiment



We can estimate Position and clock of ETS-8.

Positioning

Adding ETS-8 to GPS, we performed the positioning.

By adding ETS-8 to GPS, How change point positioning accuracy?

(Ref) LRA on ETS-8

Common characters between ETS-8 and QZS

Items	details
Array	planar type
CCR	Suprasil, Non coating, diameter 1.6 inch
other	made in USA (HTSI)

Difference between ETS-8 LRA and QZS LRA

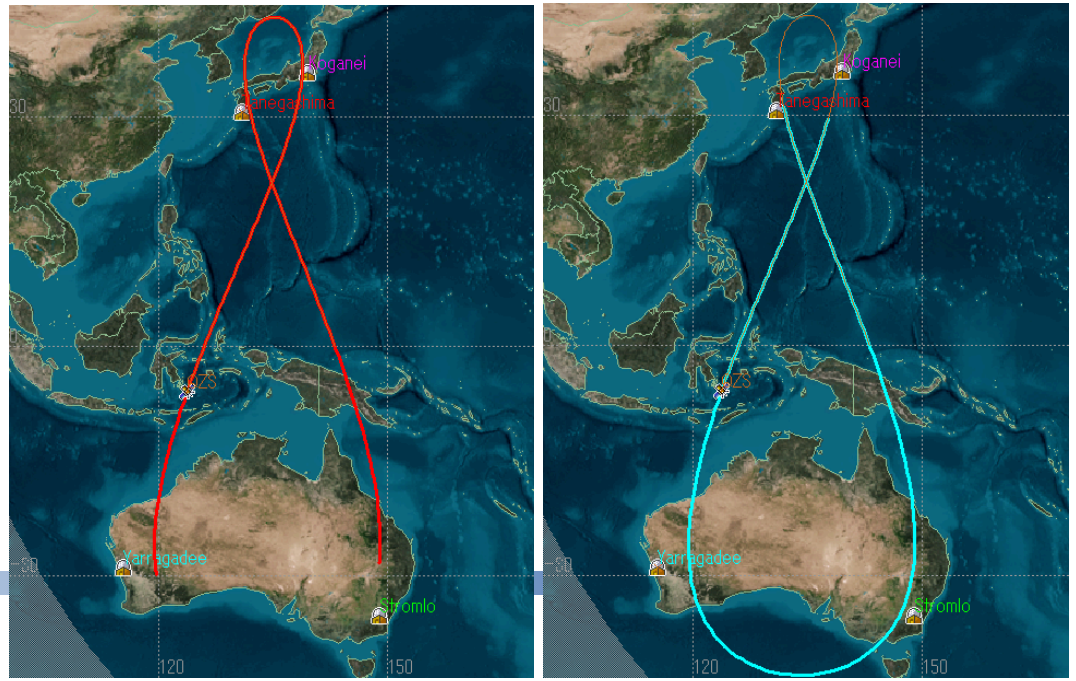
Items	ETS-8	QZS
Array size	250 * 250 * 100 (mm)	400 * 400 * 100 (mm)
Number of CCR	36 (6 row * 6 line)	56 (7row * 8 line)
Dihedral Angle	0.5 arcsec	0.8 arcsec
Optical Cross Section	1×10^{9} m^2	ETS-8 * (56/36)

Link Analysis for QZS LRA

1. SLR Stations

Since QZS orbit was designed for western pacific ocean area, SLR stations that can track QZS are limited.

Moreover, for each SLR stations, there is unobservable time everyday.



Link Analysis based on ETS-8

(1) Summary of ETS-8 Tracking

SLR Station	Return Rate (%)	Note
Tanegashima	5 % to 15 %	10Hz fire, 250mJ laser
Koganei	typically 1%	20Hz fire, 50mJ laser
Yaragadee	1 % to 3 %	5Hz fire, 100mJ laser
Mt. Stromlo	0.1 % to 1 %	60Hz fire, 21mJ laser
Changchun	0.1% to 1 %	20Hz fire, 150mJ laser

(2) Basic Concept for LRA performance

Though range for QZS is farther than one for ETS-8, JAXA expects that QZS LRA has same performance as ETS-8 even though farthest range of QZS.

Link Analysis

(3) Worst case and ,at least, necessary CCR number

SLR	Max QZS Range	Elv Ang	E8 Range	Ratio
Tanegashima	39,146 km	80	37,294 km	1.05
Koganei	38,906 km	75	37,139 km	1.04
Yaragadee	41,872 km	20	37,804 km	1.11
Mt. Staromlo	41,590 km	20	37,229 km	1.12

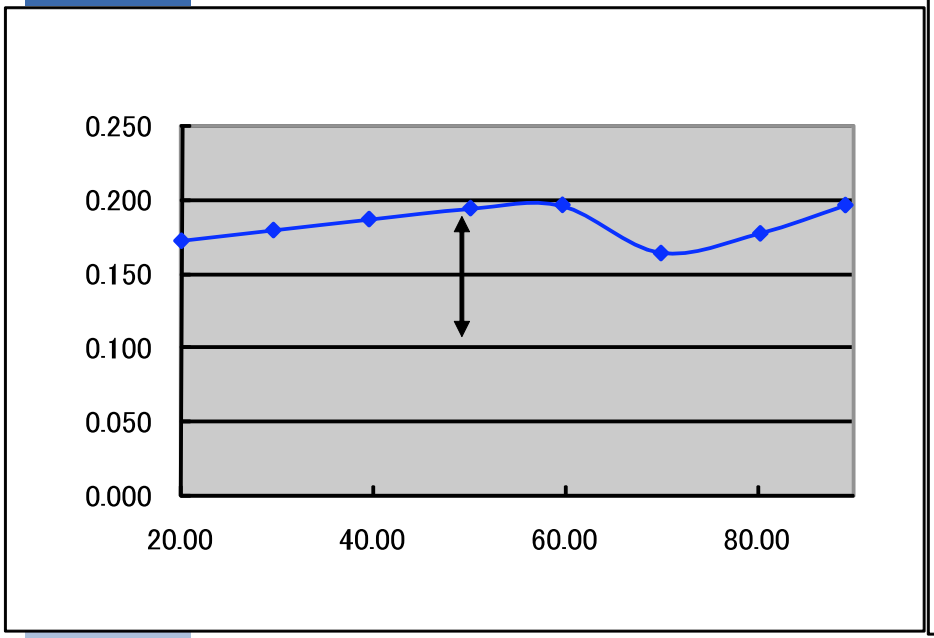
LRA on ETS-8 consists of 36 cubes (6*6 array). JAXA calculated equivalent LR of ETS8 for QZS. At first, I estimated necessary cube number for QZS,

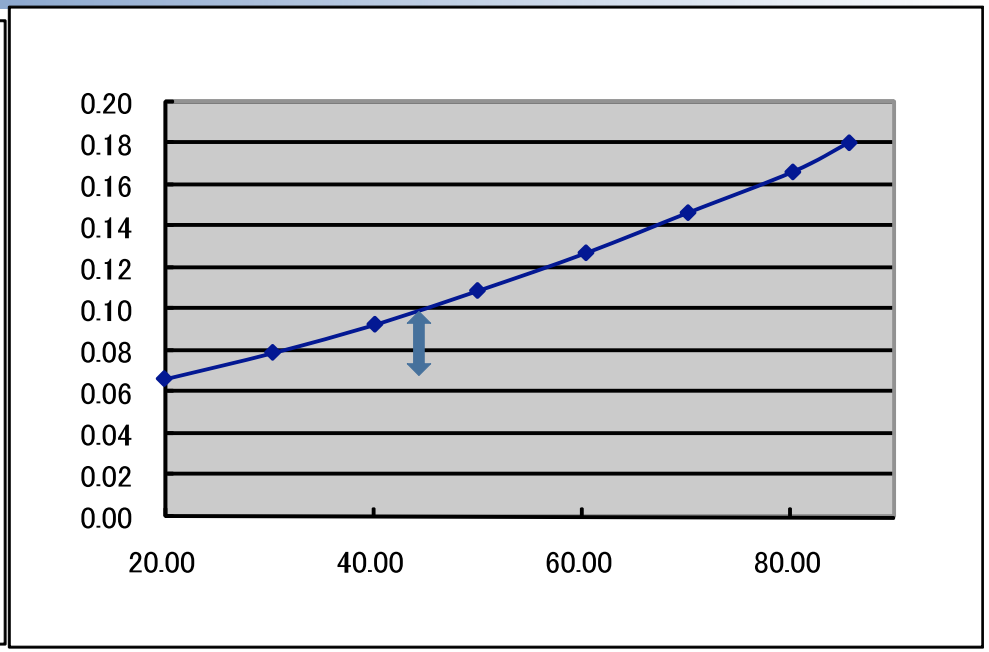
$$N = 36 \times \left(\frac{11}{10}\right)^4 = 52.7$$

JAXA needs, at least 53 CCRs on QZS, to obatain similar return with ETS8.

Note: ETS LRA has 36 CCRs

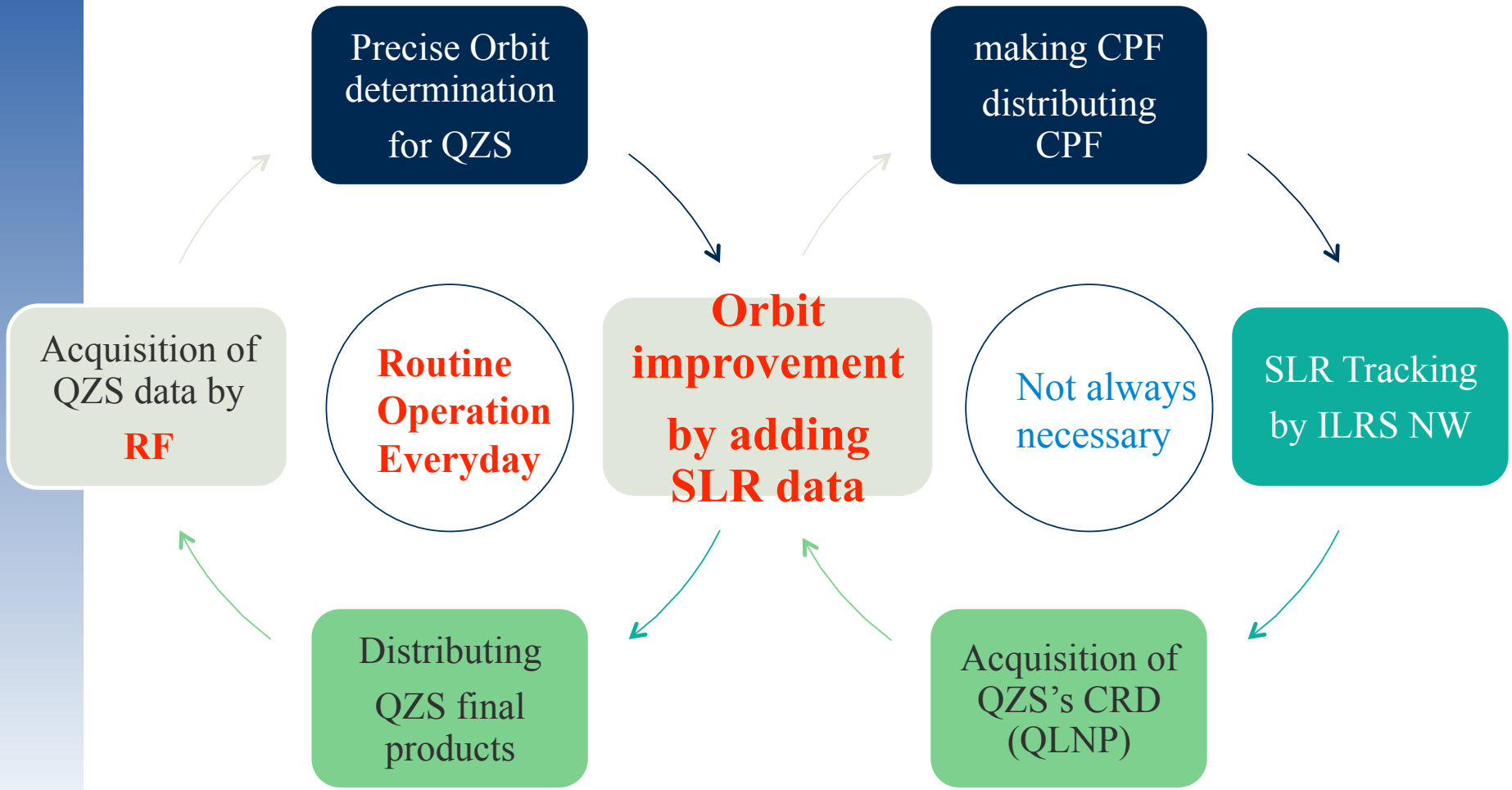
Results of Link Analysis





Apart form decreasing effect by atmosphere absorption, we expect the similar return rate to ETS-8 in spite of longest range (lowest elevation). Even at higher elevation, we expected bigger return rate than ETS-8.

SLR Tracking and QZSS operation



QZSS Tracking Schedule

JAXA hopes 2 stages tracking;

□1st stage (Campaign):

Purpose : confirmation of precise orbit determination, clock estimation, estimation of bias for each monitor station, QZS checkout

Priority : High such as GIOVE-A campaign

Frequency : in-orbit initial phase, checkout phase for satellite performance, ground system performance and every 6 months

Core Time: For example,
0:00-0:15, 4:00-4:15, 8:00-8:15, 12:00-12:15, 16:00-16:15, 20:00-20:15 (UT).

□2nd stage (Nominal Operation):

Purpose : increasing orbit determination accuracy of ordinary operation

Priority : low such as GPS35,36, Glonass, GIOVE-A

Frequency : all day, but we hope core time ;
For Example, 9:00-9:15, 12:00-12:15, 15:00-15:15 (UT)

Success Criteria on QZSS Tracking

□1st stage (Campaign)

As success criteria, the accuracy of orbit determination, accuracy of clock estimation, and bias for each monitor stations during 1st stage should be preformed only by SLR data.
Precise orbit determination have to be performed only by SLR data for long arc, such as 1 day arc.

□2nd stage (Nominal Operation)

In order to distribute reliable QZS final orbit/clock, it is better to add SLR data on QZS navigation data.
However, since accuracy validation is performed at 1st stage tracking, it is not always necessary to obtain SLR tracking data from ILRS network. But, at least, JAXA Tanegashima SLR station always tracks QZSS.As success criteria, SLR data acquisition is frequently done.

Requirement for ILRS Network

JAXA hopes to get support from ILRS western pacific ocean network tracking.

At 1st stage (check out phase)

Enough SLR data is needed to perform precise orbit determination only by SLR data.

Method ILRS campaign

Core Time Tracking : 0:00-0:15, 4:00-4:15, 8:00-8:15, 12:00-12:15, 16:00-16:15, 20:00-20:15 (UT).

Candidate SLR stations : ILRS western pacific ocean

At 2nd stage (nominal operation)

In order to improve accuracy of final QZS orbit/clock, SLR data is needed. However, it is not always necessary to get SLR data.

Method : as ILRS target during nominal operation

Core Time Tracking : For Example, 9:00-9:15, 12:00-12:15, 15:00-15:15 (UT)

Candidate SLR stations : ILRS western pacific ocean.

Point of Contact

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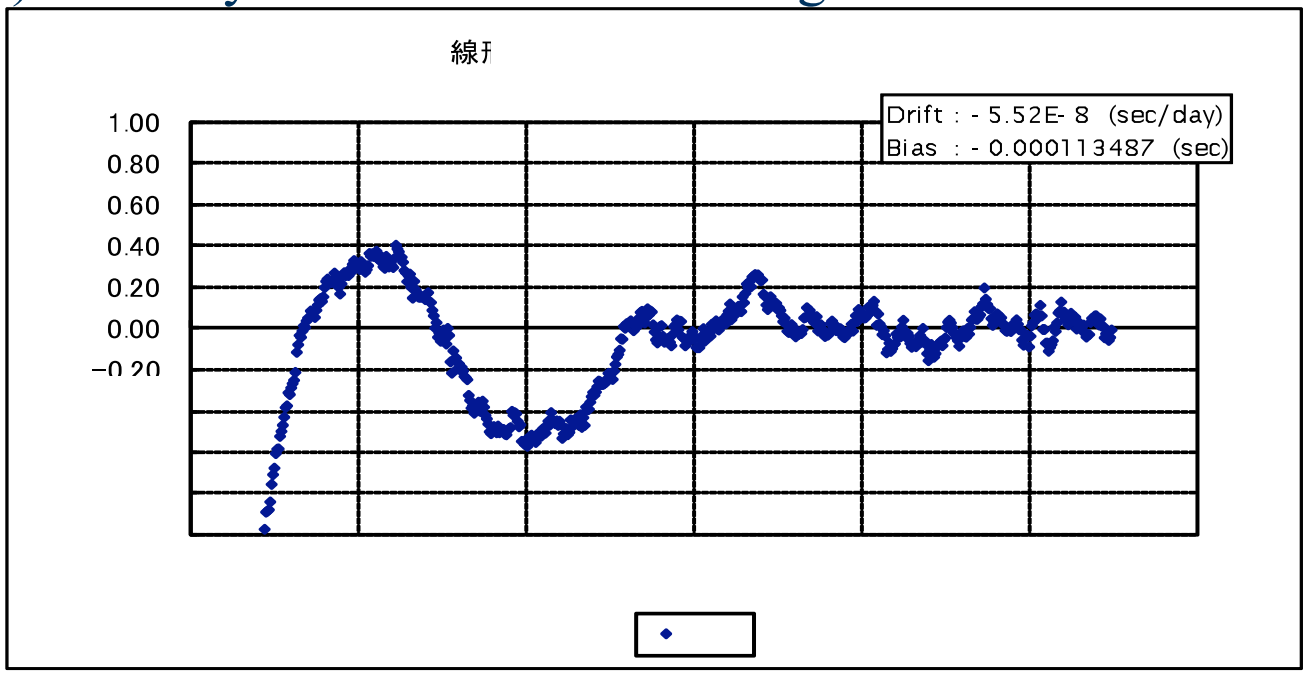
	Engineer	Motohisa Kishimoto	kishimoto.motohisa@jaxa.jp


Thank you for your attentions

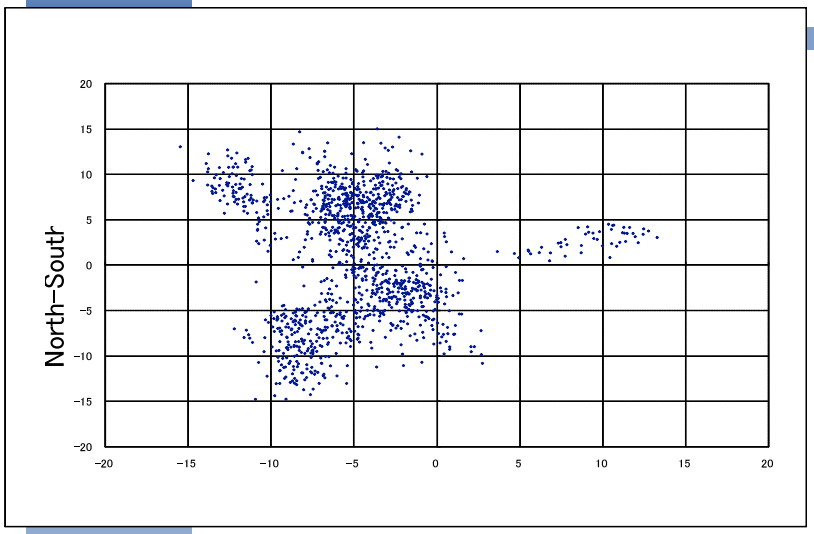
Results of ETS8 Clock Synchronization

(2) Clock synchronization between ground and ETS-8



After converging the calculation, ETS-8 clock is synchronized within +/- 20 n sec.

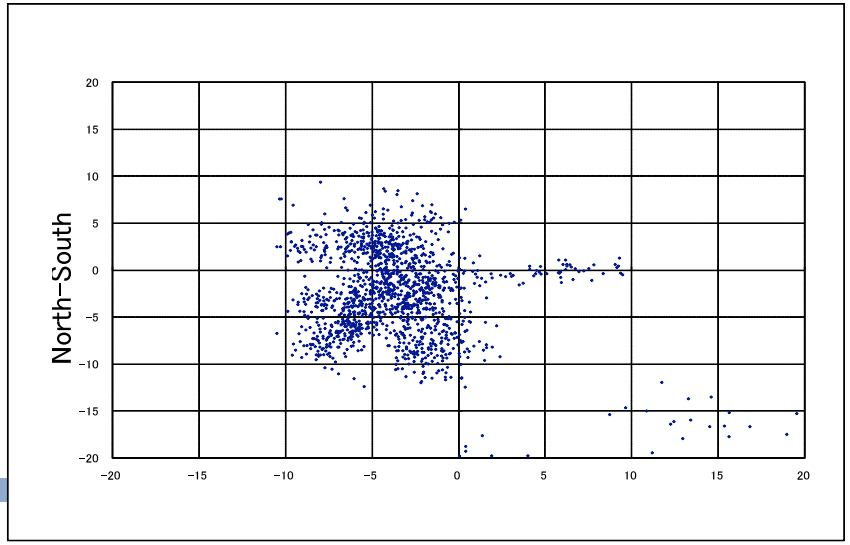
Results of Positioning



As reference state, we performed the positioning only GPS.

Adding ETS-8 to GPS, accuracy of the positioning is improved.

	Only GPS	GPS+ETS8
East-West	4.537 (m)	3.929 (m)
North-South	13.775 (m)	8.510 (m)
Up-Down	17.741 (m)	15.601 (m)



Conclusion of ETS-8 Exp.

Adding ETS-8 into GPS satellite as GPS family, the chance of positioning at middle or high elevation angle could increase.

Since the Dilution of Precision (DOP) is improved by adding ETS-VIII, the accuracy of the point positioning was improved. Since ETS-VIII located at 146 deg East longitude, navigation signal from ETS-VIII comes from almost south direction. This navigation signal makes effects to improve accuracy of positioning, especially, North-South direction.

Weak Point of GEO GNSS

Since gestational satellite does not move the sky dynamically, it takes long time to solve ambiguity.

= It takes long time to obtain accurate orbital position/ clock synchronization.

If once get accurate orbital position/clock synchronization, gestational satellite is useful as

GNSS satellite. ← same as GPS

Please keep mind that geostationary satellite is useful as GNSS family, however, there are above restrictions.

Future Vision – toward QZS --

During our ETS-8 experiment, we found that

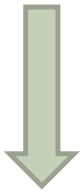
(Merit)

- Always visible → Increase point positioning accuracy

(Weak Point)

- take long time to solve ambiguity

→ it is impossible to find position quickly after orbit control.



inherit merit, correct weak point

QZSS is developing now. QZSS will compensate / interpolate GPS. By combining QZSS to GPS, we will have good GNSS environment, whenever, wherever,,,,