Status report of the QZSS technical verification results

The 6th International Committee on GNSS@Tokyo

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Japan Aerospace Exploration Agency

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Current Status

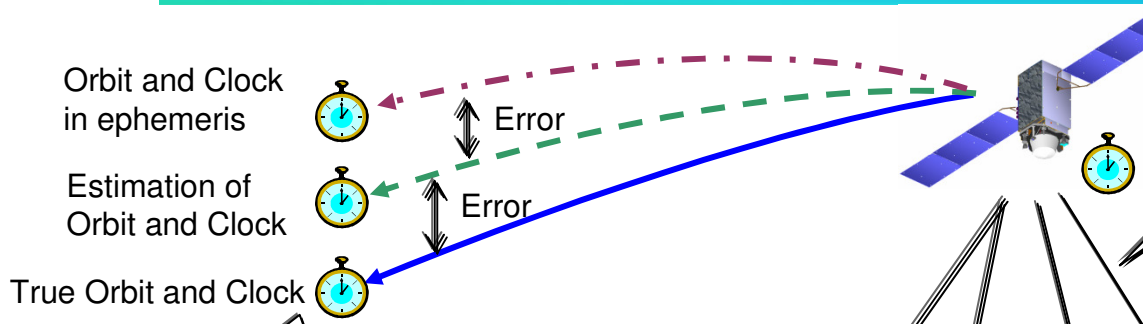
- ***The first satellite,"MICHIBIKI", was launched on 11 September, 2010.***
- ***Following to 3 months On-Orbit Checkout phase, the technical verifications and application demonstrations have been conducted since December 2010.***
- ***The accuracy of broadcasting ephemeris and clock parameters, i.e. SIS-URE met its specification value by June 2011.***
- ***After confirmation of the stability to provide specified performance in IS-QZSS, L1 C/A and L2C signals were set healthy on 22 June and L5 and L1C signals were set healthy on 14 July, 2011.***

Technical Verification Plan of JAXA (1/2)

Verification Item		Contents
A) Signal		- Quality of MICHIBIKI NAV signals including receiver - Compatibility of other RNSS
B) System Operation	Satellite	Availability of system (Minimize the orbit control maneuver and attitude maintenance maneuver)
	Ground	Operation improvement of MCS and ground tracking & control system
C) Integrity		- Notification time of integrity information to users - Error or anomaly detection algorithm
D) Accuracy	SIS-URE	- SIS-URE accuracy Improvement of MICHIBIKI - Estimate of ionospheric delay
	NAV-message	- User positioning accuracy improvement by GPS enhancement signals and LEX signals

Technical Verification Plan of JAXA (2/2)

Quasi-Zenith Satellite System Quasi-Zenith Satellite System Quasi-Zenith Satellite System



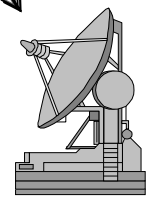
A) Signal

Long Term Evaluation of satellite clock generated by TKS (Time Keeping System)

D) Accuracy

MICHIBIKI SIS-URE Improvement (Parameter Tuning, Laser Ranging , etc.)

Notification to users



EIRP measurement using Large antenna （L-ANT pattern and compatibility）

C) Integrity

- Sooner notification time
- Algorithm verification

Detection of positioning performance degradation or anomaly@MCS

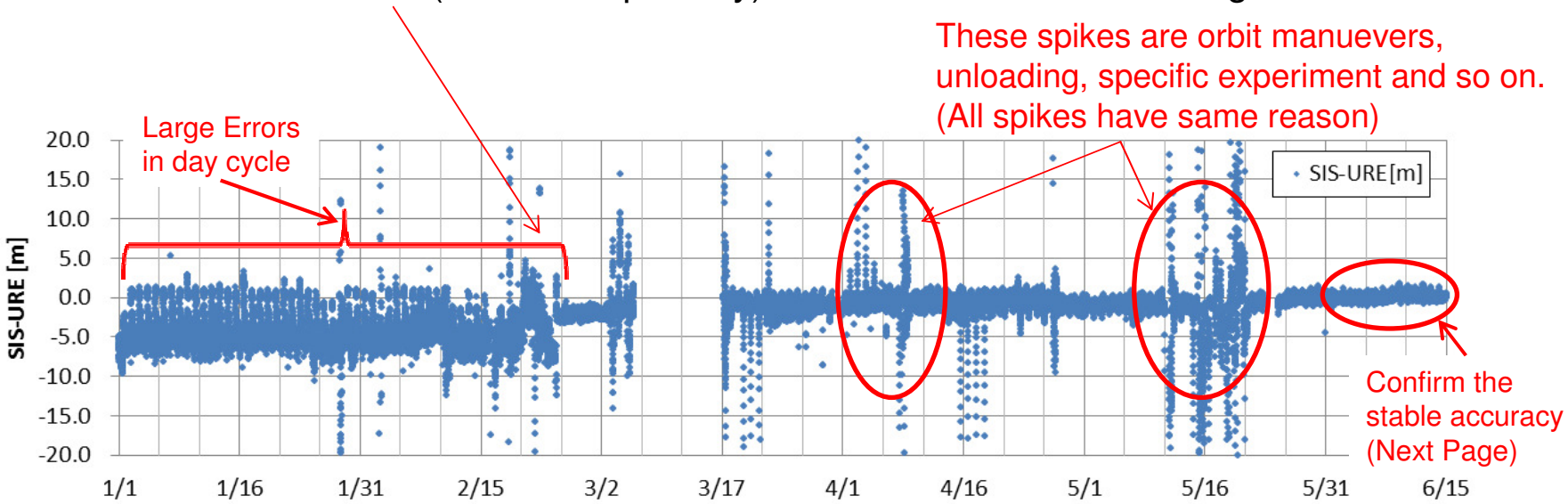
B) System Operation

Availability Improvement (orbit control maneuver , attitude maintenance maneuver and ground operation)

Accuracy Improvement Process

SIS-URE (Signal-in-Space User Range Error) is the most important metric showing the accuracy. The accuracy improvement process is shown as follows:

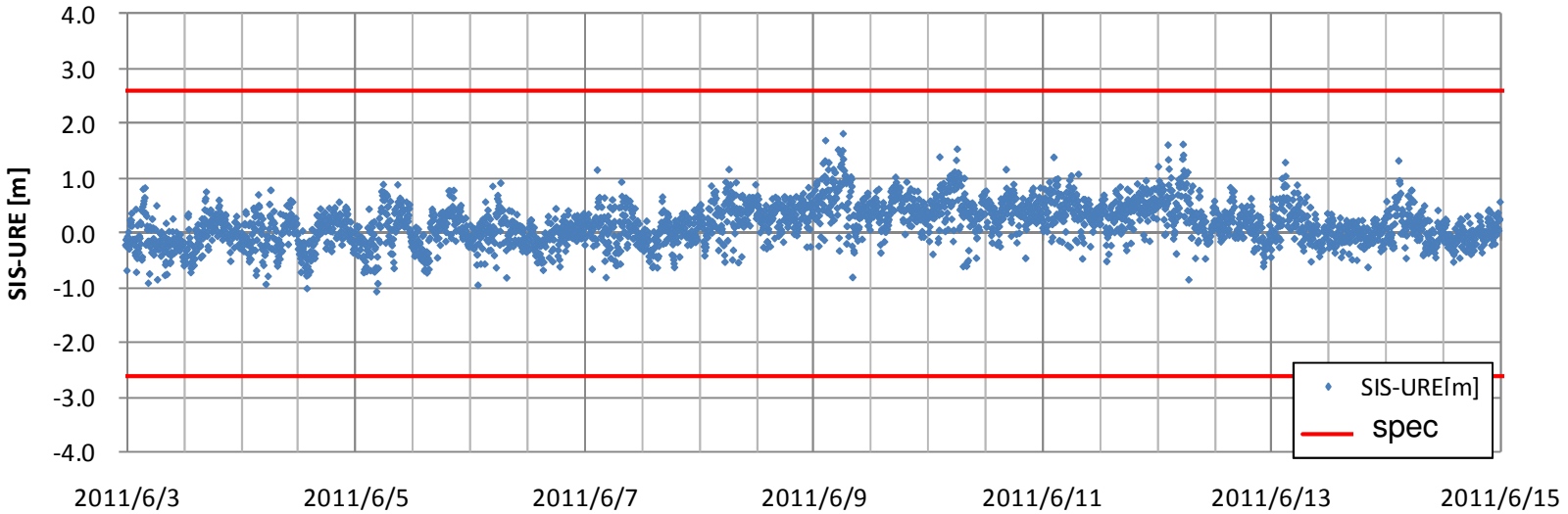
- System dynamics model (i.e., solar radiation pressure model) improvement
- Screening the bad observation data from monitoring stations
- Various parameter tuning and identification (empirical acceleration, bias between the receivers and so on)
- Identification of TGD (Time Group Delay) between the L1 and L2C signals



MICHIBIKI SIS-URE Improvement

Accuracy (SIS-URE)

SIS-URE in the IS-QZSS (Interface Specification of QZSS) is +/- 2.6m (95%).
We confirmed that the stability of MICHIBIKI SIS-URE using 12 days duration, and the time percentage in spec is 100%.

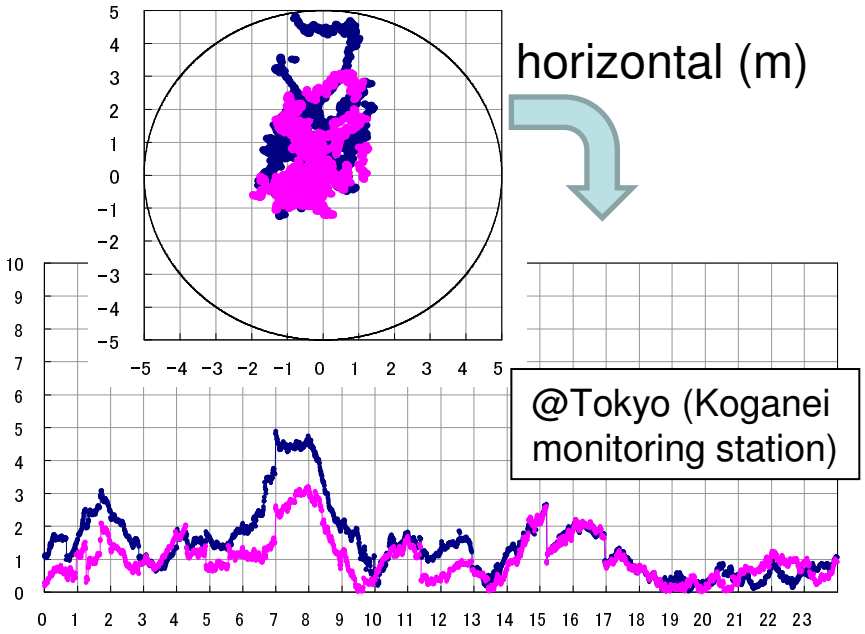


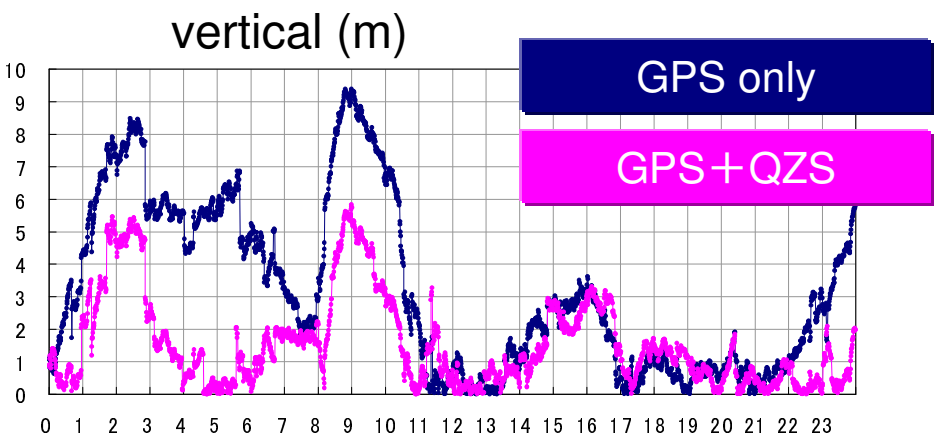
MICHIBIKI SIS-URE (12 days duration)

After MICHIBIKI performance including accuracy, integrity and availability met the IS-QZSS, the L1-C/A and L2C signals were set healthy from June 22th.
L5 and L1C signals were also set healthy from July 14h.

Accuracy (Combination of GPS + QZS)

We confirmed the accuracy of the combination of GPS+QZS improves because of DOP and good ionospheric correction parameters from MICHIBIKI.





Evaluation conditions

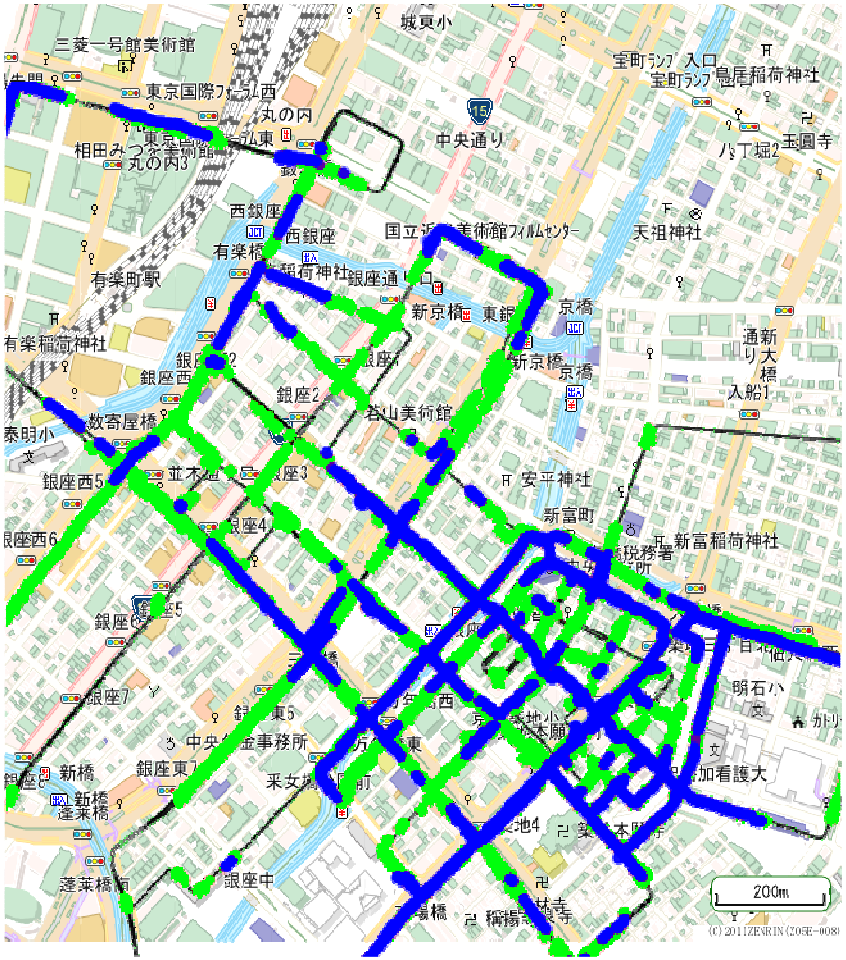
- point: Tokyo (Koganei Monitoring Station)
- date: 2011/06/03 00:00:00-23:59:30(GPST)
- mask elevation angle: 10 degrees
- ionospheric correction
  GPS only：using the parameters from GPS
  GPS+QZS： using the parameters from QZS

Improvement

Positioning accuracy (m)		GPS only	GPS+QZS
Horizontal	Average	1.451	1.027
	RMS	1.773	1.232
	Max	4.885	3.209
Vertical	Average	3.204	1.540
	RMS	4.122	2.080
	Max	9.388	5.828

One Example of Availability Improvement at Ginza in Tokyo (Feb. 19, 2011)

Quasi-Zenith Satellite System Quasi-Zenith Satellite System Quasi-Zenith Satellite System

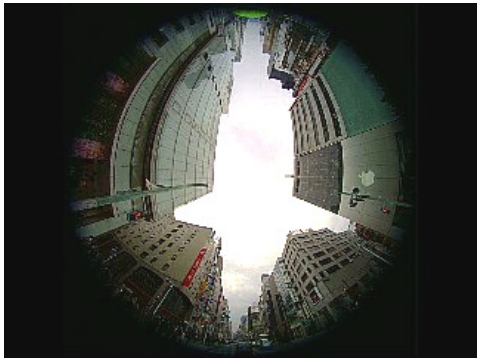


Date of Observation: 2011/2/19
250 minutes driving observation data during 6:00-12:30 obtained under JAXA-Melco joint research experiment

Single Frequency DGPS positioning Availability

GPS: 39.5%

GPS+QZSS: 69.1%



- Reference trajectry (measured by MMS)
- Positioning result for GPS standalone use
- Positioning result for GPS+QZSS combining use

Multi-points & Various-usages Observation Campaign

- *Multi-points and various-usages observation campaign*
  - ✓ *Has being conducted in Japan since February 2011.*
  - ✓ *Is aiming to evaluate the improvement of GPS performance by adding QZSS with statistical manner.*
    - *Different environment*
      - *urban canyon, forest, mountainous area*
    - *Different usage*
      - *car, pedestrian, and construction machine*
  - ✓ *45 QZSS/GNSS receivers and 270 QZSS/GPS loggers are used.*
  - ✓ *Fixed point observation and moving observation.*
  - ✓ *Universities, companies and research institutes are involved.*
  - ✓ *Domestic campaign will be continued by the end of March 2012, then observation campaign is to be extend to regional activity in Asia Oceania region.*

Multi-points & Various-usages Observation Campaign

- Availability inprovement depending on circumstance around Rx.

Time rate when PDOP is 6 or less during Michibiki is staying at higher elevation angle more than 60 degrees is evaluated for different open sky conditions.

Open sky ratio (%)	G (%)	G+Q (%)	N
75-100	99.7	99.7	34
50-75	93.7	95.2	7
25-50	45.9	53.5	15
0-25	19.3	26.9	2

G: PDOP availability for GPS
G+Q: PDOP availability for GPS+QZSS
N: Number of data set

11.9%

28.4%

60.5%

92.8%

Next Step

- *Longterm evaluation on system performance*
- *Statistical assessment for large population of data, observed in different circumstances.*
- *Improvement of offline Precise Orbit Determination (POD) accuracy*
  - ✓ *Continuous effort for optimizing models in POD software.*
- *Proto-type development for future extension of QZSS*
  - ✓ *POD for Multi-GNSS*
  - ✓ *Real-time Precise Point Positioning (PPP) using LEX*
    - *Further improvement of orbit and clock estimation accuracy*
    - *LEX message optimization for multi-GNSS PPP*
- *Advanced application demonstration for multi-GNSS usage*
  - ✓ *Multi-GNSS demonstration campaign in Asia Oceania*

Summary

- *Technical Verification and Application Demonstration have been conducted since middle of December, 2010.*
- *Technical verification results show the improvement of GPS + QZSS performance as expected.*
- *Various parameter tuning for POD (Precise Orbit Determination) has been carried out, the accuracy of broadcasting orbit and clock parameters met specifications defined in the IS-QZSS and all GPS interoperable signals have been set healthy.*
- *Long term, statistic evaluation of the system performance and improvement of POD for precise positioning like PPP will be carried out continuously.*

Our Planet from QZS-1 'MICHIBIKI'

Thank you for your attention

http://qz-vision.jaxa.jp/