Orchestrating a brighter world

NEC

Role of SLR on QZSS operation

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Outline

1. Role of SLR on QZSS Operation
2. Introduction to QZSS
3. SLR related requirements for QZSS
4. QZSS as a challenging target for SLR
5. Example of SLR data from QZS-1
6. LRA for QZS-2, 3 and 4

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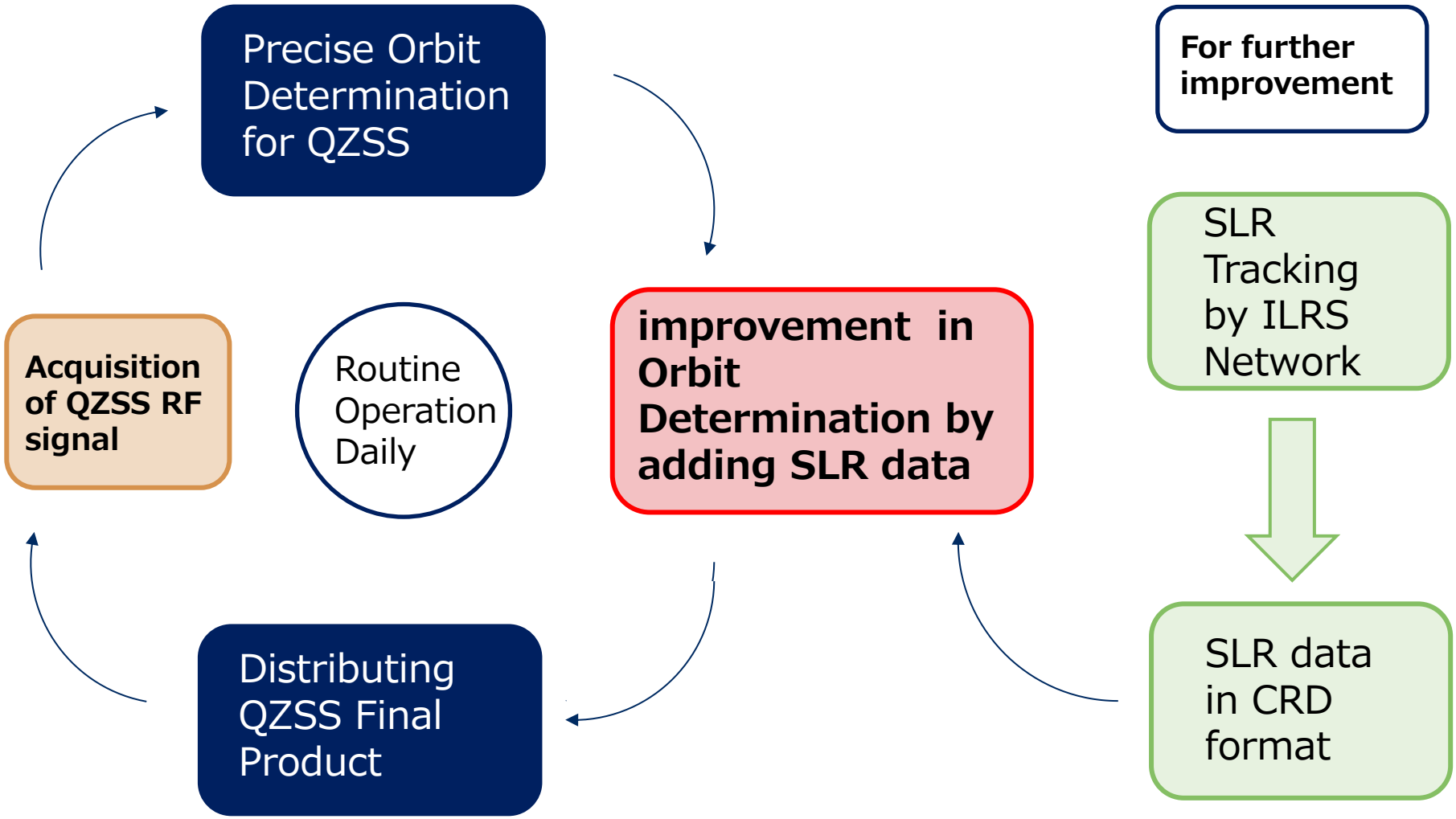
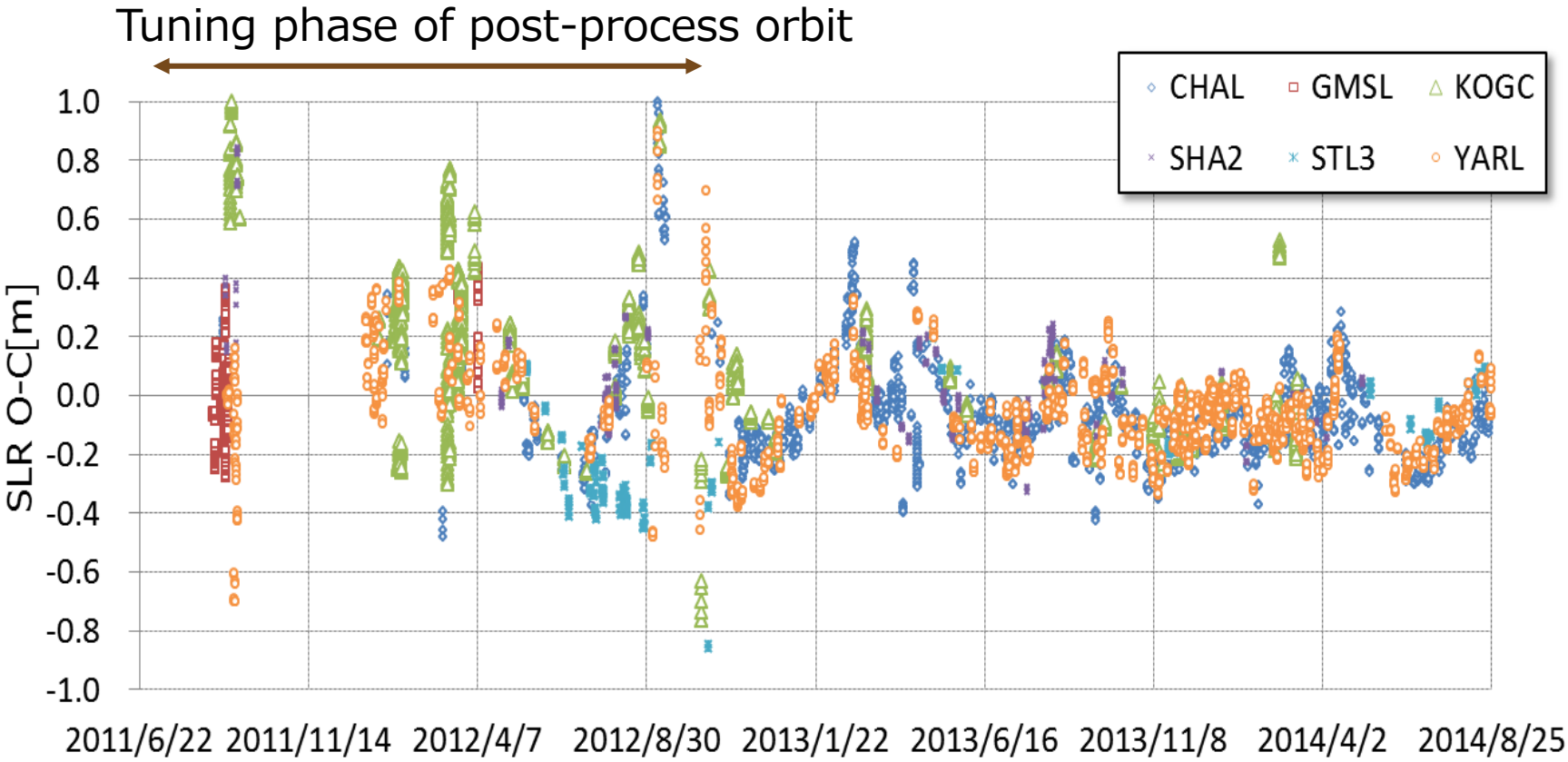
GNSS Session A Questions (from ILRS workshop website)

- Who is analyzing the GNSS SLR data?
  - TBD (QSS(QZS System Service Inc.) and/or NEC)
- What products are being derived? → Precise QZSS Orbit, Precise QZSS Clock
- Is the ILRS satisfying their present requirements? Data volume? Data Accuracy? Data coverage? What are the short falls?
  - See Slides 6 and 19.
- What is the projection for future requirements? Timeframe?
  - Support for 4-satellite constellation starting April, 2018
  - Support for 7-satellite constellation in future (2023 and after)
- What do we see from SLR-GNSS co-location?
  - Very Important for QZSS: In QZS-1, SLR data used as **reference** for radial direction of orbit determination.
- Is SLR having an impact on GNSS products?
  - YES!

Role of SLR on QZSS operation



Accuracy Evaluation of the post-processed precise orbit by SLR data



DATA provided by JAXA

- Accuracy evaluation using SLR data has helped modeling and parameter tuning for QZS-1 Orbit Determination.
- Japan appreciates ILRS' laser ranging activities and **need continuous support** for future QZSS mission.

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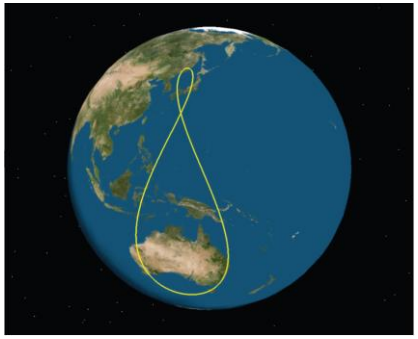
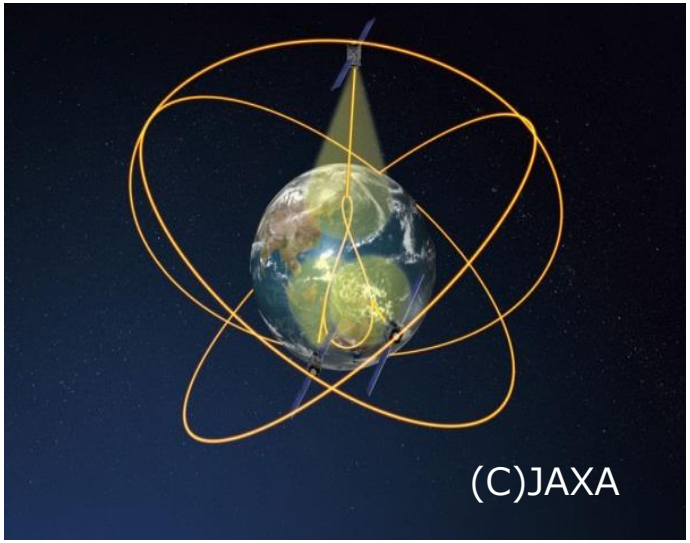
Introduction to QZSS

Quasi-Zenith Satellite System (QZSS)

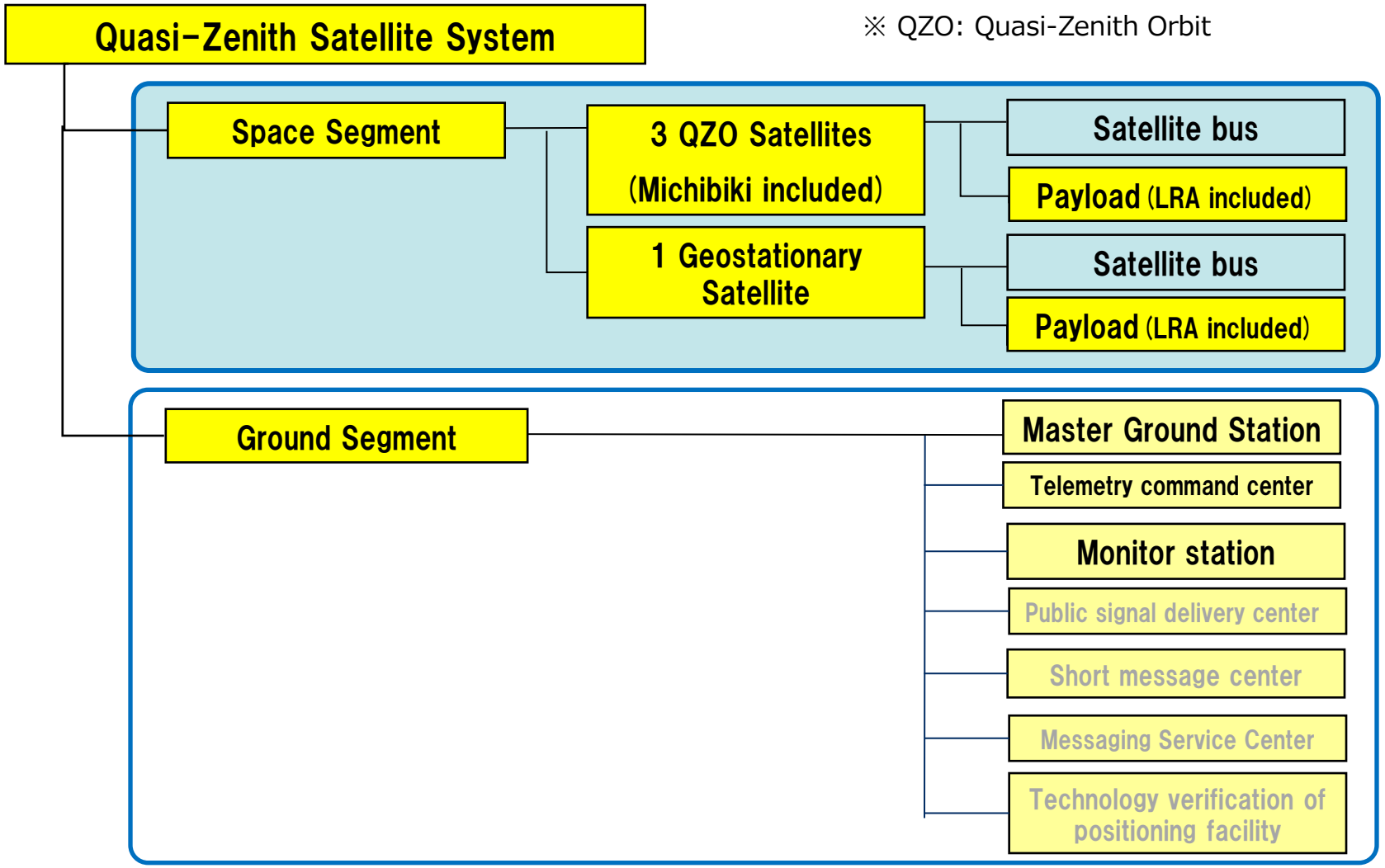
- Regional Satellite Positioning System
- Service Area: Asia-Pacific region
- 1st satellite “MICHIBIKI” launched on 9/11/2010



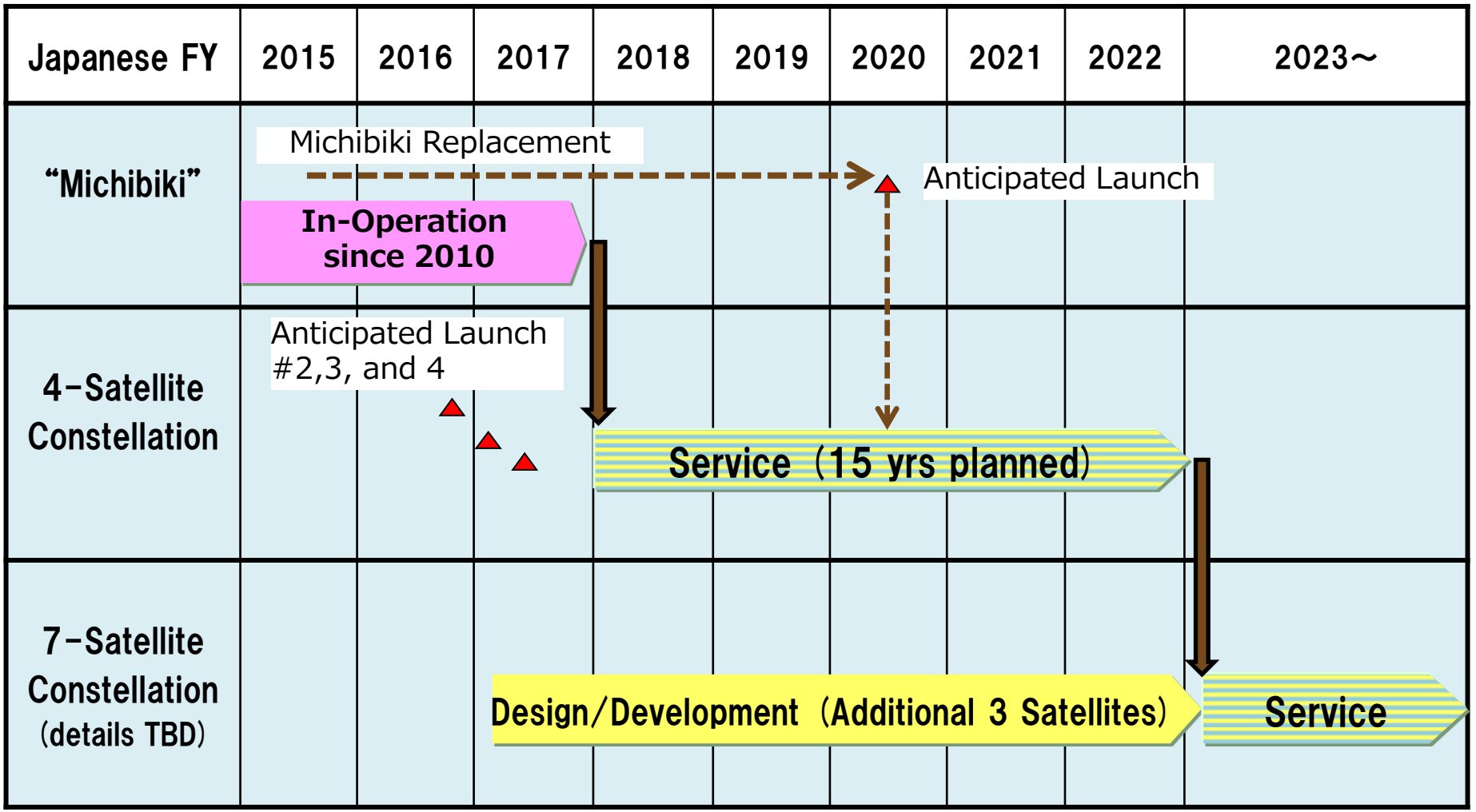


- 3 more satellites under development for 4-satellite constellation
  - QZS-2 and QZS-4: Quasi-Zenith Orbit (inclined geo-synchronous orbit)
  - QZS-3: Geo-stationary orbit
- 7-satellite constellation officially decided by the Government of Japan

System Configuration



Deployment Schedule



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SLR related requirements for QZSS

- Anticipated Launch Date: one in 2016; two in 2017
- Expected Mission Duration: 15+ years
- Orbital Accuracy Required: ***TBD***
- Anticipated Orbital Parameters: See below

QZS-2 and 4	
Orbit type	Inclined Geo-synchronous
Semi-Major Axis	a=42164km
Eccentricity	e=0.075+/-0.015
Inclination	40 degrees (nominal)
Frequency of Orbital Maneuvers	Twice a year (based on "Michibiki" operation)
Mission Timeline	2-3 months of IOT (Initial Orbit Test) followed by nominal operation.

QZS-3	
Orbit type	Geo-synchronous
Position	127E
Inclination	I< 0.1 degrees
Eccentricity	e > 0.00001
Frequency of Orbital Maneuvers	Every 23 days
Mission Timeline	Same as QZS-2 and 4

SLR/LRA Related Requirements

1. Requirements for on-board LRA

- ✓ LRA shall be prism-array type.
- ✓ Wavelength of applied light shall be at 532nm.
- ✓ Field of View shall be more than 10 degrees.
- ✓ Reflection Coefficient (after 15 years on orbit) shall be more than 0.75.

2. SLR tracking requirement

- ✓ Three SLR stations shall be for **primary use**: (NOT an exclusive list. More data, the better!)

SLR station		Nominal Fire Rate
Tanegashima	GUTS	10 Hz
Yarragadee	Moblas-5	1 Hz
Mt. Stromlo	STR3	60 Hz

- Koganei (KOGC)
- Changchun (CHAL)
- Shanghai (SHA2)
- Beijing (BEIL)

3. Operations Requirements

- Normal Point Time Span: 300sec
- ***Expected number of photo-electron detected in NP shall be >15*** (with mean waiting time of 60 seconds; with clear sky condition; during night; with target SLR stations listed above; for satellite elevation more than 20 degrees.)

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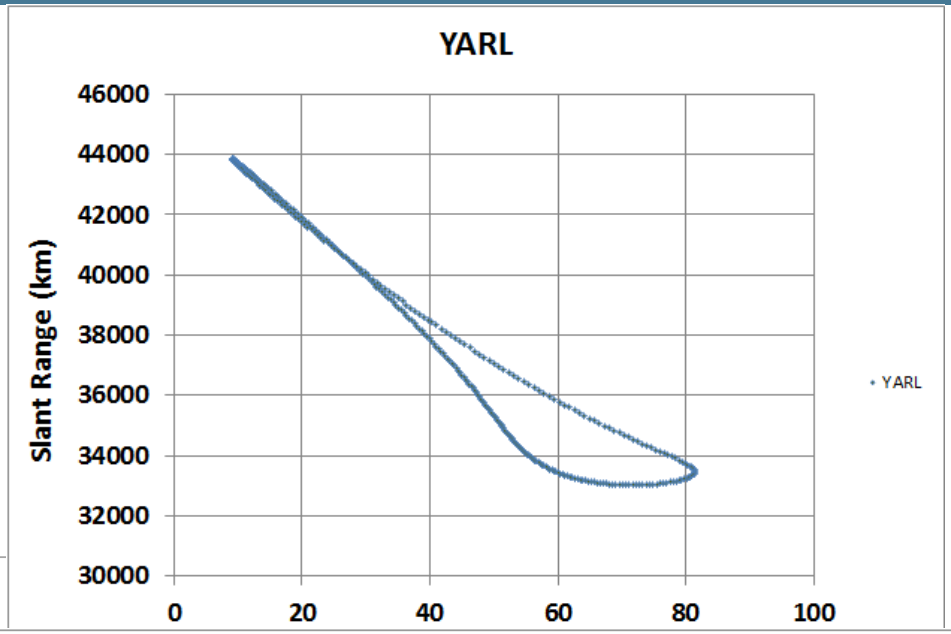
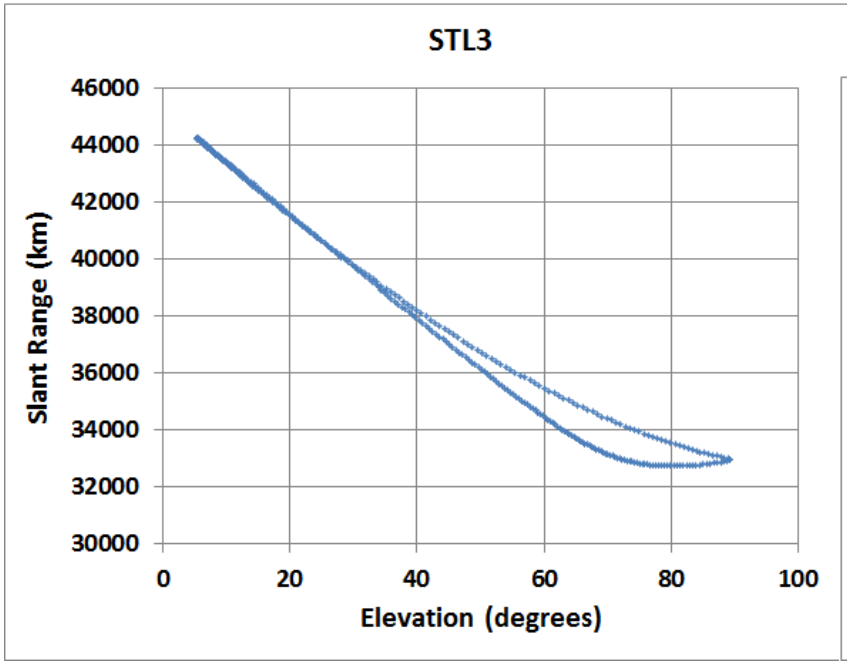
QZSS as SLR Target is challenging

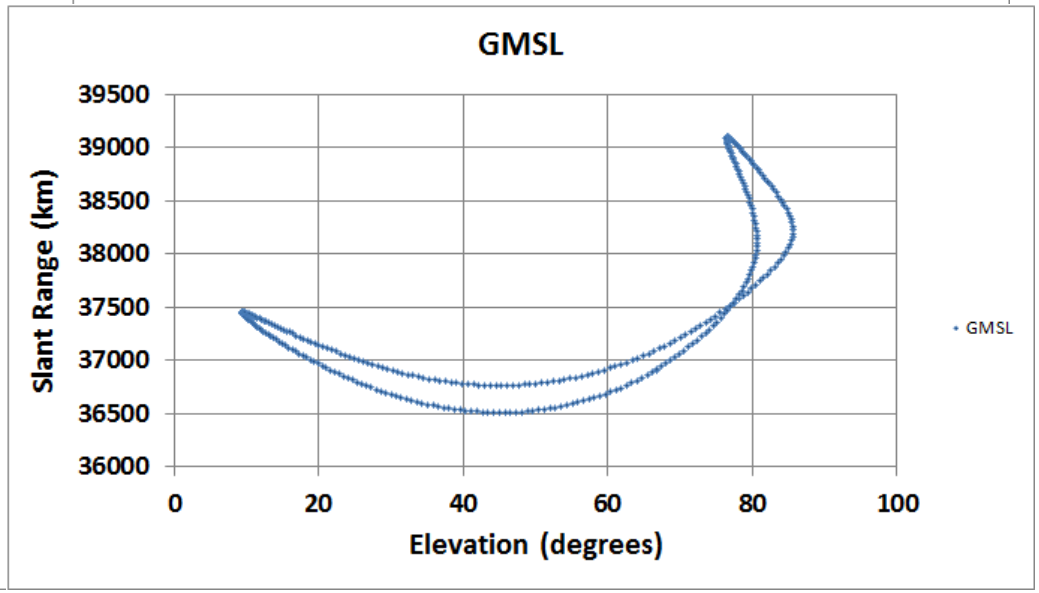
QZS being challenging target

- Semi-major axis ~**42164km**
- Inclination~ **40 degrees**

- Slant Rang:
  - longer than GEO
  - Changes with time.



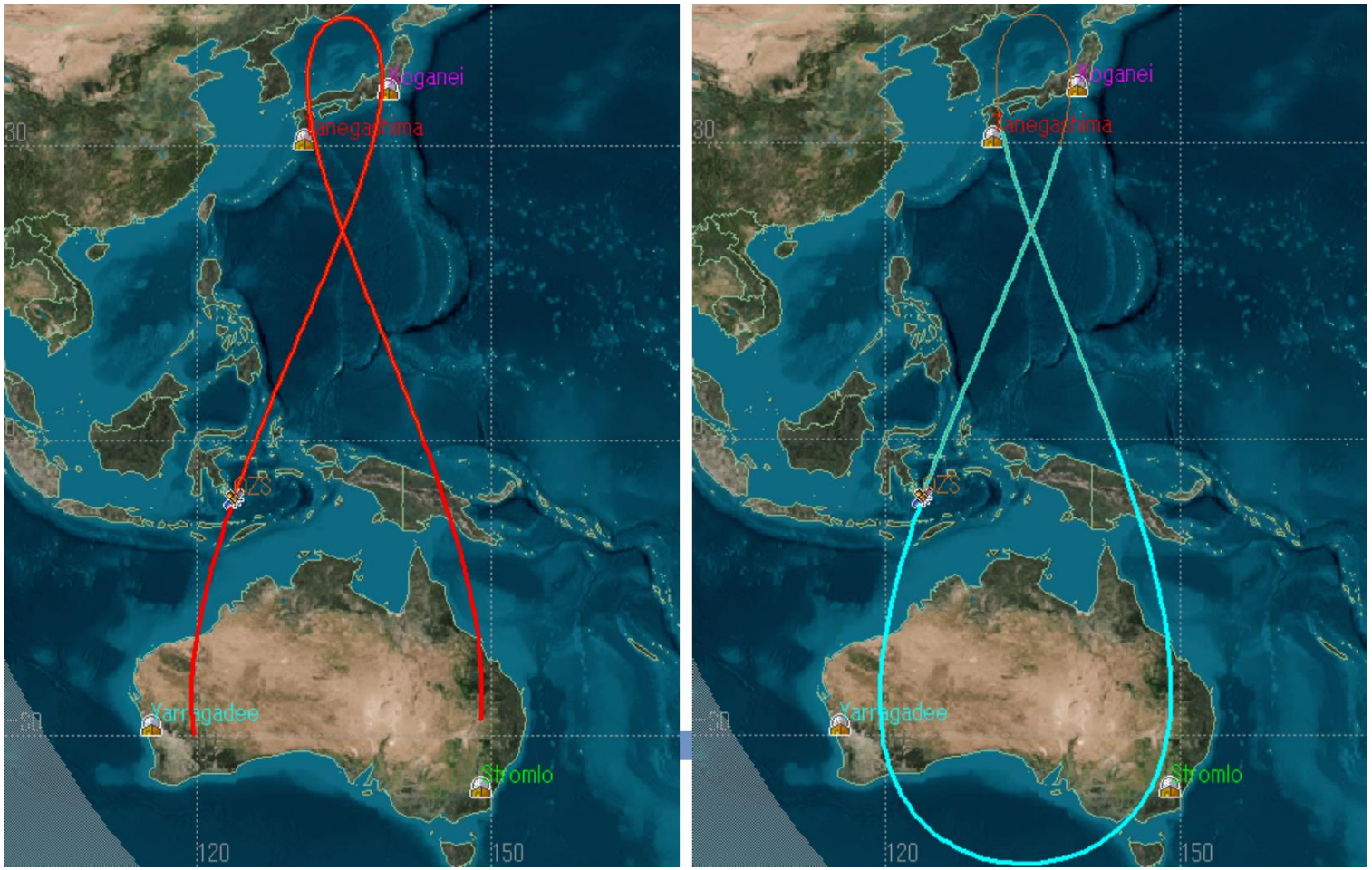




QZSS as SLR Target (2)

QZS being challenging target

- SLR stations that can track QZSS are limited.



From Dr. Nakamura's presentation for QZS-1

QZSS Tracking Schedule

There are two stages of tracking planned.

1. IOT

- Initial Orbit Test for 2-3 months after launch (planned)
- Frequency of SLR: Every day preferred.
- Candidate SLR stations: ILRS stations located at western pacific ocean i.e., Western Pacific Laser Tracking Network (WPLTN)

2. Nominal Operation

- Purpose: To increase the accuracy of orbit determination during the nominal operation (i.e., 15+ years of on-orbit life)
- Frequency of SLR: Every day preferred.
- Candidate SLR stations: ILRS stations located at western pacific ocean i.e., Western Pacific Laser Tracking Network (WPLTN); including but **not limited** to Tanegashima, Yarragadee and Stromlo.

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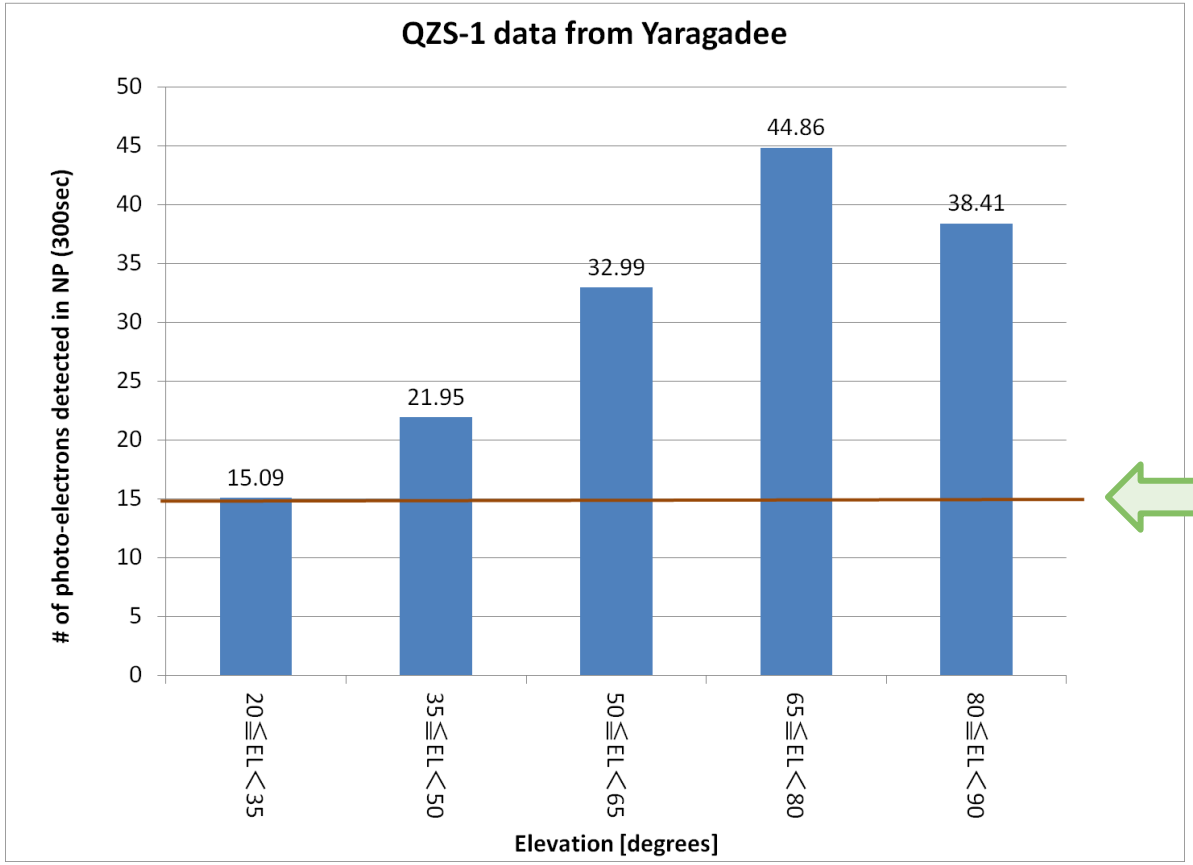
Example of SLR data for QZS-1

- Data used: 2012 to 2014
- SLR station: Yarragadee (most difficult target station to satisfy requirement)



Satisfies λ >15 requirement!

λ : requirement for # of detected photo-electron detected in NP

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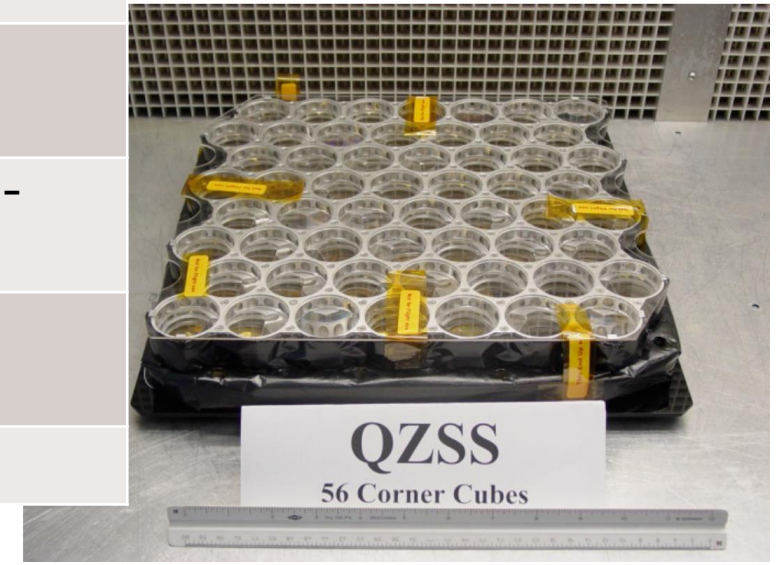
LRA for QZS-2, 3 and 4

With successful tracking record with QZS-1, QZS-2, 3 and 4 will be equipped with the same LRA as QZS-1.

Specification	
LRA manufacturer	Honeywell Technology Solutions Inc.
Type of Array	Planar Array
Shape and size of each CCR	Circular 40.6 mm (1.60"), Height - 29.7 mm (1.17")
Dihedral angle offset	0.8 +/- 0.3 arcsec
Flatness of cube's surfaces	λ/10
Coating	Coated with MgF2 anti-reflective
Envelope	400mm x 400mm x 100mm
Number of CCR	56 (7 rows x 8 lines)

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Backup Slides

Orbit (s) of QZSS

Quasi-Zenith Orbit Parameter and Tracking Range

Orbit Parameter	Nominal Allocation	Tracking Range
Semimajor Axis (A)	42164km	-
Eccentricity(e)	0.075	0.075±0.015
Inclination (i)	40 degree	36 ～ 45 degree
Argument of Perigee (w)	270 degree	270±2.5 degree
RAAN (Ω)	Block I_Q: 117 degree Block II_Q: 117±130 degree	-
Central Longitude (λ)	136 degree	130～140 degree

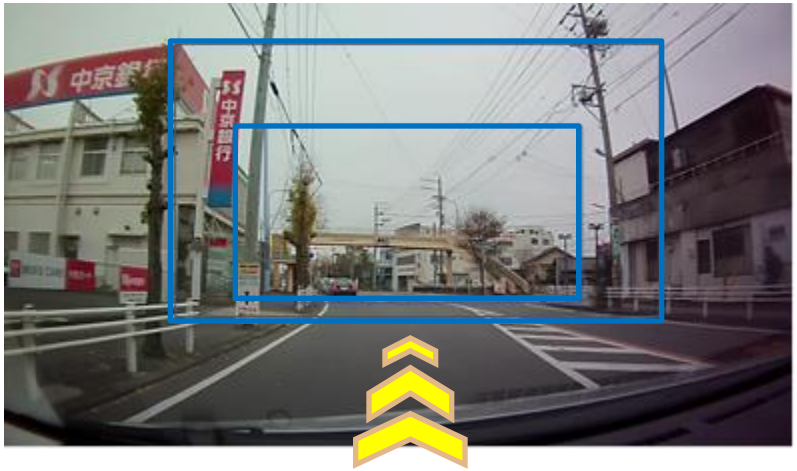
RAAN: Right Ascension of the Ascending Node

Geosynchronous Orbit Parameter and Tracking Range

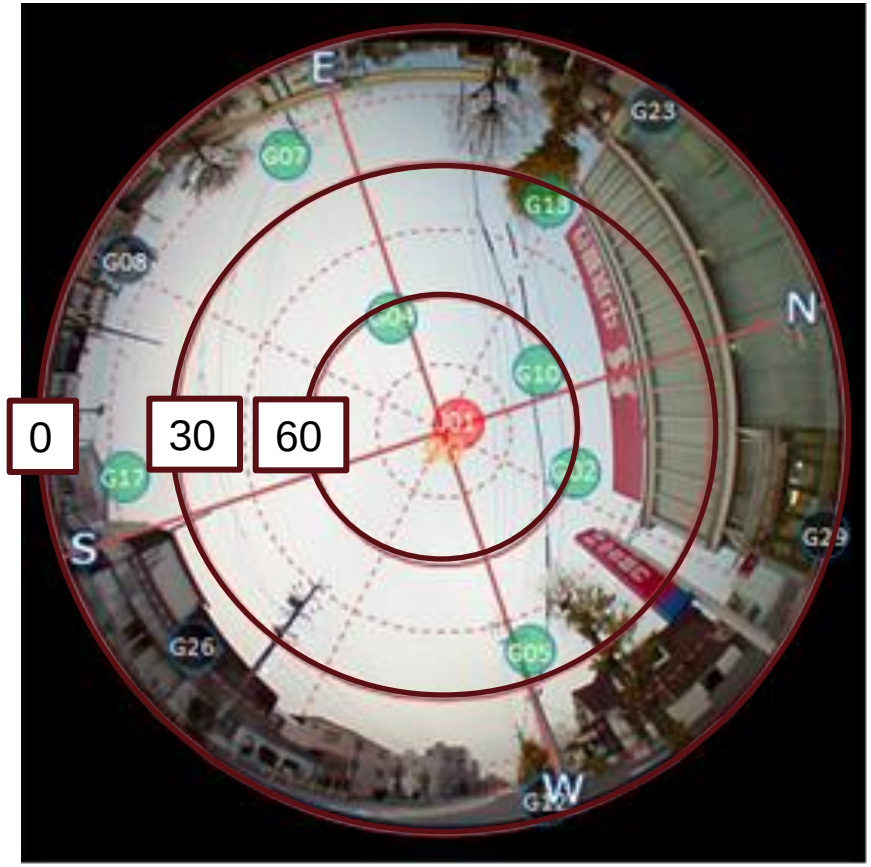
Orbit Parameter	Nominal Allocation	Tracking Range
Longitude	E 127	127±0.1 degree
Latitude	0	0±0.1 degree

Benefit of QZSS for users

A Scene during the Experiment

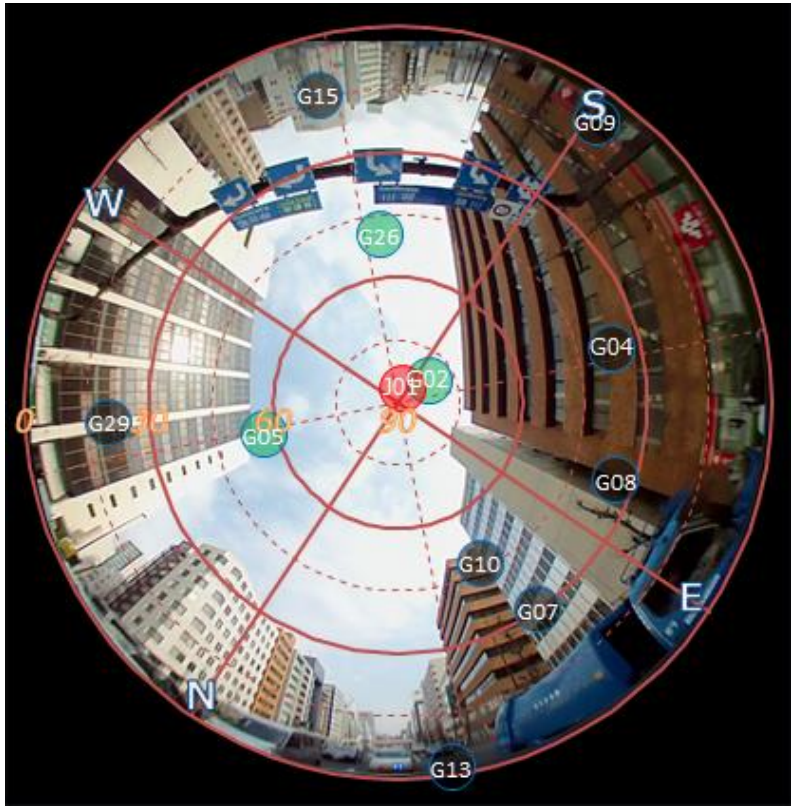


J01: QZS-1
G##: GPS ##
(Grays: Blocked)



Benefit of QZSS for users (2)

In Ginza, Tokyo



- Need at least 4 satellites in sight.
  - ✕ : GPS only
  - ✓ : GPS+QZS

Positioning Signal of QZSS (as of Sept. 2015)

Positioning Signal of QZSS						
Not only positioning complementation signal, but satellite orbit, time, and ionosphere correction information will be also transmitted as augment information.						
				1st Satellite	2nd–4th Satellite	
				QZO	QZO	GEO
L1C/A	1575.42 MHz	Positioning	complement GPS	○	○	○
L1C		Positioning	complement GPS	○	○	○
L1S		Augmentation (SLAS)		○	○	○
		Message Service		○	○	○
L2C	1227.60 MHz	Positioning	complement GPS	○	○	○
L5	1176.45 MHz	Positioning	complement GPS	○	○	○
L5S		Augmentation Experimental Use		–	○	○
L6	1278.75 MHz	Augmentation (CLAS)		○	○	○
L1Sb	1575.42	Augmentation	SBAS (*)	–	–	○

(*) SBAS Service will be available from the beginning of 2020's.