

## QZS-4 SATELLITE INFORMATION

May 14 ,2018 rev.B

## 1. Introduction

This documentation describes the information about QZS-4 satellite properties which need to be known in order to properly implement advanced processing algorithms for precise orbit determination (POD) and precise point positioning (PPP) etc.

## 2. Reference Frame

The QZS-4 satellite coordinate system is aligned with the main body axes and originates at the center of the launch adapter plane. The individual axes of QZS-4 satellite coordinate system are aligned in the following way: (see Figure 1)

- origin : Center of the launch adapter plane
- The +Z-axis is oriented to the bore sight direction of the L-ANT antenna.
- The +Y-axis is parallel to the rotation axis of the solar panels.
- The +X-axis is constituted by a right handed system with +Y/+Z axis.

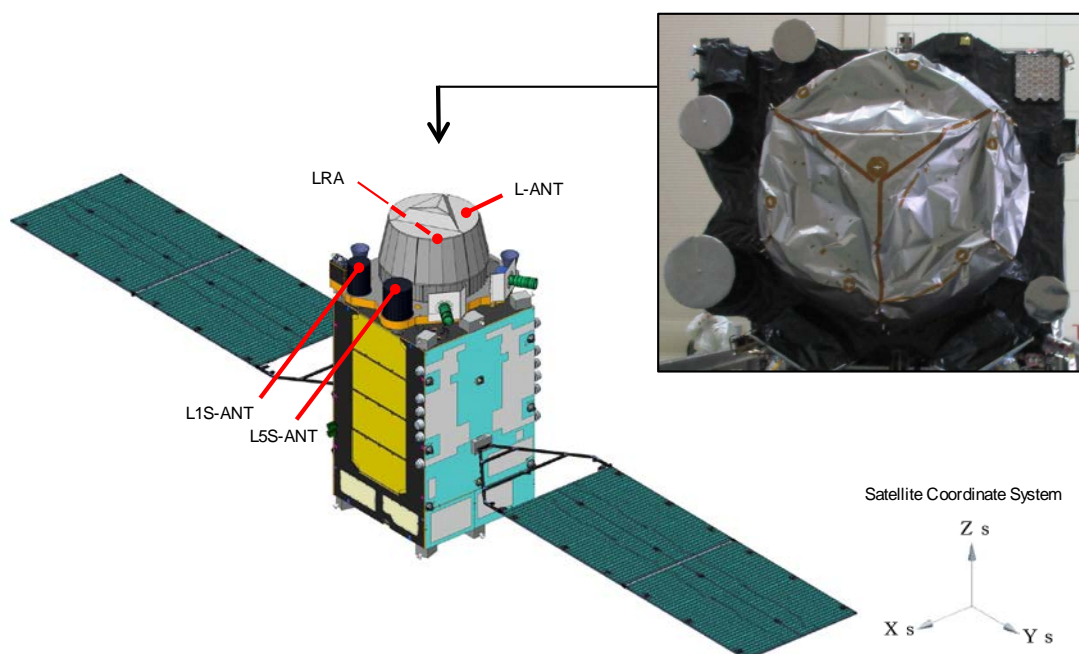


Figure 1 Reference Frame

### 3. Attitude Law

QZS-4 takes always attitude of the yaw steering mode except the period that the orbit control maneuver is conducted.

#### ① Yaw steering mode (see Figure 2)

The +z-axis is pointing to the Earth.

The y-axis is oriented perpendicular to the plane made up by the Sun, Earth and satellite.

The x-axis is oriented within the plane made up by the Sun, Earth and satellite. The Sun is located in the *negative* hemisphere.

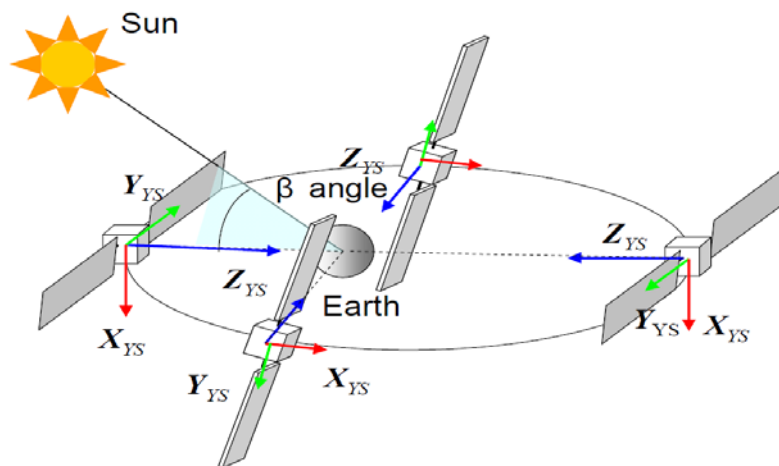


Figure 2 Yaw Steering mode

The nominal yaw angle  $\psi$  is expressed as

$$\psi = \text{atan2}(\tan\beta, -\sin\mu) ,$$

where  $\beta$  and  $\mu$  denote the sun elevation angle from the orbital plane and the orbital latitude of the satellite position from the midnight point, respectively.

If the nominal yaw rate at the midnight or noon time  $t_1$  exceeds  $\omega_c = 0.055^\circ/\text{s}$ , the pseudo-yaw-steering yaw motion around  $t_1$  is obtained as follows.

The yaw angle  $\psi_1$  at  $t_1$  is given by

$$\psi_1 = \begin{cases} +90^\circ & (\beta > 0) \\ -90^\circ & (\beta < 0) \end{cases} .$$

The rotational direction  $R$  is given by

$$R = \begin{cases} +1 & (\psi_1 - \psi > 0) \\ -1 & (\psi_1 - \psi < 0) \end{cases} .$$

The yaw rate keeps  $R\omega_c$  during this motion, and the yaw angle coincides with the nominal at the beginning and the end.

This motion can occur while  $|\beta| < 5^\circ$ . In the case of  $|\beta| < 0.03^\circ$ , the rotational direction cannot be predicted because of estimation errors.

The transition history of the rotational direction in the case of  $|\beta| < 0.03^\circ$  might be published by operational history information (OHI-QZSS).

② Orbit normal mode

When QZS-4 conducts the orbit control, the attitude mode takes orbit normal mode.

The +z-axis is pointing to the Earth.

The -y-axis is perpendicular to the orbital plane in the direction of the orbital angular momentum vector.

The +x-axis completes the right hand system with the y and z axes (roughly oriented in the flight direction).

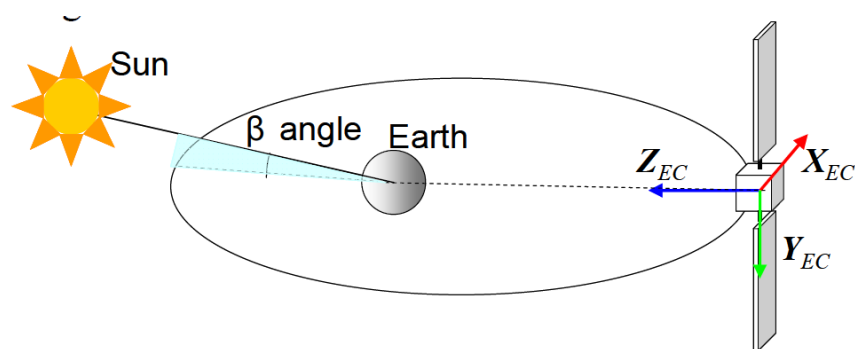


Figure 3 Orbit normal mode

#### 4. Mass and Center Of Mass

The spacecraft mass and the center of mass with respect to the satellite reference frame are provided in Table 1.

Table 1 Mass and center of mass

|     | Mass [kg] | CoM (w.r.t. origin) [mm] |      |        |
|-----|-----------|--------------------------|------|--------|
|     |           | Xs                       | Ys   | Zs     |
| BOL | 2360.0    | 3.3                      | -1.4 | 1768.1 |
| MOL | 2125.9    | 3.6                      | -1.5 | 1800.0 |
| EOL | 1891.9    | 4.1                      | -1.7 | 1849.3 |

BOL : Completion of IOT(In Orbit Test) (Estimation)

MOL : 7.5 years after launch (Prediction)

EOL : 15 years after launch (Prediction)

#### 5. Navigation Antenna Phase Center Corrections †

The phase center offsets of the navigation antenna are provided in Table 2. The offsets from the center of mass are obtained by subtracting the X/Y/Z coordinates in Table 1 from those in Table 2.

Table 2 Phase center location

| Signal | Coordinates (w.r.t. origin) [mm] |      |         |
|--------|----------------------------------|------|---------|
|        | X                                | Y    | Z       |
| L1     | 0.00                             | 0.00 | 4155.49 |
| L2     | 0.00                             | 0.00 | 5010.49 |
| L5     | 0.00                             | 0.00 | 4955.49 |
| L6     | 0.00                             | 0.00 | 5075.49 |

The phase center variations of the navigation antenna are provided in Table 3, imitating the ANTEX format. The first column shows azimuth angles followed by PCVs at nadir angles from 0deg to 10deg at 0.5deg intervals. The azimuth angles count in the GNSS standard coordinate system, of which x and y axes are opposite to those of the QZS-4 satellite coordinate system respectively.

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† PCO/PCV data are contained in the IGS ANTEX file:  
<ftp://ftp.igs.org/pub/station/general/igs14.atx>

Table 3 Phase center variations

(a) L1

|       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| NOAZI | +0.00 | -0.12 | -0.41 | -0.84 | -1.40 | -2.04 | -2.75 | -3.48 | -4.17 | -4.79 | -5.31 | -5.70 | -5.92 | -5.95 | -5.81 | -5.47 | -4.92 | -4.17 | -3.21 | -2.04 | -0.61 |
| 0.0   | +0.00 | -0.17 | -0.49 | -0.97 | -1.57 | -2.24 | -3.00 | -3.74 | -4.46 | -5.12 | -5.65 | -6.04 | -6.26 | -6.29 | -6.13 | -5.77 | -5.18 | -4.38 | -3.40 | -2.22 | -0.71 |
| 10.0  | +0.00 | -0.18 | -0.50 | -0.95 | -1.54 | -2.23 | -2.98 | -3.71 | -4.43 | -5.07 | -5.61 | -5.98 | -6.17 | -6.19 | -6.03 | -5.65 | -5.06 | -4.28 | -3.27 | -2.08 | -0.60 |
| 20.0  | +0.00 | -0.16 | -0.50 | -0.96 | -1.56 | -2.22 | -2.96 | -3.69 | -4.40 | -5.04 | -5.57 | -5.94 | -6.13 | -6.14 | -5.96 | -5.59 | -5.00 | -4.17 | -3.23 | -1.97 | -0.46 |
| 30.0  | +0.00 | -0.16 | -0.50 | -0.97 | -1.56 | -2.24 | -2.95 | -3.69 | -4.38 | -5.00 | -5.48 | -5.86 | -6.05 | -6.07 | -5.91 | -5.55 | -4.97 | -4.17 | -3.19 | -2.00 | -0.49 |
| 40.0  | +0.00 | -0.18 | -0.51 | -0.98 | -1.59 | -2.24 | -2.97 | -3.70 | -4.41 | -5.00 | -5.51 | -5.89 | -6.10 | -6.09 | -5.94 | -5.60 | -5.03 | -4.27 | -3.27 | -2.08 | -0.62 |
| 50.0  | +0.00 | -0.16 | -0.49 | -0.94 | -1.51 | -2.19 | -2.90 | -3.64 | -4.33 | -4.94 | -5.45 | -5.82 | -6.03 | -6.07 | -5.92 | -5.58 | -5.01 | -4.26 | -3.32 | -2.14 | -0.69 |
| 60.0  | +0.00 | -0.17 | -0.51 | -0.97 | -1.56 | -2.19 | -2.92 | -3.65 | -4.30 | -4.91 | -5.41 | -5.80 | -6.00 | -6.06 | -5.92 | -5.60 | -5.05 | -4.32 | -3.35 | -2.15 | -0.76 |
| 70.0  | +0.00 | -0.18 | -0.49 | -0.96 | -1.54 | -2.21 | -2.91 | -3.64 | -4.31 | -4.93 | -5.44 | -5.82 | -6.04 | -6.06 | -5.94 | -5.58 | -5.03 | -4.31 | -3.34 | -2.15 | -0.72 |
| 80.0  | +0.00 | -0.14 | -0.46 | -0.92 | -1.48 | -2.12 | -2.86 | -3.61 | -4.29 | -4.93 | -5.44 | -5.82 | -6.05 | -6.08 | -5.92 | -5.58 | -5.01 | -4.24 | -3.30 | -2.14 | -0.66 |
| 90.0  | +0.00 | -0.16 | -0.47 | -0.91 | -1.49 | -2.14 | -2.85 | -3.58 | -4.24 | -4.87 | -5.40 | -5.78 | -6.01 | -6.07 | -5.93 | -5.60 | -5.04 | -4.31 | -3.34 | -2.17 | -0.74 |
| 100.0 | +0.00 | -0.15 | -0.47 | -0.92 | -1.48 | -2.13 | -2.85 | -3.61 | -4.28 | -4.90 | -5.44 | -5.83 | -6.07 | -6.09 | -5.96 | -5.62 | -5.08 | -4.35 | -3.40 | -2.23 | -0.82 |
| 110.0 | +0.00 | -0.11 | -0.41 | -0.86 | -1.40 | -2.05 | -2.76 | -3.47 | -4.17 | -4.80 | -5.35 | -5.76 | -5.99 | -6.03 | -5.89 | -5.54 | -5.00 | -4.26 | -3.31 | -2.14 | -0.69 |
| 120.0 | +0.00 | -0.12 | -0.41 | -0.84 | -1.38 | -2.04 | -2.77 | -3.49 | -4.19 | -4.84 | -5.39 | -5.79 | -6.01 | -6.06 | -5.90 | -5.56 | -5.03 | -4.26 | -3.31 | -2.14 | -0.71 |
| 130.0 | +0.00 | -0.12 | -0.39 | -0.82 | -1.39 | -2.03 | -2.72 | -3.46 | -4.16 | -4.81 | -5.34 | -5.74 | -5.97 | -6.00 | -5.87 | -5.54 | -4.99 | -4.22 | -3.26 | -2.12 | -0.70 |
| 140.0 | +0.00 | -0.10 | -0.37 | -0.78 | -1.32 | -1.97 | -2.69 | -3.40 | -4.11 | -4.77 | -5.31 | -5.70 | -5.92 | -5.95 | -5.80 | -5.44 | -4.90 | -4.12 | -3.15 | -2.00 | -0.57 |
| 150.0 | +0.00 | -0.11 | -0.37 | -0.79 | -1.32 | -1.93 | -2.67 | -3.39 | -4.07 | -4.69 | -5.23 | -5.61 | -5.86 | -5.90 | -5.75 | -5.41 | -4.87 | -4.14 | -3.18 | -1.97 | -0.59 |
| 160.0 | +0.00 | -0.07 | -0.34 | -0.75 | -1.29 | -1.90 | -2.59 | -3.31 | -4.04 | -4.64 | -5.18 | -5.55 | -5.76 | -5.82 | -5.67 | -5.33 | -4.77 | -4.06 | -3.08 | -1.94 | -0.48 |
| 170.0 | +0.00 | -0.07 | -0.32 | -0.74 | -1.23 | -1.84 | -2.53 | -3.25 | -3.93 | -4.55 | -5.06 | -5.48 | -5.69 | -5.72 | -5.60 | -5.24 | -4.68 | -3.92 | -3.01 | -1.80 | -0.39 |
| 180.0 | +0.00 | -0.06 | -0.33 | -0.71 | -1.22 | -1.82 | -2.50 | -3.23 | -3.89 | -4.50 | -5.01 | -5.40 | -5.60 | -5.67 | -5.53 | -5.21 | -4.67 | -3.91 | -2.99 | -1.82 | -0.40 |
| 190.0 | +0.00 | -0.08 | -0.34 | -0.71 | -1.24 | -1.83 | -2.52 | -3.20 | -3.85 | -4.46 | -4.96 | -5.33 | -5.54 | -5.58 | -5.45 | -5.09 | -4.57 | -3.80 | -2.86 | -1.70 | -0.25 |
| 200.0 | +0.00 | -0.08 | -0.32 | -0.70 | -1.25 | -1.83 | -2.50 | -3.17 | -3.83 | -4.42 | -4.93 | -5.29 | -5.50 | -5.54 | -5.40 | -5.04 | -4.50 | -3.77 | -2.78 | -1.60 | -0.19 |
| 210.0 | +0.00 | -0.08 | -0.33 | -0.73 | -1.21 | -1.84 | -2.51 | -3.17 | -3.80 | -4.38 | -4.87 | -5.23 | -5.45 | -5.49 | -5.35 | -5.04 | -4.50 | -3.78 | -2.80 | -1.68 | -0.22 |
| 220.0 | +0.00 | -0.07 | -0.33 | -0.73 | -1.23 | -1.82 | -2.51 | -3.20 | -3.84 | -4.42 | -4.93 | -5.28 | -5.48 | -5.54 | -5.39 | -5.06 | -4.54 | -3.79 | -2.80 | -1.70 | -0.28 |
| 230.0 | +0.00 | -0.08 | -0.32 | -0.71 | -1.22 | -1.80 | -2.47 | -3.15 | -3.81 | -4.40 | -4.90 | -5.27 | -5.48 | -5.54 | -5.43 | -5.09 | -4.56 | -3.85 | -2.91 | -1.77 | -0.35 |
| 240.0 | +0.00 | -0.07 | -0.34 | -0.75 | -1.26 | -1.84 | -2.51 | -3.17 | -3.84 | -4.42 | -4.93 | -5.30 | -5.53 | -5.58 | -5.47 | -5.14 | -4.64 | -3.94 | -3.04 | -1.81 | -0.45 |
| 250.0 | +0.00 | -0.10 | -0.34 | -0.74 | -1.26 | -1.87 | -2.53 | -3.24 | -3.89 | -4.49 | -5.01 | -5.39 | -5.60 | -5.64 | -5.53 | -5.20 | -4.66 | -3.96 | -3.02 | -1.89 | -0.49 |
| 260.0 | +0.00 | -0.11 | -0.35 | -0.75 | -1.27 | -1.90 | -2.57 | -3.26 | -3.94 | -4.55 | -5.06 | -5.43 | -5.65 | -5.69 | -5.55 | -5.21 | -4.69 | -3.94 | -2.99 | -1.85 | -0.40 |
| 270.0 | +0.00 | -0.11 | -0.38 | -0.80 | -1.33 | -1.95 | -2.62 | -3.32 | -4.00 | -4.60 | -5.13 | -5.50 | -5.71 | -5.74 | -5.59 | -5.26 | -4.69 | -3.96 | -3.04 | -1.87 | -0.42 |
| 280.0 | +0.00 | -0.12 | -0.40 | -0.85 | -1.38 | -2.03 | -2.74 | -3.48 | -4.18 | -4.79 | -5.34 | -5.72 | -5.96 | -5.99 | -5.83 | -5.51 | -4.96 | -4.21 | -3.27 | -2.10 | -0.70 |
| 290.0 | +0.00 | -0.10 | -0.38 | -0.80 | -1.38 | -1.99 | -2.73 | -3.49 | -4.17 | -4.82 | -5.35 | -5.77 | -6.00 | -6.04 | -5.89 | -5.56 | -4.99 | -4.22 | -3.28 | -2.08 | -0.71 |
| 300.0 | +0.00 | -0.12 | -0.41 | -0.84 | -1.42 | -2.07 | -2.78 | -3.57 | -4.24 | -4.90 | -5.44 | -5.85 | -6.08 | -6.12 | -5.97 | -5.63 | -5.07 | -4.35 | -3.38 | -2.21 | -0.85 |
| 310.0 | +0.00 | -0.13 | -0.44 | -0.86 | -1.47 | -2.13 | -2.88 | -3.63 | -4.34 | -5.02 | -5.55 | -5.95 | -6.20 | -6.23 | -6.06 | -5.74 | -5.19 | -4.44 | -3.52 | -2.35 | -0.94 |
| 320.0 | +0.00 | -0.15 | -0.43 | -0.88 | -1.47 | -2.15 | -2.92 | -3.71 | -4.44 | -5.12 | -5.65 | -6.06 | -6.29 | -6.33 | -6.19 | -5.83 | -5.29 | -4.50 | -3.62 | -2.41 | -0.96 |
| 330.0 | +0.00 | -0.14 | -0.48 | -0.91 | -1.49 | -2.19 | -2.94 | -3.70 | -4.42 | -5.08 | -5.65 | -6.04 | -6.28 | -6.32 | -6.17 | -5.82 | -5.27 | -4.52 | -3.59 | -2.42 | -0.99 |
| 340.0 | +0.00 | -0.15 | -0.49 | -0.97 | -1.57 | -2.24 | -3.03 | -3.80 | -4.51 | -5.18 | -5.72 | -6.13 | -6.35 | -6.38 | -6.21 | -5.88 | -5.29 | -4.53 | -3.58 | -2.41 | -0.99 |
| 350.0 | +0.00 | -0.15 | -0.46 | -0.93 | -1.53 | -2.21 | -2.96 | -3.72 | -4.48 | -5.12 | -5.68 | -6.07 | -6.30 | -6.32 | -6.15 | -5.78 | -5.22 | -4.44 | -3.45 | -2.23 | -0.78 |
| 360.0 | +0.00 | -0.17 | -0.49 | -0.97 | -1.57 | -2.24 | -3.00 | -3.74 | -4.46 | -5.12 | -5.65 | -6.04 | -6.26 | -6.29 | -6.13 | -5.77 | -5.18 | -4.38 | -3.40 | -2.22 | -0.71 |

## (b) L2

|       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| NOAZI | +0.00 | +0.05 | +0.13 | +0.21 | +0.29 | +0.39 | +0.49 | +0.60 | +0.71 | +0.81 | +0.92 | +1.03 | +1.13 | +1.23 | +1.32 | +1.40 | +1.47 | +1.53 | +1.56 | +1.57 | +1.55 |
| 0.0   | +0.00 | +0.10 | +0.18 | +0.27 | +0.39 | +0.54 | +0.68 | +0.78 | +0.94 | +1.08 | +1.22 | +1.34 | +1.48 | +1.64 | +1.77 | +1.86 | +1.94 | +2.04 | +2.08 | +2.11 | +2.10 |
| 10.0  | +0.00 | +0.08 | +0.18 | +0.29 | +0.39 | +0.52 | +0.63 | +0.75 | +0.88 | +1.01 | +1.15 | +1.28 | +1.41 | +1.52 | +1.67 | +1.77 | +1.88 | +1.98 | +2.03 | +2.09 | +2.10 |
| 20.0  | +0.00 | +0.10 | +0.22 | +0.35 | +0.48 | +0.63 | +0.77 | +0.92 | +1.07 | +1.22 | +1.34 | +1.49 | +1.64 | +1.77 | +1.88 | +2.00 | +2.06 | +2.17 | +2.23 | +2.29 | +2.27 |
| 30.0  | +0.00 | +0.05 | +0.15 | +0.24 | +0.37 | +0.50 | +0.65 | +0.78 | +0.93 | +1.09 | +1.24 | +1.41 | +1.56 | +1.70 | +1.84 | +1.98 | +2.09 | +2.18 | +2.27 | +2.31 | +2.34 |
| 40.0  | +0.00 | +0.08 | +0.16 | +0.27 | +0.38 | +0.50 | +0.61 | +0.73 | +0.86 | +0.98 | +1.12 | +1.23 | +1.38 | +1.51 | +1.65 | +1.78 | +1.89 | +2.00 | +2.09 | +2.15 | +2.19 |
| 50.0  | +0.00 | +0.09 | +0.20 | +0.33 | +0.43 | +0.58 | +0.71 | +0.88 | +1.02 | +1.15 | +1.30 | +1.45 | +1.58 | +1.70 | +1.83 | +1.94 | +2.00 | +2.11 | +2.15 | +2.18 | +2.19 |
| 60.0  | +0.00 | +0.08 | +0.18 | +0.27 | +0.40 | +0.51 | +0.63 | +0.79 | +0.94 | +1.07 | +1.22 | +1.39 | +1.53 | +1.68 | +1.80 | +1.91 | +2.01 | +2.11 | +2.16 | +2.21 | +2.19 |
| 70.0  | +0.00 | +0.07 | +0.17 | +0.26 | +0.37 | +0.48 | +0.60 | +0.70 | +0.84 | +0.95 | +1.07 | +1.21 | +1.34 | +1.47 | +1.60 | +1.72 | +1.82 | +1.91 | +1.97 | +2.02 | +2.04 |
| 80.0  | +0.00 | +0.08 | +0.18 | +0.29 | +0.39 | +0.52 | +0.65 | +0.78 | +0.93 | +1.07 | +1.17 | +1.31 | +1.44 | +1.56 | +1.69 | +1.78 | +1.85 | +1.96 | +2.00 | +2.02 | +2.02 |
| 90.0  | +0.00 | +0.05 | +0.13 | +0.22 | +0.31 | +0.43 | +0.53 | +0.65 | +0.79 | +0.92 | +1.05 | +1.20 | +1.33 | +1.47 | +1.60 | +1.70 | +1.81 | +1.89 | +1.96 | +1.99 | +1.99 |
| 100.0 | +0.00 | +0.06 | +0.15 | +0.20 | +0.31 | +0.39 | +0.50 | +0.60 | +0.70 | +0.81 | +0.93 | +1.05 | +1.15 | +1.27 | +1.40 | +1.49 | +1.59 | +1.68 | +1.75 | +1.79 | +1.81 |
| 110.0 | +0.00 | +0.06 | +0.14 | +0.24 | +0.32 | +0.44 | +0.55 | +0.66 | +0.79 | +0.89 | +0.99 | +1.13 | +1.23 | +1.33 | +1.42 | +1.50 | +1.56 | +1.66 | +1.67 | +1.69 | +1.69 |
| 120.0 | +0.00 | +0.04 | +0.12 | +0.20 | +0.29 | +0.36 | +0.47 | +0.58 | +0.69 | +0.78 | +0.89 | +1.01 | +1.12 | +1.24 | +1.34 | +1.43 | +1.50 | +1.58 | +1.61 | +1.62 | +1.59 |
| 130.0 | +0.00 | +0.02 | +0.10 | +0.17 | +0.24 | +0.35 | +0.42 | +0.52 | +0.59 | +0.69 | +0.80 | +0.88 | +0.99 | +1.07 | +1.18 | +1.26 | +1.31 | +1.41 | +1.43 | +1.46 | +1.45 |
| 140.0 | +0.00 | +0.05 | +0.12 | +0.20 | +0.30 | +0.39 | +0.48 | +0.58 | +0.70 | +0.79 | +0.89 | +1.00 | +1.08 | +1.19 | +1.25 | +1.33 | +1.38 | +1.43 | +1.45 | +1.46 | +1.44 |
| 150.0 | +0.00 | +0.04 | +0.08 | +0.14 | +0.22 | +0.30 | +0.37 | +0.49 | +0.59 | +0.70 | +0.79 | +0.90 | +1.00 | +1.08 | +1.20 | +1.26 | +1.32 | +1.39 | +1.39 | +1.42 | +1.39 |
| 160.0 | +0.00 | +0.03 | +0.10 | +0.16 | +0.22 | +0.30 | +0.37 | +0.45 | +0.52 | +0.60 | +0.66 | +0.75 | +0.83 | +0.91 | +0.96 | +1.03 | +1.09 | +1.15 | +1.16 | +1.17 | +1.16 |
| 170.0 | +0.00 | +0.07 | +0.12 | +0.18 | +0.25 | +0.34 | +0.42 | +0.52 | +0.60 | +0.68 | +0.75 | +0.82 | +0.88 | +0.96 | +1.01 | +1.05 | +1.06 | +1.11 | +1.09 | +1.08 | +1.03 |
| 180.0 | +0.00 | +0.01 | +0.08 | +0.11 | +0.18 | +0.24 | +0.31 | +0.39 | +0.47 | +0.54 | +0.64 | +0.70 | +0.78 | +0.87 | +0.92 | +0.96 | +1.03 | +1.05 | +1.05 | +1.01 | +0.97 |
| 190.0 | +0.00 | +0.04 | +0.12 | +0.14 | +0.20 | +0.27 | +0.31 | +0.39 | +0.48 | +0.54 | +0.60 | +0.67 | +0.75 | +0.81 | +0.86 | +0.92 | +0.96 | +1.01 | +1.01 | +1.00 | +0.96 |
| 200.0 | +0.00 | +0.05 | +0.10 | +0.16 | +0.24 | +0.32 | +0.39 | +0.50 | +0.58 | +0.65 | +0.74 | +0.82 | +0.88 | +0.94 | +1.01 | +1.05 | +1.07 | +1.10 | +1.09 | +1.06 | +0.98 |
| 210.0 | +0.00 | +0.04 | +0.06 | +0.10 | +0.17 | +0.24 | +0.33 | +0.41 | +0.51 | +0.60 | +0.69 | +0.79 | +0.89 | +0.96 | +1.05 | +1.10 | +1.17 | +1.20 | +1.21 | +1.18 | +1.14 |
| 220.0 | +0.00 | +0.02 | +0.05 | +0.10 | +0.16 | +0.22 | +0.28 | +0.36 | +0.43 | +0.50 | +0.56 | +0.66 | +0.73 | +0.79 | +0.86 | +0.92 | +0.98 | +1.01 | +1.03 | +1.02 | +0.99 |
| 230.0 | +0.00 | +0.04 | +0.10 | +0.17 | +0.23 | +0.33 | +0.40 | +0.48 | +0.58 | +0.65 | +0.73 | +0.82 | +0.88 | +0.94 | +1.01 | +1.05 | +1.07 | +1.08 | +1.07 | +1.03 | +0.96 |
| 240.0 | +0.00 | +0.01 | +0.07 | +0.13 | +0.18 | +0.27 | +0.35 | +0.45 | +0.55 | +0.64 | +0.73 | +0.82 | +0.91 | +0.98 | +1.05 | +1.12 | +1.15 | +1.21 | +1.17 | +1.16 | +1.09 |
| 250.0 | +0.00 | +0.03 | +0.08 | +0.14 | +0.20 | +0.25 | +0.35 | +0.41 | +0.50 | +0.58 | +0.65 | +0.73 | +0.82 | +0.90 | +0.98 | +1.05 | +1.09 | +1.13 | +1.14 | +1.15 | +1.10 |
| 260.0 | +0.00 | +0.05 | +0.12 | +0.20 | +0.28 | +0.37 | +0.47 | +0.54 | +0.63 | +0.73 | +0.82 | +0.88 | +0.97 | +1.05 | +1.11 | +1.16 | +1.20 | +1.22 | +1.22 | +1.20 | +1.14 |
| 270.0 | +0.00 | +0.05 | +0.06 | +0.16 | +0.21 | +0.28 | +0.37 | +0.48 | +0.58 | +0.69 | +0.79 | +0.90 | +1.00 | +1.09 | +1.18 | +1.28 | +1.33 | +1.36 | +1.39 | +1.36 | +1.33 |
| 280.0 | +0.00 | +0.03 | +0.09 | +0.14 | +0.19 | +0.27 | +0.34 | +0.40 | +0.46 | +0.55 | +0.62 | +0.70 | +0.79 | +0.87 | +0.95 | +1.01 | +1.05 | +1.10 | +1.12 | +1.13 | +1.10 |
| 290.0 | +0.00 | +0.05 | +0.12 | +0.19 | +0.29 | +0.37 | +0.46 | +0.56 | +0.66 | +0.75 | +0.84 | +0.93 | +0.99 | +1.06 | +1.13 | +1.17 | +1.22 | +1.25 | +1.24 | +1.22 | +1.19 |
| 300.0 | +0.00 | +0.05 | +0.12 | +0.19 | +0.27 | +0.36 | +0.46 | +0.56 | +0.67 | +0.77 | +0.88 | +1.00 | +1.09 | +1.17 | +1.27 | +1.34 | +1.38 | +1.43 | +1.45 | +1.43 | +1.37 |
| 310.0 | +0.00 | +0.05 | +0.10 | +0.18 | +0.28 | +0.35 | +0.43 | +0.52 | +0.61 | +0.71 | +0.82 | +0.92 | +0.98 | +1.07 | +1.17 | +1.25 | +1.32 | +1.37 | +1.38 | +1.37 | +1.35 |
| 320.0 | +0.00 | +0.08 | +0.16 | +0.25 | +0.39 | +0.51 | +0.63 | +0.74 | +0.86 | +0.97 | +1.09 | +1.18 | +1.27 | +1.36 | +1.45 | +1.51 | +1.55 | +1.59 | +1.60 | +1.58 | +1.54 |
| 330.0 | +0.00 | +0.04 | +0.12 | +0.20 | +0.30 | +0.42 | +0.54 | +0.65 | +0.81 | +0.92 | +1.05 | +1.19 | +1.29 | +1.41 | +1.53 | +1.62 | +1.70 | +1.76 | +1.79 | +1.78 | +1.75 |
| 340.0 | +0.00 | +0.08 | +0.17 | +0.27 | +0.35 | +0.48 | +0.57 | +0.67 | +0.79 | +0.88 | +0.99 | +1.09 | +1.21 | +1.30 | +1.43 | +1.51 | +1.62 | +1.67 | +1.72 | +1.74 | +1.75 |
| 350.0 | +0.00 | +0.10 | +0.21 | +0.33 | +0.43 | +0.57 | +0.73 | +0.84 | +1.00 | +1.13 | +1.25 | +1.36 | +1.49 | +1.58 | +1.68 | +1.75 | +1.83 | +1.90 | +1.92 | +1.94 | +1.93 |
| 360.0 | +0.00 | +0.10 | +0.18 | +0.27 | +0.39 | +0.54 | +0.68 | +0.78 | +0.94 | +1.08 | +1.22 | +1.34 | +1.48 | +1.64 | +1.77 | +1.86 | +1.94 | +2.04 | +2.08 | +2.11 | +2.10 |

## (c) L5

|       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| NOAZI | +0.00 | +0.05 | +0.08 | +0.13 | +0.16 | +0.22 | +0.27 | +0.33 | +0.42 | +0.50 | +0.59 | +0.68 | +0.78 | +0.86 | +0.95 | +1.02 | +1.07 | +1.15 | +1.19 | +1.23 | +1.25 |
| 0.0   | +0.00 | +0.09 | +0.14 | +0.21 | +0.28 | +0.36 | +0.45 | +0.56 | +0.69 | +0.82 | +0.94 | +1.09 | +1.22 | +1.35 | +1.47 | +1.59 | +1.66 | +1.76 | +1.83 | +1.89 | +1.96 |
| 10.0  | +0.00 | +0.06 | +0.11 | +0.18 | +0.23 | +0.30 | +0.38 | +0.47 | +0.60 | +0.67 | +0.80 | +0.91 | +1.04 | +1.14 | +1.25 | +1.35 | +1.44 | +1.52 | +1.60 | +1.66 | +1.74 |
| 20.0  | +0.00 | +0.11 | +0.18 | +0.26 | +0.35 | +0.45 | +0.52 | +0.62 | +0.74 | +0.87 | +0.99 | +1.11 | +1.22 | +1.35 | +1.47 | +1.55 | +1.64 | +1.74 | +1.79 | +1.87 | +1.91 |
| 30.0  | +0.00 | +0.07 | +0.14 | +0.20 | +0.27 | +0.35 | +0.43 | +0.53 | +0.66 | +0.77 | +0.91 | +1.03 | +1.16 | +1.28 | +1.41 | +1.52 | +1.60 | +1.73 | +1.79 | +1.88 | +1.93 |
| 40.0  | +0.00 | +0.08 | +0.12 | +0.19 | +0.24 | +0.33 | +0.37 | +0.46 | +0.57 | +0.66 | +0.77 | +0.87 | +0.99 | +1.09 | +1.20 | +1.28 | +1.37 | +1.46 | +1.52 | +1.58 | +1.64 |
| 50.0  | +0.00 | +0.11 | +0.16 | +0.25 | +0.30 | +0.40 | +0.45 | +0.55 | +0.65 | +0.77 | +0.87 | +0.97 | +1.08 | +1.17 | +1.28 | +1.36 | +1.41 | +1.49 | +1.54 | +1.59 | +1.63 |
| 60.0  | +0.00 | +0.08 | +0.14 | +0.20 | +0.26 | +0.33 | +0.41 | +0.49 | +0.62 | +0.72 | +0.83 | +0.95 | +1.06 | +1.16 | +1.28 | +1.35 | +1.42 | +1.52 | +1.59 | +1.63 | +1.67 |
| 70.0  | +0.00 | +0.07 | +0.11 | +0.18 | +0.23 | +0.28 | +0.35 | +0.41 | +0.51 | +0.59 | +0.69 | +0.79 | +0.88 | +0.98 | +1.08 | +1.14 | +1.21 | +1.29 | +1.33 | +1.37 | +1.40 |
| 80.0  | +0.00 | +0.09 | +0.14 | +0.21 | +0.28 | +0.34 | +0.40 | +0.48 | +0.60 | +0.67 | +0.77 | +0.87 | +0.97 | +1.04 | +1.16 | +1.22 | +1.30 | +1.38 | +1.44 | +1.47 | +1.51 |
| 90.0  | +0.00 | +0.06 | +0.11 | +0.16 | +0.21 | +0.27 | +0.34 | +0.41 | +0.50 | +0.61 | +0.67 | +0.78 | +0.89 | +0.97 | +1.07 | +1.13 | +1.21 | +1.29 | +1.33 | +1.36 | +1.40 |
| 100.0 | +0.00 | +0.06 | +0.07 | +0.13 | +0.16 | +0.22 | +0.24 | +0.32 | +0.38 | +0.48 | +0.55 | +0.63 | +0.73 | +0.80 | +0.89 | +0.95 | +1.00 | +1.08 | +1.11 | +1.16 | +1.17 |
| 110.0 | +0.00 | +0.06 | +0.09 | +0.14 | +0.18 | +0.21 | +0.26 | +0.33 | +0.40 | +0.48 | +0.54 | +0.63 | +0.72 | +0.79 | +0.88 | +0.91 | +0.96 | +1.02 | +1.06 | +1.09 | +1.11 |
| 120.0 | +0.00 | +0.05 | +0.06 | +0.12 | +0.15 | +0.21 | +0.24 | +0.31 | +0.38 | +0.48 | +0.56 | +0.65 | +0.74 | +0.80 | +0.89 | +0.96 | +1.00 | +1.07 | +1.10 | +1.13 | +1.16 |
| 130.0 | +0.00 | +0.03 | +0.06 | +0.09 | +0.11 | +0.15 | +0.18 | +0.25 | +0.33 | +0.39 | +0.46 | +0.54 | +0.62 | +0.69 | +0.77 | +0.84 | +0.85 | +0.91 | +0.94 | +0.96 | +0.97 |
| 140.0 | +0.00 | +0.04 | +0.07 | +0.11 | +0.14 | +0.20 | +0.26 | +0.31 | +0.38 | +0.45 | +0.52 | +0.61 | +0.69 | +0.75 | +0.82 | +0.87 | +0.91 | +0.99 | +1.00 | +1.03 | +1.02 |
| 150.0 | +0.00 | +0.04 | +0.06 | +0.09 | +0.10 | +0.16 | +0.19 | +0.24 | +0.34 | +0.40 | +0.50 | +0.57 | +0.66 | +0.74 | +0.82 | +0.86 | +0.91 | +0.96 | +0.99 | +1.01 | +1.01 |
| 160.0 | +0.00 | +0.03 | +0.03 | +0.03 | +0.04 | +0.07 | +0.08 | +0.11 | +0.17 | +0.22 | +0.28 | +0.35 | +0.43 | +0.49 | +0.55 | +0.58 | +0.62 | +0.69 | +0.70 | +0.72 | +0.72 |
| 170.0 | +0.00 | +0.04 | +0.04 | +0.05 | +0.07 | +0.10 | +0.15 | +0.18 | +0.26 | +0.32 | +0.38 | +0.46 | +0.52 | +0.57 | +0.63 | +0.67 | +0.68 | +0.74 | +0.74 | +0.74 | +0.74 |
| 180.0 | +0.00 | +0.01 | +0.00 | +0.02 | +0.01 | +0.06 | +0.09 | +0.15 | +0.24 | +0.31 | +0.40 | +0.48 | +0.57 | +0.65 | +0.73 | +0.79 | +0.82 | +0.89 | +0.90 | +0.91 | +0.91 |
| 190.0 | +0.00 | +0.01 | +0.01 | +0.01 | +0.01 | +0.03 | +0.06 | +0.09 | +0.15 | +0.20 | +0.26 | +0.33 | +0.39 | +0.46 | +0.53 | +0.57 | +0.59 | +0.65 | +0.67 | +0.67 | +0.66 |
| 200.0 | +0.00 | +0.04 | +0.07 | +0.09 | +0.11 | +0.15 | +0.17 | +0.23 | +0.31 | +0.35 | +0.42 | +0.49 | +0.56 | +0.62 | +0.68 | +0.72 | +0.76 | +0.82 | +0.82 | +0.85 | +0.84 |
| 210.0 | +0.00 | +0.03 | +0.04 | +0.07 | +0.07 | +0.12 | +0.14 | +0.20 | +0.27 | +0.34 | +0.41 | +0.50 | +0.58 | +0.65 | +0.73 | +0.79 | +0.83 | +0.89 | +0.91 | +0.95 | +0.96 |
| 220.0 | +0.00 | +0.01 | +0.02 | +0.04 | +0.04 | +0.06 | +0.09 | +0.11 | +0.17 | +0.23 | +0.29 | +0.37 | +0.43 | +0.50 | +0.57 | +0.62 | +0.64 | +0.72 | +0.72 | +0.74 | +0.75 |
| 230.0 | +0.00 | +0.05 | +0.06 | +0.10 | +0.11 | +0.14 | +0.18 | +0.23 | +0.31 | +0.38 | +0.44 | +0.52 | +0.60 | +0.67 | +0.74 | +0.79 | +0.81 | +0.86 | +0.86 | +0.89 | +0.89 |
| 240.0 | +0.00 | +0.01 | +0.03 | +0.06 | +0.08 | +0.12 | +0.16 | +0.21 | +0.28 | +0.37 | +0.44 | +0.54 | +0.62 | +0.70 | +0.79 | +0.84 | +0.88 | +0.98 | +0.98 | +1.01 | +1.01 |
| 250.0 | +0.00 | +0.05 | +0.05 | +0.06 | +0.08 | +0.11 | +0.13 | +0.17 | +0.23 | +0.29 | +0.35 | +0.41 | +0.49 | +0.55 | +0.62 | +0.71 | +0.72 | +0.79 | +0.80 | +0.84 | +0.84 |
| 260.0 | +0.00 | +0.05 | +0.09 | +0.11 | +0.14 | +0.18 | +0.23 | +0.28 | +0.35 | +0.41 | +0.48 | +0.56 | +0.65 | +0.71 | +0.79 | +0.85 | +0.91 | +0.97 | +1.02 | +1.03 | +1.06 |
| 270.0 | +0.00 | +0.04 | +0.06 | +0.08 | +0.12 | +0.16 | +0.20 | +0.26 | +0.31 | +0.40 | +0.48 | +0.57 | +0.66 | +0.77 | +0.84 | +0.92 | +0.99 | +1.05 | +1.11 | +1.13 | +1.20 |
| 280.0 | +0.00 | +0.06 | +0.06 | +0.08 | +0.09 | +0.13 | +0.14 | +0.18 | +0.25 | +0.31 | +0.38 | +0.45 | +0.54 | +0.60 | +0.69 | +0.77 | +0.80 | +0.89 | +0.91 | +0.95 | +0.99 |
| 290.0 | +0.00 | +0.06 | +0.09 | +0.13 | +0.16 | +0.20 | +0.24 | +0.29 | +0.36 | +0.45 | +0.52 | +0.61 | +0.70 | +0.78 | +0.86 | +0.94 | +0.99 | +1.06 | +1.10 | +1.13 | +1.17 |
| 300.0 | +0.00 | +0.06 | +0.06 | +0.11 | +0.14 | +0.20 | +0.23 | +0.30 | +0.39 | +0.48 | +0.57 | +0.67 | +0.77 | +0.86 | +0.97 | +1.06 | +1.13 | +1.22 | +1.26 | +1.31 | +1.36 |
| 310.0 | +0.00 | +0.04 | +0.07 | +0.11 | +0.15 | +0.21 | +0.24 | +0.32 | +0.41 | +0.48 | +0.58 | +0.68 | +0.77 | +0.85 | +0.96 | +1.03 | +1.11 | +1.17 | +1.21 | +1.27 | +1.30 |
| 320.0 | +0.00 | +0.08 | +0.14 | +0.19 | +0.25 | +0.34 | +0.40 | +0.49 | +0.59 | +0.69 | +0.79 | +0.90 | +1.02 | +1.11 | +1.20 | +1.28 | +1.34 | +1.42 | +1.50 | +1.54 | +1.58 |
| 330.0 | +0.00 | +0.08 | +0.12 | +0.20 | +0.25 | +0.33 | +0.40 | +0.49 | +0.61 | +0.71 | +0.82 | +0.94 | +1.06 | +1.17 | +1.29 | +1.40 | +1.47 | +1.57 | +1.62 | +1.68 | +1.71 |
| 340.0 | +0.00 | +0.09 | +0.11 | +0.18 | +0.21 | +0.27 | +0.33 | +0.40 | +0.50 | +0.59 | +0.69 | +0.80 | +0.90 | +1.01 | +1.11 | +1.20 | +1.28 | +1.37 | +1.42 | +1.49 | +1.55 |
| 350.0 | +0.00 | +0.09 | +0.15 | +0.22 | +0.28 | +0.38 | +0.44 | +0.54 | +0.65 | +0.77 | +0.86 | +0.98 | +1.08 | +1.18 | +1.31 | +1.38 | +1.45 | +1.54 | +1.59 | +1.66 | +1.71 |
| 360.0 | +0.00 | +0.09 | +0.14 | +0.21 | +0.28 | +0.36 | +0.45 | +0.56 | +0.69 | +0.82 | +0.94 | +1.09 | +1.22 | +1.35 | +1.47 | +1.59 | +1.66 | +1.76 | +1.83 | +1.89 | +1.96 |

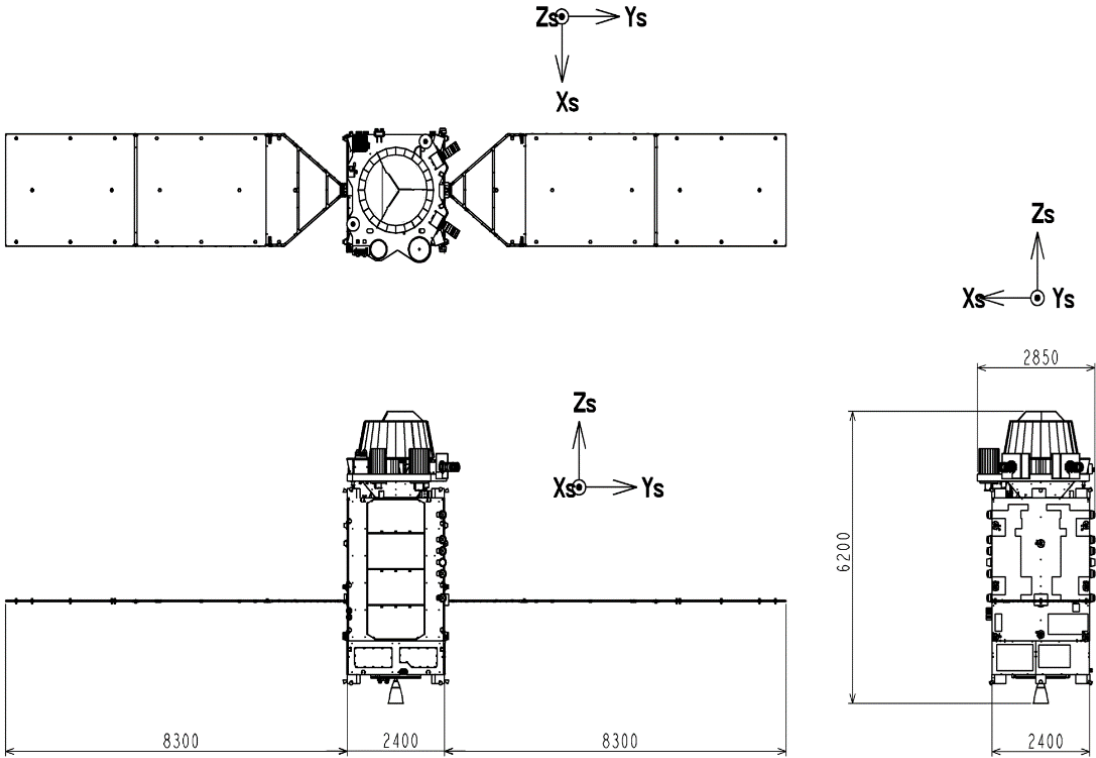
## (d) L6

|       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| NOAZI | +0.00 | +0.02 | +0.07 | +0.10 | +0.13 | +0.18 | +0.22 | +0.27 | +0.34 | +0.40 | +0.46 | +0.50 | +0.53 | +0.54 | +0.52 | +0.47 | +0.39 | +0.29 | +0.15 | -0.01 | -0.19 |
| 0.0   | +0.00 | +0.01 | +0.03 | +0.04 | +0.03 | +0.04 | +0.04 | +0.07 | +0.13 | +0.18 | +0.22 | +0.27 | +0.32 | +0.35 | +0.36 | +0.35 | +0.31 | +0.27 | +0.19 | +0.09 | -0.05 |
| 10.0  | +0.00 | +0.03 | +0.06 | +0.09 | +0.12 | +0.18 | +0.20 | +0.25 | +0.34 | +0.39 | +0.46 | +0.52 | +0.60 | +0.60 | +0.63 | +0.61 | +0.56 | +0.52 | +0.40 | +0.32 | +0.16 |
| 20.0  | +0.00 | +0.03 | +0.07 | +0.10 | +0.13 | +0.18 | +0.23 | +0.29 | +0.37 | +0.45 | +0.53 | +0.62 | +0.69 | +0.74 | +0.77 | +0.78 | +0.75 | +0.69 | +0.61 | +0.50 | +0.34 |
| 30.0  | +0.00 | +0.07 | +0.11 | +0.15 | +0.21 | +0.25 | +0.33 | +0.41 | +0.48 | +0.57 | +0.65 | +0.73 | +0.82 | +0.86 | +0.91 | +0.91 | +0.89 | +0.82 | +0.74 | +0.65 | +0.50 |
| 40.0  | +0.00 | +0.09 | +0.16 | +0.22 | +0.31 | +0.37 | +0.48 | +0.59 | +0.67 | +0.78 | +0.89 | +0.96 | +1.05 | +1.11 | +1.13 | +1.13 | +1.10 | +1.03 | +0.94 | +0.83 | +0.70 |
| 50.0  | +0.00 | +0.06 | +0.14 | +0.20 | +0.28 | +0.36 | +0.44 | +0.54 | +0.67 | +0.80 | +0.90 | +1.00 | +1.08 | +1.17 | +1.19 | +1.21 | +1.15 | +1.11 | +1.02 | +0.91 | +0.76 |
| 60.0  | +0.00 | +0.07 | +0.19 | +0.26 | +0.32 | +0.43 | +0.50 | +0.59 | +0.70 | +0.80 | +0.89 | +0.98 | +1.05 | +1.09 | +1.15 | +1.13 | +1.10 | +1.08 | +0.98 | +0.89 | +0.74 |
| 70.0  | +0.00 | +0.10 | +0.22 | +0.31 | +0.42 | +0.55 | +0.67 | +0.78 | +0.89 | +1.00 | +1.11 | +1.20 | +1.26 | +1.31 | +1.34 | +1.32 | +1.27 | +1.22 | +1.11 | +1.01 | +0.87 |
| 80.0  | +0.00 | +0.09 | +0.22 | +0.33 | +0.41 | +0.53 | +0.65 | +0.77 | +0.89 | +1.02 | +1.13 | +1.23 | +1.31 | +1.38 | +1.41 | +1.39 | +1.37 | +1.30 | +1.19 | +1.07 | +0.93 |
| 90.0  | +0.00 | +0.13 | +0.24 | +0.36 | +0.46 | +0.57 | +0.69 | +0.80 | +0.91 | +1.05 | +1.15 | +1.23 | +1.32 | +1.38 | +1.40 | +1.39 | +1.34 | +1.29 | +1.19 | +1.08 | +0.93 |
| 100.0 | +0.00 | +0.12 | +0.25 | +0.38 | +0.49 | +0.65 | +0.76 | +0.89 | +1.03 | +1.13 | +1.26 | +1.34 | +1.42 | +1.45 | +1.48 | +1.45 | +1.39 | +1.35 | +1.25 | +1.11 | +0.96 |
| 110.0 | +0.00 | +0.10 | +0.23 | +0.35 | +0.48 | +0.59 | +0.71 | +0.84 | +0.98 | +1.11 | +1.23 | +1.32 | +1.41 | +1.47 | +1.48 | +1.48 | +1.43 | +1.37 | +1.26 | +1.14 | +1.00 |
| 120.0 | +0.00 | +0.08 | +0.23 | +0.35 | +0.44 | +0.53 | +0.65 | +0.74 | +0.89 | +0.99 | +1.10 | +1.17 | +1.23 | +1.27 | +1.29 | +1.27 | +1.23 | +1.16 | +1.07 | +0.96 | +0.82 |
| 130.0 | +0.00 | +0.10 | +0.23 | +0.34 | +0.47 | +0.59 | +0.70 | +0.82 | +0.94 | +1.05 | +1.14 | +1.23 | +1.27 | +1.32 | +1.30 | +1.28 | +1.17 | +1.10 | +0.97 | +0.80 | +0.65 |
| 140.0 | +0.00 | +0.10 | +0.22 | +0.31 | +0.42 | +0.53 | +0.63 | +0.74 | +0.86 | +1.00 | +1.09 | +1.17 | +1.24 | +1.25 | +1.26 | +1.21 | +1.13 | +1.02 | +0.89 | +0.76 | +0.55 |
| 150.0 | +0.00 | +0.10 | +0.21 | +0.30 | +0.42 | +0.50 | +0.61 | +0.69 | +0.79 | +0.89 | +0.98 | +1.04 | +1.08 | +1.11 | +1.10 | +1.04 | +0.95 | +0.87 | +0.73 | +0.58 | +0.40 |
| 160.0 | +0.00 | +0.07 | +0.19 | +0.27 | +0.37 | +0.46 | +0.55 | +0.65 | +0.76 | +0.85 | +0.94 | +0.98 | +1.01 | +1.02 | +1.00 | +0.93 | +0.82 | +0.70 | +0.54 | +0.38 | +0.15 |
| 170.0 | +0.00 | +0.07 | +0.14 | +0.20 | +0.27 | +0.36 | +0.44 | +0.51 | +0.61 | +0.69 | +0.78 | +0.81 | +0.85 | +0.87 | +0.87 | +0.80 | +0.68 | +0.57 | +0.40 | +0.23 | +0.03 |
| 180.0 | +0.00 | +0.05 | +0.12 | +0.16 | +0.20 | +0.24 | +0.31 | +0.35 | +0.40 | +0.46 | +0.50 | +0.52 | +0.54 | +0.55 | +0.53 | +0.46 | +0.35 | +0.24 | +0.09 | -0.09 | -0.29 |
| 190.0 | +0.00 | +0.03 | +0.10 | +0.12 | +0.19 | +0.24 | +0.27 | +0.32 | +0.37 | +0.44 | +0.45 | +0.48 | +0.47 | +0.46 | +0.40 | +0.33 | +0.19 | +0.07 | -0.11 | -0.33 | -0.53 |
| 200.0 | +0.00 | +0.00 | +0.05 | +0.05 | +0.06 | +0.12 | +0.13 | +0.18 | +0.24 | +0.29 | +0.31 | +0.35 | +0.35 | +0.32 | +0.29 | +0.20 | +0.05 | -0.08 | -0.25 | -0.44 | -0.68 |
| 210.0 | +0.00 | -0.01 | +0.02 | +0.01 | +0.03 | +0.04 | +0.05 | +0.09 | +0.10 | +0.11 | +0.14 | +0.17 | +0.20 | +0.14 | +0.10 | +0.03 | -0.07 | -0.22 | -0.37 | -0.57 | -0.79 |
| 220.0 | +0.00 | -0.01 | +0.01 | +0.01 | +0.01 | +0.04 | +0.05 | +0.09 | +0.11 | +0.12 | +0.15 | +0.16 | +0.14 | +0.12 | +0.06 | -0.05 | -0.14 | -0.32 | -0.48 | -0.67 | -0.89 |
| 230.0 | +0.00 | -0.04 | -0.05 | -0.07 | -0.09 | -0.08 | -0.09 | -0.07 | -0.05 | -0.01 | +0.01 | +0.01 | -0.01 | -0.01 | -0.05 | -0.15 | -0.26 | -0.40 | -0.58 | -0.79 | -1.02 |
| 240.0 | +0.00 | -0.06 | -0.06 | -0.11 | -0.14 | -0.15 | -0.17 | -0.20 | -0.18 | -0.18 | -0.18 | -0.18 | -0.20 | -0.24 | -0.29 | -0.40 | -0.52 | -0.65 | -0.84 | -1.04 | -1.27 |
| 250.0 | +0.00 | -0.03 | -0.07 | -0.09 | -0.11 | -0.12 | -0.15 | -0.15 | -0.15 | -0.12 | -0.12 | -0.13 | -0.17 | -0.22 | -0.30 | -0.40 | -0.55 | -0.70 | -0.89 | -1.13 | -1.37 |
| 260.0 | +0.00 | -0.04 | -0.08 | -0.12 | -0.18 | -0.20 | -0.20 | -0.22 | -0.22 | -0.20 | -0.20 | -0.22 | -0.25 | -0.30 | -0.38 | -0.47 | -0.61 | -0.78 | -0.96 | -1.19 | -1.43 |
| 270.0 | +0.00 | -0.06 | -0.10 | -0.17 | -0.20 | -0.24 | -0.27 | -0.29 | -0.29 | -0.28 | -0.28 | -0.29 | -0.30 | -0.35 | -0.42 | -0.53 | -0.64 | -0.78 | -0.96 | -1.17 | -1.37 |
| 280.0 | +0.00 | -0.07 | -0.11 | -0.14 | -0.18 | -0.21 | -0.22 | -0.25 | -0.26 | -0.27 | -0.29 | -0.30 | -0.34 | -0.38 | -0.45 | -0.56 | -0.67 | -0.81 | -1.00 | -1.17 | -1.38 |
| 290.0 | +0.00 | -0.05 | -0.12 | -0.16 | -0.19 | -0.20 | -0.26 | -0.28 | -0.27 | -0.27 | -0.28 | -0.29 | -0.31 | -0.35 | -0.40 | -0.50 | -0.60 | -0.74 | -0.89 | -1.08 | -1.28 |
| 300.0 | +0.00 | -0.05 | -0.07 | -0.14 | -0.17 | -0.20 | -0.21 | -0.24 | -0.25 | -0.24 | -0.25 | -0.28 | -0.29 | -0.33 | -0.39 | -0.47 | -0.57 | -0.68 | -0.84 | -1.02 | -1.21 |
| 310.0 | +0.00 | -0.04 | -0.07 | -0.12 | -0.12 | -0.16 | -0.17 | -0.15 | -0.17 | -0.16 | -0.16 | -0.15 | -0.16 | -0.21 | -0.26 | -0.34 | -0.44 | -0.59 | -0.74 | -0.93 | -1.15 |
| 320.0 | +0.00 | -0.06 | -0.10 | -0.11 | -0.16 | -0.17 | -0.18 | -0.20 | -0.17 | -0.13 | -0.13 | -0.10 | -0.10 | -0.13 | -0.16 | -0.26 | -0.37 | -0.49 | -0.67 | -0.87 | -1.06 |
| 330.0 | +0.00 | -0.03 | -0.05 | -0.08 | -0.10 | -0.11 | -0.11 | -0.12 | -0.08 | -0.04 | -0.01 | +0.01 | +0.01 | +0.01 | -0.04 | -0.09 | -0.19 | -0.31 | -0.45 | -0.61 | -0.82 |
| 340.0 | +0.00 | -0.03 | -0.04 | -0.05 | -0.07 | -0.04 | -0.02 | +0.00 | +0.07 | +0.12 | +0.15 | +0.20 | +0.22 | +0.23 | +0.22 | +0.16 | +0.07 | -0.02 | -0.16 | -0.30 | -0.49 |
| 350.0 | +0.00 | -0.05 | -0.02 | -0.07 | -0.05 | -0.05 | -0.03 | -0.01 | +0.05 | +0.12 | +0.19 | +0.24 | +0.27 | +0.30 | +0.31 | +0.29 | +0.23 | +0.19 | +0.05 | -0.08 | -0.22 |
| 360.0 | +0.00 | +0.01 | +0.03 | +0.04 | +0.03 | +0.04 | +0.04 | +0.07 | +0.13 | +0.18 | +0.22 | +0.27 | +0.32 | +0.35 | +0.36 | +0.35 | +0.31 | +0.27 | +0.19 | +0.09 | -0.05 |



6. Geometry

The spacecraft dimensions are described in Figure 4.



(Unit: mm)

Figure 4 Satellite dimensions

The optical properties of surfaces at BOL are provided in Table 4.

Table 4 Optical properties<sup>(\*2)</sup>

| Location | Material           | Area [m <sup>2</sup> ] | Absorption | Specular | Diffuse |
|----------|--------------------|------------------------|------------|----------|---------|
| +X       | MLI                | 10.1                   | 0.926      | 0.035    | 0.039   |
| -X       | MLI                | 10.1                   | 0.926      | 0.035    | 0.039   |
| +Y       | MLI                | 6.2                    | 0.926      | 0.035    | 0.039   |
|          | Radiator           | 3.9                    | 0.026      | 0.954    | 0.020   |
|          | SAP                | 14.9                   | 0.923      | 0.068    | 0.009   |
| -Y       | MLI                | 5.7                    | 0.926      | 0.035    | 0.039   |
|          | Radiator           | 4.4                    | 0.026      | 0.954    | 0.020   |
|          | SAP                | 14.9                   | 0.923      | 0.068    | 0.009   |
| +Z       | MLI                | 2.7                    | 0.926      | 0.035    | 0.039   |
|          | L-ANT Cover        | (*1)                   | 0.553      | 0.100    | 0.347   |
|          | L1S/L5S-ANT Covers | 0.3                    | 0.553      | 0.100    | 0.347   |
| -Z       | MLI                | 5.6                    | 0.926      | 0.035    | 0.039   |

\*1 : L-ANT shape is approximately depicted as a truncated circular cone comprised of  $\varnothing$ 1.5m and  $\varnothing$ 1.8m circles 0.8m apart.

\*2 : Regarding the acquisition of these data, we received significant support from the assistant professor " Dr. Satoshi Ikari " of University of Tokyo.

## 7. Laser Retro Reflector Location

The location of the optical center of the laser retro-reflector array (LRA) with respect to the satellite reference frame is provided in Table 5.

Table 5 Location of LRA optical center

|                | Coordinates (w.r.t. origin) [mm] |        |         |
|----------------|----------------------------------|--------|---------|
|                | X                                | Y      | Z       |
| Optical Center | -988.2                           | -860.8 | +4373.3 |

## 8. Satellite Group Delay

### 8.1 Satellite Group Delay

N/A

### 8.2 Differential Code Bias

The differential code bias (DCB) between L1, L2, and L5 signals are provided in Table 7.

Table 7 Differential code bias

| Signal | DCB [ns] |
|--------|----------|
| L1-L2  | 1.55     |
| L1-L5  | 1.98     |

## 9. Antenna Transmit Power

Total transmit power is approximately 500W.

## 10. GNSS Bibliography

[1] Quasi-Zenith Satellite System Interface Specification Satellite Positioning, Navigation and Timing Service, the Cabinet Office, Government of Japan, 2017.

[2] ILRS SLR Mission Support Request Form

## Revision History

| Rev.No | Date              | Page | Revisions   |
|--------|-------------------|------|---|
| Org    | November 30, 2017 |      | Original  |
| A      |                   | 3    | Add description of yaw steering mode              |
|        |                   | 4    | Add ftp site of ANTEX file<br>Improve explanation |
|        |                   | 10   | Add optical properties                            |