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MEMO

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from/*de*	Alberto Bigazzi & Björn Frommknecht	visa/*visa*			
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Subject/*objet* **GOCE instruments positioning**

Note on GOCE instruments Positioning

CHANGE LOG

reason for change /*raison du changement*	issue/*issue*	revision/*revision*	date/*date*
First Issue	1	0	30 June 09
Formatting clean-up	1	1	16 Jul 09
Updated after HPF PM#16	2	0	06 Aug 09
Updated according to new information from Industry on +/-Z mounting, resulting most notably in the updating of Table 9 (Antenna Phase Centres Locations). Also LRR coordinates are affected. Updated version of STR-Gradio Rotation Matrix are also available	3	0	01 Dec 09
Includes all corrections and clarifications sent to A.J. (HPF Team) on 30/12/2009.	3	1	01 Mar 2010

CHANGE RECORD

Issue: 1 Revision: 1

reason for change/*raison du changement*	page(s)/*page(s)*	paragraph(s)/*paragraph(s)*

reason for change/*raison du changement*	page(s)/*page(s)*	paragraph(s)/*paragraph(s)*
- Figures in Table 4 are rounded-off consistent with precision in center of mounting knowledge Added Table 4 caption. (following tables get re-numbered accordingly) - Formatting and cross-references cleaned-up		

Issue: 2 Revision: 0

reason for change/*raison du changement*	page(s)/*page(s)*	paragraph(s)/*paragraph(s)*
Par. 6 Sign of rotation added to text. New Table 1 and Table 2 labels added to pre-existing tables. All Tables numbering have been shifted accordingly +X/-X notation, changed to Top and Bottom, for clarity GPS Antennas center of mounting coordinates in Table 7 have been referred to most recent Test Report in place of Design documents. Table 5 has been removed in favour of a textual explaination. New Table 8 with Measured Antennas Centre of Mounting and Tip Z-coordinates added. Figure 5 removed as no longer necessary.		

Issue: 3 Revision: 0

reason for change/*raison du changement*	page(s)/*page(s)*	paragraph(s)/*paragraph(s)*
New reference documents for Antenna positioning		Par 2
Paragraph restructured.		Par 6
LRR configuration changed: Z-→ -Z		
Figure 1 updated accordingly		
Table 2 updated accordingly		
Figure 4 Updated according to new configuration.		Par 6
Antenna Reference Frame to Satellite Reference Frame rotation angle updated to new configuration and text updated accordingly.		Par 6
Table 7 reporting baseline and alternate values.and Table 8 updated and contents re-arranged for improved readability.		
New rotation matrices from AUX EGG_DB version 0010.		Par 7
Figures 5, 6 and 7 on rotation matrices have been removed, as no longer current.		

Issue: 3 Revision: 1

reason for change/*raison du changement*	page(s)/*page(s)*	paragraph(s)/*paragraph(s)*
New paragraph 1.1, containing a summary of Dusk-Dawn configuration and the solar arrays plane definition.		
Table 1. Units have been changed from mm to m and figures corrected accordingly, where appropriate.		

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1. Scope

This Memo describes positioning of GOGE's LRR, GPS Antenna and on the relative positioning of STR to Gradiometer.

Current industry documentation on Spacecraft Configuration is not univocal, some conflicting information still remaining across it.
This Note will assume as valid the information on antenna configuration reported in the S/C Reconfiguration activity Log Book [RD.12], where a –Z mounting is reported.
This is consistent with the configurations appropriate to the Dusk-Dawn orbit, in [RD.1] and [RD.5].
It has to be noted, however, that this conflicts with what reported by the satellite configuration list, [RD.12] (version valid at launch), and the PFM Alignment Test Reports [RD.4], prior to launch, where a +Z mounting is reported instead, for antennas.

1.1 Dusk-Dawn configuration

The selected Goce orbit at launch was Dusk-Dawn. GOCE Dusk-Dawn congiguration is such that [RD.1]:

- GPS FM Antennas (q.ty 2) mounted at zenith wing -Z;
- GPS Dummies Antennas (q.ty 2) mounted at zenith wing +Z;
- LRR Dummy (q.ty 1) mounted on tip of S/L on - Z;
- LRR FM (q.ty 1) mounted on tip of S/L on + Z;
- STR's (q.ty 3) positioned on Floor 4 (that is equipped with all inserts points to have free choice of positions).on the +Y/-Z quadrant;
- Solar Arrays surface is oriented as the –Y plane.

2. Reference Documents

RD.1 GO-IC-AI-0002 Satellite Mechanical ICD, Issue 5
RD.2 GOCE-LRR-01 LRR Set of documents
RD.3 GO-RW-AI-1006 Satellite Mass evaluation (RFW)
RD.4 GO-TR-AI-0034 Goce PFM Alignment Test Reports Is 2, 23 Jan 09
RD.5 GO-TN-AI-0137 Goce SSTI Performance Assessment, Is 3, 14 Jun 07
RD.6 FM2-L1CP.TXT Rymsa antenna offsets correction file
RD.7 FM2-L2CP.TXT Rymsa antenna offsets correction file
RD.8 FM3-L1CP.TXT Rymsa antenna offsets correction file
RD.9 FM3-L2CP.TXT Rymsa antenna offsets correction file
RD.10 TN-GOCE-PCV Technical Note on GOCE PCV, 07 Aug 2007

RD.11 EWI 260 (S/C Reconfiguration activity) Log Book section 17 of EIDP
RD.12 satellite configuration list, GO-CS-AI-0010, iss18

3. Satellite Reference Frame

All coordinates are referred to the Satellite Reference Frame (SL) described in [RD.01].

- SL:{O_{SL}, X_{SL} ,Y_{SL} ,Z_{SL} }
- Coordinate System is Right-handed.

Figure 1 shows the reference frame in the X-Z plane. Figure is not to scale.

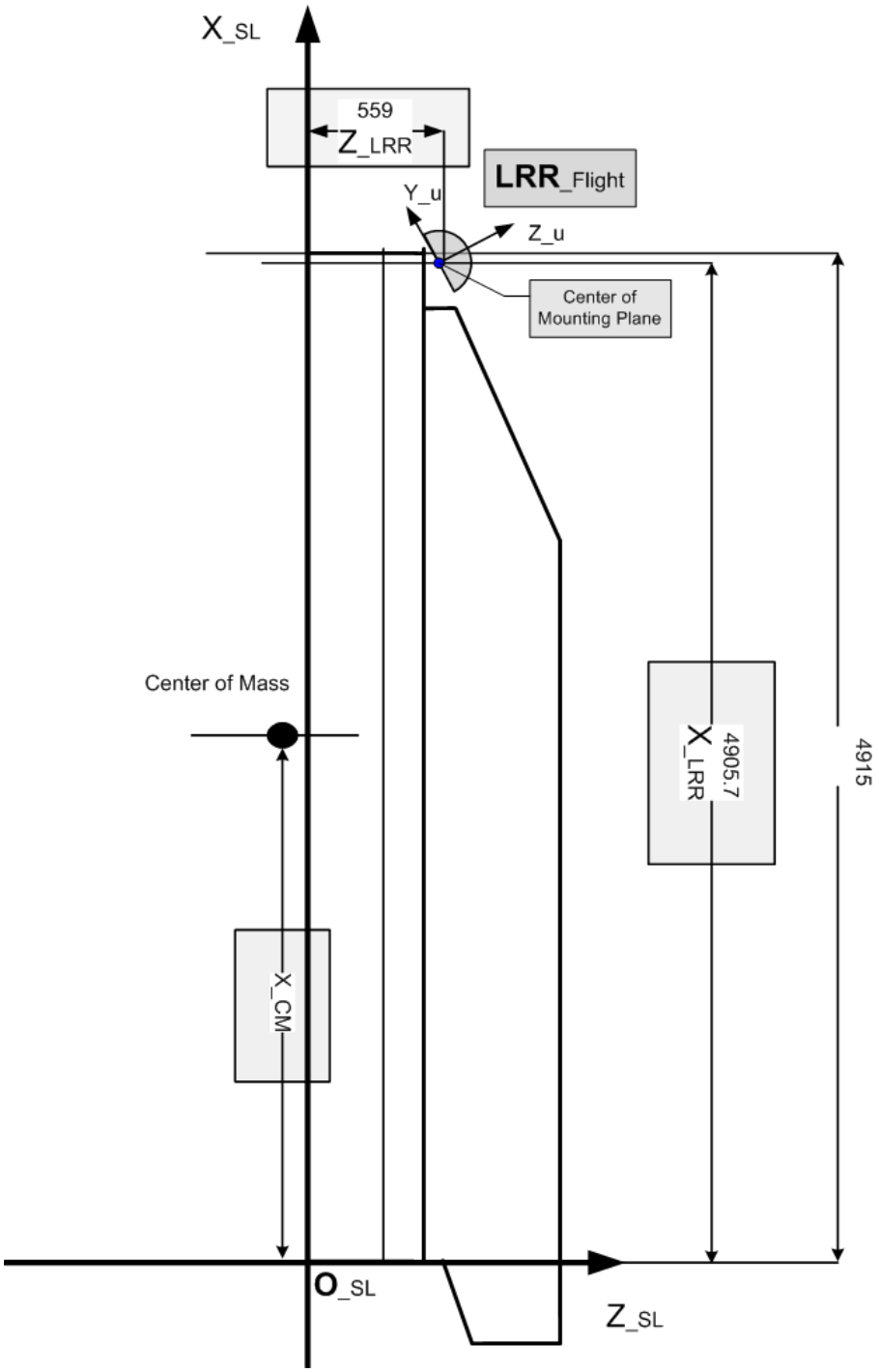

Figure 1 LRR mounting (not to scale)

4. Satellite Centre of Mass position

Satellite's Centre of Mass position changes during operational lifetime.
Beginning of Life (BoL) and End of Life (EoL) Center of Mass positions as declared in [RD.03] are listed below

Center of Mass	X_{CM} [m]	Y_{CM} [m]	Z_{CM} [m]
BoL	2.500	0.0036	0.0011
EoL	2.529	0.0038	0.0012

Table 1 Center of Mass Coordinates

5. LRR Centre of Mounting Plane position

Two Laser Retro Reflectors (LRR) are symmetrically mounted on Goce:

- LRR +Z: Flight
- LRR - Z: Dummy

Where + or – Z refers to the SL coordinate reference frame.
We give below the centre of mounting plane coordinates.

LRR Flight (-Z)	X_{LRR} [mm]	Y_{LRR} [mm]	Z_{LRR} [mm]
Center of Mounting Plane	4906.6	0.4	559.0

Table 2 Coordinates of LRR Centre of Mounting Plane [RD.1] and [RD.4]

Positions are calculated considering design specs [RD.1] and the results from the GOCE Dimensional Verification Test Reports, [RD.4], as shown hereafter:

- $X_{LRR} = 4905.7+0.9$ [mm]
- $Y_{LRR} = 0.0 +0.4$ [mm]
- $Z_{LRR} = 559.0+0.0$ [mm]

First figure is from design spec [RD.1] and second one is the correction reported by the Test Reports [RD.4]
Figure 2 reports all other LRR relevant dimensions, referred to the centre of mounting plane.

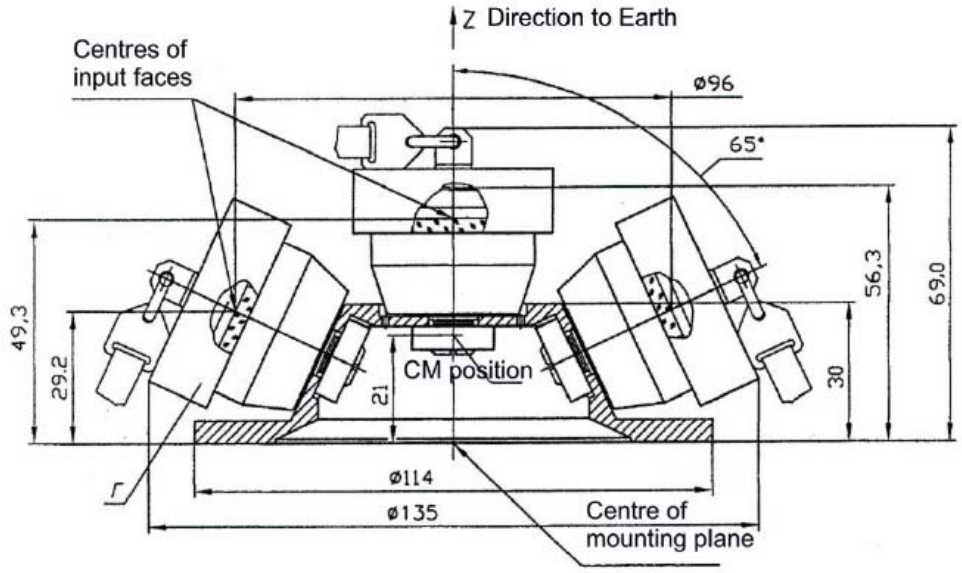

Figure 2 LRR schema with dimensions from [RD.2]

By requirement, sizing error for the position of equivalent reflective plane of the GOCE-LRR Laser Retro Reflector with respect to the centre of mounting plane is less than 0.8 mm.

Range-determination systematic corrections

By requirement, range-determination systematic correction relative to GOCE-LRR mounting surface on the spacecraft varies from 21.4 to 13.7 mm, depending on elevation angle (see Table 3).
The systematic correction shall be added to the measured range.

Elevation angle, deg	20	30	40	50	60	70	80	90
Systematic correction, mm	20.7	21.4	20.6	18.3	13.7	17.9	20.5	21.4

Table 3 LRR range-determination systematic corrections [RD.2]

LRR Center of Mounting Plane position w.r.t. CoM

Laser Retro Reflectors (LRR) position w.r.t the Center of Mass, **R**, is given by:

- $\mathbf{R}_{\_LRR\text{-}CM} = \mathbf{R}_{\_LRR} - \mathbf{R}_{\_CM}$

Table below reports the BoL and EoL values, truncated at 0.1 mm precision. Higher precision would not reflect true knowledge.

LRR Flight (-Z)-CM	$X_{\_LRR\text{-}CM}$ [mm]	$Y_{\_LRR\text{-}CM}$ [mm]	$Z_{\_LRR\text{-}CM}$ [mm]
BoL	2406.6	0.4	559.0
EoL	2377.6	0.4	559.0

Table 4 LRR coordinates w.r.t. CoM

6. GPS Antennas

Concerning Antenna positions, they are derived from the SSTI antenna performance assessment, [RD.5] as updated by the PFM Alignment Test Reports prior to launch, [RD.4]. Absolute positions of centers of mounting in the Satellite Reference Frame are derived from the design specifications in [RD.1].

Reference Frames

Antenna performance evaluation has been carried out in the Antenna Reference Frame whose relation to Satellite Reference Frame is shown in Figure 3 and Figure 4.
In order to convert Satellite Reference Frame coordinates into Centre of Mass Frame, Table 1 may be used.

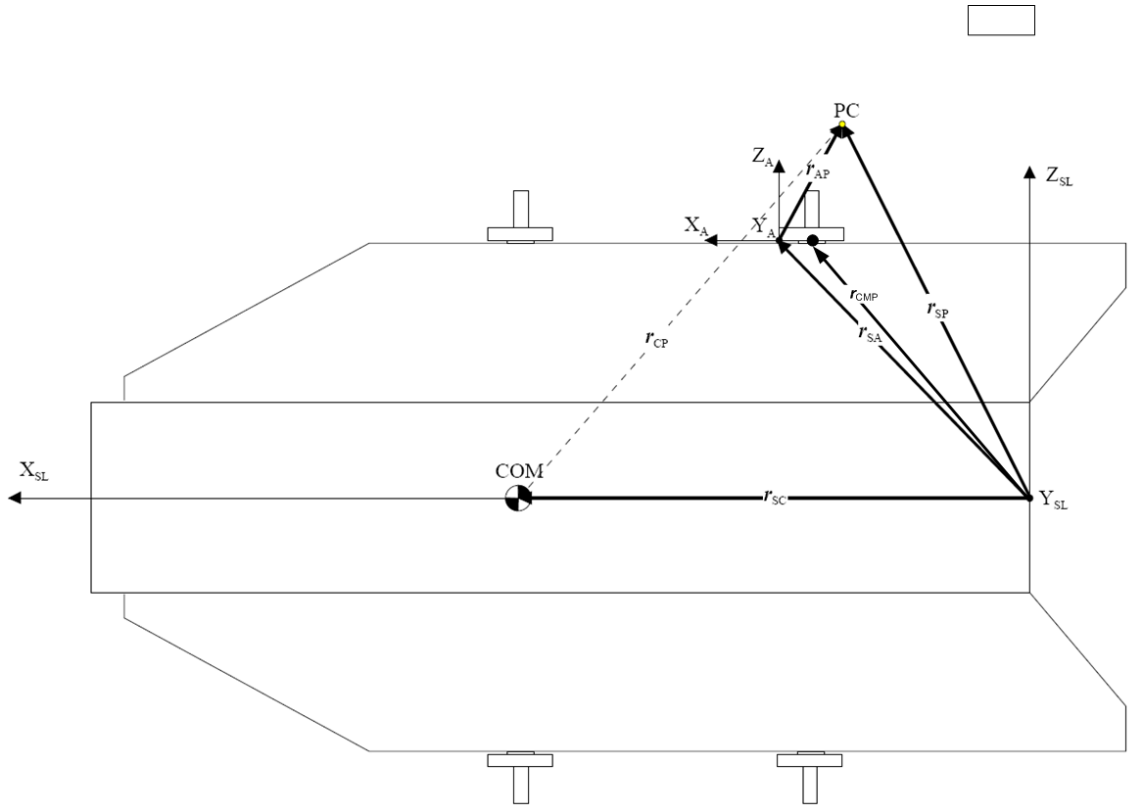

Figure 3 Antennas and Satellite Reference Frames [RD.5]

Antennas Configuration

Two GPS antennas are mounted on GOCE, nominal and redundant ones, with the following configuration (Dusk-Dawn orbital config), see [RD.5].
Flight models are mounted in +Z plane.

GPS Antenna location	Type	Id
GPS ant -Z, Top	Nominal	FM 002
GPS ant -Z, Bottom	Redundant	FM 003

Table 5 Antennas flight configuration

GPS Antennas Coordinates

The origin of the Antenna Reference Frame is not on antenna's helix axis. Antenna Reference Frame is on the mounting reference hole, which is on the edges of the antenna mounting, see Figure 4 , displaced from the centre by an amount equal to 69.5 mm, by design, see [RD.1]. We note here a discrepancy w.r.t. [RD.5], where a value of 69.4mm is given, instead. We shall assume the former as the baseline value, but report both for completeness, see Table 6 .

Ant. Center of Mounting Plane coordinates in Antenna Ref. frame (SL, Design)	X [mm]	Y [mm]	Z [mm]
Baseline value [RD.1]	-69.5	0	0
Non-baseline value [RD.5]	-69.4	0	0

Table 6 Ant. Center of Mounting Plane coordinates in Antenna Ref. frame (SL, Design), [RD.1] and [RD.5].

A 135 degrees counter-clockwise rotation on the Z axis is also applied, when transforming from Satellite to Antenna RF, see Figure 4. Note that drawing actually refers to DADU configuration for Dummies, which we assume to be the same as that for DUDA configuration for Flight models.

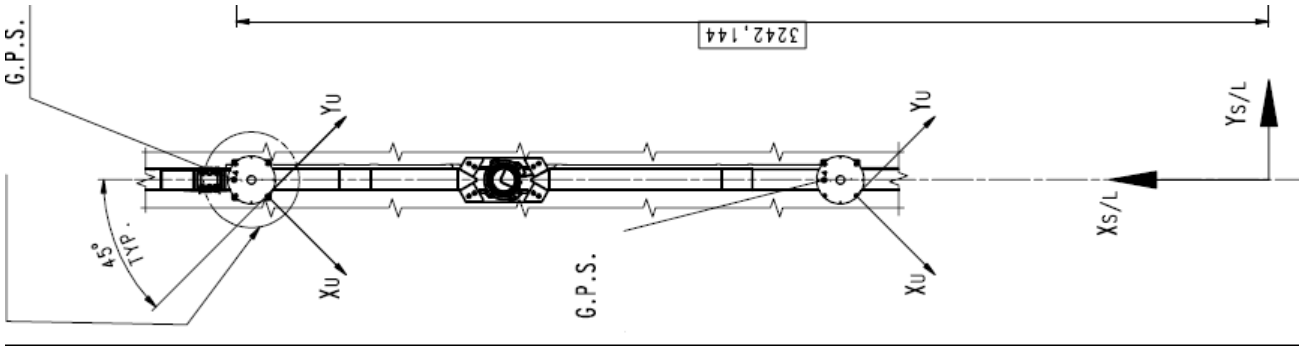

Figure 4 Antenna Reference Frame center and rotation w.r.t. S/L Reference Frame [RD.1], Z_s/l is pointing into the plane Solar panels are in the –Y plane. Note: this drawing originally refers to DADU configuration for Dummies, here assumed to be the same as DUDA for FM.

GPS antennas Centre of Mounting coordinates, by design and measured, are given in Table 7. Values are expressed in the Satellite Reference Frame.

Center of Mounting Plane	X (des) [mm]	Y (des) [mm]	Z (des) [mm]	Z (measured) [mm]
GPS ant Top.	3193.0	0.0	-1093.0	-1092.2
GPS ant Bottom.	1345.0	0.0	-1093.0	-1090.3

Table 7 GPS antennas. Coordinates of Centre of Mounting according to Design [RD.1] and Test [RD.4], SL frame.

Measured Z-coordinates of Antenna tips are given in Table 8.
Values are expressed in the Satellite Reference Frame.

Antenna Tip	Z (measured) [mm]
GPS ant Top.	-1217.8
GPS ant Bottom	-1215.8

Table 8 Measured Z-Coordinates of GPS Antennas Tip, [RD.4] SL frame.

GPS Antennas mean Phase Centres and Offsets Calculation

Mean phase centres for antennas, for both L1 and L2 carriers, are given in Table 9 X' coordinate, w.r.t antenna helix centre, is also given for reference. This value may be used if applying a different offset, see Table 6.

MeanPhase Centres	L1				L2			
(Antenna RF)	*X'[mm]*	X[mm]	Y[mm]	Z [mm]	*X'[mm]*	X[mm]	Y[mm]	Z [mm]
FM SN 002	*-2.35*	-71.85	2.61	81.11	*1.57*	-67.93	0.16	84.18
FM SN 003	*-1.54*	-71.04	2.9	81.33	*1.9*	-67.6	0.2	84.18

Table 9 Antennas Phase Centre Location Coordinates, in Antenna Reference Frame [RD.5]. X' coordinates, w.r.t antenna helix centre, is also given, see Table 6.

Phase centre location depends on GPS signal direction of arrival (DoA). Phase centres are calculated by adding an offset, dependent on azimuth and elevation, to the mean phase centre given in Table 9

A set of separate files from Rymsa, [RD.6] to [RD.9], one for each antenna and carrier combination, contain the phase offsets to be applied, in degrees, as a function of the DoA angle. A companion Technical Note, [RD.10] gives details on how angles are defined within the Rymsa files.

7. STR to Gradiometer Rotation Matrix

GOCE product AUX_EGG_DB contains the STR to Gradiometer rotation matrices.
The version valid at launch, consistent with values reported in [RD.4], was version 0005.
The current version is 0010.
Current version takes into account the in-flight determination of the relative orientation of the star trackers.

SST-1	X_{GRF}	Y_{GRF}	Z_{GRF}
X_{SSRF}	9.99991953964E-01	-2.87527613216E-03	-2.79728350732E-03
Y_{SSRF}	-3.85545306786E-03	-4.96285685373E-01	-8.68150709252E-01
Z_{SSRF}	1.10792125081E-03	8.68154508875E-01	-4.96292777733E-01

Table 10 STR-1 Transformation Matrix according to AUX_EGG_DB file v0010

SST-2	X_{GRF}	Y_{GRF}	Z_{GRF}
X_{SSRF}	9.99868439135E-01	1.61493120811E-02	1.51793982847E-03
Y_{SSRF}	1.57267935130E-02	-9.42268716879E-01	-3.34488165946E-01
Z_{SSRF}	-3.97144656483E-03	3.34468032720E-01	-9.42398728087E-01

Table 11 STR-2 Transformation Matrix according to AUX_EGG_DB file v0010

SST-3	X_{GRF}	Y_{GRF}	Z_{GRF}
X_{SSRF}	1.18462427802E-02	-4.91411293086E-01	-8.70847063243E-01
Y_{SSRF}	-7.69183928773E-01	5.51999304112E-01	-3.21951629871E-01
Z_{SSRF}	6.38917639645E-01	6.73655482637E-01	-3.71446551289E-01

Table 12 STR-3 Transformation Matrix according to AUX_EGG_DB file v0010

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