

SENTINEL-3 PROPERTIES FOR GPS POD

COPERNICUS SENTINEL-1, -2 AND -3 PRECISE ORBIT DETERMINATION SERVICE (SENTINELSPOD)

19/11/2019

Prepared by:

XM

M. Fernández Project Engineer

Signed by: Marc Fernández Usón

19/11/2019

19/11/2019

Approved by:

J. Aguilar

Quality Manager

Firmado por: Juan Antonio Aguilar Miguel

Authorised by: X take this

J. Fernández

Project Manager

Signed by: Jaime Fernández Sánchez

Document ID: GMV-GMESPOD-TN-0027

DIL Code: TD-22

Internal Code: GMV 20885/16 V8/19

Version: 1.7

Date: 18/11/2019

ESA contract number: 4000108273/13/1-NB



Code:
Date:
Version:
ESA contract:
Page: GMV-GMESPOD-TN-0027 18/11/2019 1.7

4000108273/13/1-NB 2 of 23

DOCUMENT STATUS SHEET

Version	Date	Pages	Changes		
1.0	01/04/2016	24	First version		
1.1	10/06/2016	24	Updated information on: GNSS Antenna Centre of Frame (section 3.2) DORIS Antenna Phase Centre Offset variations (section 3.3) SLR Antenna corrections (section 3.4) SRAL Antenna corrections (section 3.5)		
1.2	12/06/2016	25	Updated information on: Include additional reference documents (section 1.4.2) LRR azimuth – elevation corrections (section 3.4) Solar Array area (section 5.1) Thermo-Optical Surface Properties (section 5.3)		
1.3	30/03/2016	22	Jpdate list of applicable documents (section 1.4.1). Jpdate all references to Sentinel-3A to Sentinel-3 to make this document applicable to both satellites.		
1.4	07/05/2018	23	Correct location of Mech. Mounting ref. point of GNSS-1 antenna of S-3A (Table 3 2) Include the S3 ESOC IDs in section 4.3. Include the format of Outages NAPEOS file in section 4.4.		
1.5	21/01/2019	23	Update the format of the NAPEOS attitude files (section 4.1)		
1.6	16/09/2019	23	Include table with acronyms (section 1.3) Added reference to quaternions file format in section 2 and removed explicit description from section 4 Updated list of applicable and reference documents (section 1.4)		
1.7	18/11/2019	23	Update origin of Sentinel-3A antenna reference point (section 3.1)		



Page:

Code: GMV-GMESPOD-TN-0027
Date: 18/11/2019
Version: 1.7
ESA contract: 4000108273/13/1-NB
Page: 3 of 23 3 of 23

TABLE OF CONTENTS

1. INTRODUCTION	6
1.1. PURPOSE	6
1.2. SCOPE	6
1.3. DEFINITIONS AND ACRONYMS	6
1.4. APPLICABLE AND REFERENCE DOCUMENTS	
1.4.1. APPLICABLE DOCUMENTS	
1.4.2. REFERENCE DOCUMENTS	
2. SENTINEL-3 NOMINAL ATTITUDE MODE	_
2.1. ATTITUDE POINTING MODE	
2.2. ATTITUDE IMPLEMENTATION	9
3. CONFIGURATION OF SATELLITE AND POD INSTRUMENTS	12
3.1. CENTRE OF GRAVITY (COG) AND MASS	12
3.2. GNSS ANTENNAE	12
3.3. DORIS ANTENNA	14
3.4. LASER RETRO REFLECTOR (LRR)	15
3.5. SRAL ANTENNA	17
4. NAPEOS FORMAT SPECIFICATION	18
4.1. SENTINEL MASS HISTORY FILE FORMAT	18
4.2. SENTINEL MANOEUVRE FILE FORMAT	18
4.3. SENTINEL-3 OUTAGES NAPEOS FORMAT	19
5. SATELLITE DESCRIPTION	20
5.1. SPACECRAFT GEOMETRICAL MODEL	20
5.2. SOLAR ARRAY	21
5.3. THERMO OPTICAL SURFACE PROPERTIES	22



GMV-GMESPOD-TN-0027 18/11/2019 1.7 4000108273/13/1-NB 4 of 23

LIST OF TABLES

Table 1-	l: Acronyms	. 6
Table 1-	2: Applicable Documents	. 7
Table 1-	3: Reference Documents	. 7
Table 3-	L: Mass and CoG of Sentinel-3	.12
Table 3-	2: Origin and orientation of GNSS-1 antenna	.13
Table 3-	3: Origin and orientation of GNSS-2 antenna	.13
Table 3-	4: PCO values for GPS antennas (design values)	.13
Table 3-	5: PCO values for GPS antennas (used in POD)	.13
Table 3-	5: Origin and orientation of DORIS antenna	.14
Table 3-	7: DORIS antenna centre of phase offset	.14
Table 3-	3: Origin and orientation of LRR instrument	.15
Table 3-	9: Origin and orientation of SRAL instrument	.17
Table 3-	LO: Origin and orientation of SRAL antenna centre of phase	.17
Table 4-	L: Format of mass history file	18
Table 4-	2: Format of the manoeuvre file (header)	.18
Table 4-	3: Format of the manoeuvre file (body)	.18
Table 4-	1: Outages file format description (header)	.19
Table 4-	5: Outages file format description (body)	.19
Table 5-	L: Spacecraft surface properties in visible spectrum	.22
Table 5-	2: Spacecraft surface properties in IR spectrum	22



Page:

GMV-GMESPOD-TN-0027 18/11/2019

> 4000108273/13/1-NB 5 of 23

LIST OF FIGURES

gure 2-1: Sentinel-3 axes showing flight direction	8
gure 2-2: Cartesian coordinates (x, y, z) and geodetic coordinates (λ, Φ, h)	
gure 2-3: Implementation from TRL to T'R'L' frame of reference	
gure 3-1: GNSS antenna location	12
gure 3-2: DORIS antenna reference axes	14
gure 3-3: LRR reference axes	15
gure 3-4: LRR array	16
gure 3-5: Elevation-Azimuth range correction proposed for Sentinel-3 based on CryoSat-1/2 and PROBA-2/V analysis (extracted from [RD.6])	
gure 3-6: SRAL reference axes	17
gure 5-1: Sentinel-3 geometry (side oriented toward Earth)	20
gure 5-2: Sentinel-3 geometry (side oriented opposite to Earth)	21
gure 5-3: Solar Array geometry	22



Code: GMV-GMESPOD-TN-0027
Date: 18/11/2019
Version: 1.7
ESA contract: 4000108273/13/1-NB

Page: 6 of 23

1. INTRODUCTION

1.1. PURPOSE

This document describes the required information concerning Sentinel-3 in order to carry out GNSS based POD processing. In particular, the nominal attitude of the satellite, the GPS, DORIS and SLR configuration parameters, and the format of the NAPEOS internal files for attitude and mass history file are described. Unless specified otherwise, all the information contained in this document is applicable to both Sentinel-3A and -3B.

1.2. SCOPE

This document has been prepared by GMV in the frame of the Provision of the Precise Orbit Determination Service for the Sentinel missions.

1.3. DEFINITIONS AND ACRONYMS

Acronyms used in this document and needing a definition are included in the following table:

Table 1-1: Acronyms

Acronym	Definition		
AOCS	Attitude and Orbit Control System		
BOL	Beginning Of Life		
DIL	Document Item List		
DLR	Deutsche Zentrum für Luft- und Raumfahrt		
DORIS	Doppler Orbytography and Radiopositioning Integrated by Satellite		
ESA	European Space Agency		
ESOC	European Space Operation Centre		
FOS	Flight Operations System		
GMES	Global Monitoring for Environment and Security		
GNSS	Global Navigation Satellite System		
GOCE	Gravity field and Ocean Circulation Explorer		
GPS	Global Positioning System		
GSOC	German Space Operations Center		
ICD	Interface Control Document		
LRA	Laser Retro-reflector Array		
LRR	Laser Retro-reflector		
MOM	linutes of Meeting		
NAPEOS	NAvigation Package for Earth Orbiting Satellites		
NAVATT	NAVigation and ATTitude information		
PCO	Phase Centre Offset		
PIM	Payload Interface Module		
POD	Precise Orbit Determination		
PROBA	Project for On-Board Autonomy		
QWG	Quality Working Group		
SLR	Satellite Laser Ranging		
SRAL	SAR Radar Altimeter		
SVM	Service Module		
UTC	Coordinated Universal Time		



Code: GMV-GMESPOD-TN-0027 Date: Version: ESA contract:

Page:

18/11/2019 1.7

4000108273/13/1-NB 7 of 23

Acronym	Definition
XML	Extensible Markup Language

1.4. APPLICABLE AND REFERENCE DOCUMENTS

1.4.1. APPLICABLE DOCUMENTS

The following documents, of the exact issue shown, form part of this document to the extent specified herein. Applicable documents are those referenced in the Contract or approved by the Approval Authority. They are referenced in this document in the form [AD.X]:

Table 1-2: Applicable Documents

Ref.	Title	Code	Version	Date
[AD.1]	Sentinels POD Service File Format Specification	GMES-GSEG-EOPG-FS-10-0075	1.23	16/09/2019

1.4.2. REFERENCE DOCUMENTS

The following documents, although not part of this document, extend or clarify its contents. Reference documents are those not applicable and referenced within this document. They are referenced in this document in the form [RD.X]:

Table 1-3: Reference Documents

Ref.	Title	Code	Version	Date
[RD.1]	Sentinel-3 satellite to POD ICD	ESIG_S3-ID-TAF-SC-01290	6.0	08/06/2016
[RD.2]	NAVATT Packet definition	S3-ID-TAF-SC-01890	7.0	11/06/2016
[RD.3]	Satellite Overall Assembly and Geometrical Drawings	ESIG_S3-ID-TAF-SC-00897	3.0	09/06/2014
[RD.4]	POD QWG #3 Minutes of Meeting	GMV-GMESPOD-MOM- PODQWG-003	1.0	01/06/2016
[RD.5]	S-3 LRR Mechanical ICD	S3-LRR-ICD	1.0	N/A
[RD.6]	Range Correction for the CryoSat and GOCE Laser Retroreflector Arrays	DLR_GSOC_TN_1101_IPIE_LRA	1.0	25/09/2011
[RD.7]	Precise orbit determination of the Sentinel-3A altimetry satellite using ambiguity-fixed GPS carrier phase observations. O. Montenbruck, S. Hackel, A. Jäggi Journal of Geodesy 2017	,	N/A	13/11/2017



Code: GMV-GMESPOD-TN-0027 Date: Version: ESA contract:

4000108273/13/1-NB Page:

8 of 23

1.7

18/11/2019

2. SENTINEL-3 NOMINAL ATTITUDE MODE

According to [RD.1], the **Satellite Reference frame** is defined as (see section 4.1):

- The origin is located at the centre of the launch vehicle interface ring
- +Xs is perpendicular to the launch vehicle interface plane and oriented from launch vehicle toward satellite
- +Zs is parallel to the launch vehicle interface plane and pointed towards the perpendicular of the panel supporting the altimeter reflector
- +Ys completes this frame so as (+Xs, +Ys, +Zs) be right-handed orthogonal frame.

Figure 2-1 shows the satellite configuration from the bottom (i.e. side oriented towards Earth), with the satellite axes including a legend indicating the direction of the flight.

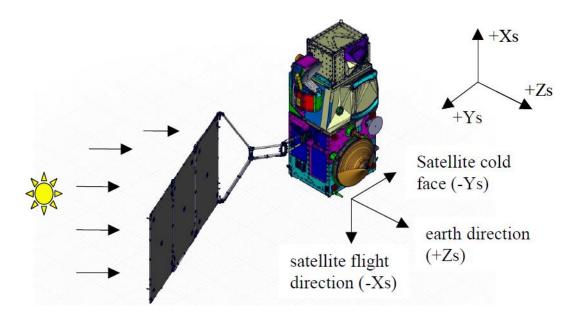


Figure 2-1: Sentinel-3 axes showing flight direction

All spacecraft mechanical and geometric parameters will ultimately be referenced to this satellite reference system including unit positions and mass properties.

The **Spacecraft Attitude Definition** is defined as the orientation of the spacecraft Satellite Reference Frame with respect to the Inertial Reference Frame (J2000).

The attitude is computed on-board by the AOCS and the resulting quaternions are provided in the NAVATT LO packages. The quaternions represent the rotation from J2000 Inertial Reference Frame to Satellite Reference Axis (see Section 4.1). The format of the quaternions files is described in [AD.1].

The nominal attitude mode is described in Section 2.1, and the actual implementation in NAPEOS SW is included in Section 2.2.

2.1. ATTITUDE POINTING MODE

In a Nominal Mission Mode, the nominal pointing mode of the satellite for acquiring Observation data is Geodetic pointing with yaw-steering guidance, flagged as mode 4 in the quaternions file despite the flag being described as 5 according to section 2.7 of [RD.2].

The "Geodetic pointing with yaw-steering guidance" frame is a modification of the "Geodetic pointing" frame, both described herein.

The "Geodetic pointing" frame (denoted by ged) is defined as follows:



Code: GMV-GMESPOD-TN-0027
Date: 18/11/2019
Version: 1.7
ESA contract: 4000108273/13/1-NB
Page: 9 of 23

- The origin of this reference frame is at the centre of mass of the satellite.
- The Xged belongs to the orbital plane with a positive projection onto the satellite velocity.
- The Zged points towards the Earth along the local vertical defined above the WGS84 ellipsoid.
- The Yged completes the right handed orthogonal reference frame.
- The target point of this vertical on the ellipsoid is on the same meridian as the sub-satellite point defined by the intersection of the earth centred position vector with the ellipsoid.

The "Geodetic pointing" coordinates are depicted in Figure 2-2.

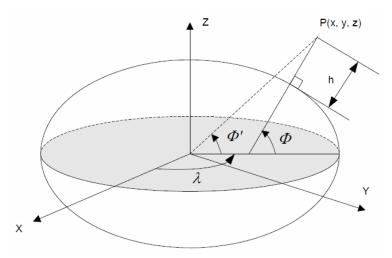


Figure 2-2: Cartesian coordinates (x, y, z) and geodetic coordinates (λ, Φ, h) . Φ' represents the geocentric latitude

The following reference ellipsoid definition (WGS84) is used by the GNSS receiver software:

- Semi major axis: 6378137 m
- Inverse flattening 1/f = 298.257223563
- The resulting semi-minor axis b is b=a*(1-f)=6356752.3142 m
- The eccentricity e is determined by:

$$e = \sqrt{\frac{a^2 - b^2}{a^2}} = 8.18191909e - 2$$

The "Geodetic with yaw-steering guidance pointing" frame (denoted by yst) differs from the "Geodetic pointing" frame in a rotation around the Zged axis. The velocity of the target point (at the local vertical) **relative** to the earth surface shall be perpendicular to the intersection of the (Yyst, Zyst) plane with the ellipsoid.

In case yaw steering is applied without geocentric pointing, the target point shall be replaced by the sub-satellite point.

2.2. ATTITUDE IMPLEMENTATION

The attitude implementation in NAPEOS SW is carried out by a number of consecutive rotations from an Inertial Reference Frame (in this case, J2000) to Satellite Reference Frame.

- From Inertial Reference Frame (J2000) to Orbital Reference Frame (Radial, Along and Cross-track)
- From Orbital Reference Frame (RAC: Radial, Along and Cross-track) to TRL frame (Local Orbital Reference Frame: T = -Cross, R = Along, L = Radial)
- From TRL frame to T'R'L' frame (Local Relative Yaw Steering Orbital Reference Frame). The code implementation is included in Figure 2-3.
- From T'R'L' frame to Satellite Reference Frame though two consecutive rotations:
 90 deg around Z axis, and 180 deg around X (Xsat = -R', Ysat = T', Zsat = -L').



Code: GMV-GMESPOD-TN-0027
Date: 18/11/2019
Version: 1.7
ESA contract: 4000108273/13/1-NB

10 of 23

Page:

```
SUBROUTINE AMat_AtoTpRpLpfromTRLSen ( stateVc, a )
  Synopsis: Calculate the transformation matrix from the
                TRL frame (Local Orbital Reference Frame) to the
                T'R'L' frame (Local Relative Yaw Steering Reference Frame)
  TYPE(ORvc_VecType), INTENT(IN)
DOUBLE PRECISION, DIMENSION(3,3), INTENT(OUT)
:: a ! Transformation matrix
                                                            :: stateVc ! State vector
! T'R'L' is deduced from TRL through three rotations
    eAngle(1) = + deltaMu
    eAngle(2) = + deltaXi
eAngle(3) = + deltaDseta
  DOUBLE PRECISION, DIMENSION(3)
                                          :: eAngle
  TYPE( ORvc_VecType )
TYPE( ORvc_VecType )
                                           tSSi, tSSef, tGeo
tVi, tVef, tVtopo
  DOUBLE PRECISION
                                           :: rAzim, rCosAz, rSinAz, rFact
  DOUBLE PRECISION
                                            :: rCosLat, rSinLat, rCosLon, rSinLon
  DOUBLE PRECISION
DOUBLE PRECISION, DIMENSION(3)
                                           :: rHeight, rRmer, rRnor, rRadius
                                           :: arVssp
  DOUBLE PRECISION, DIMENSION(3) :: arT, arR, DOUBLE PRECISION, DIMENSION(3) :: arTp, arR, DOUBLE PRECISION, DIMENSION(3) :: arLlr, ar2 DOUBLE PRECISION, DIMENSION(3,3) :: arTopoMat
                                           :: arT, arR, arL
                                         arTp, arRp, arLp
arLlr, arZ
  DOUBLE PRECISION, PARAMETER :: crRp = DBcb_rEquator * ( DBc_one - DBcb_flat )
! Compute TRL
  arL = ORvc_Unit( stateVc%x(1:3) )
  arT = -ORvc_Normal(stateVc)
  arR = ORvc_Unit(ORvc_CrossPr( arL, arT ))
! Get subsatellite point (EF) at epoch
  CALL ATcb_VecTrans( ORvc_j2000,
                                                ORvc_cartesian, stateVc,
                           ORvc_earthFixed, ORvc_geodetic, tGeo, short=.TRUE.)
             = tGeo\%x(3)
  rHeight
  tGeo%x(3) = DBc_zero
  CALL ATcb_VecTrans( ORvc_earthFixed, ORvc_geodetic, tGeo, ORvc_earthFixed, ORvc_cartesian, tSSef, short=.TRUE. )
! Convert SSP to J2000 including the Earth velocity tSSef%x(4:6) = DBc_zero
  CALL ATcb_VecTrans( ORvc_earthFixed, ORvc_cartesian, tSSef,
                           ORvc_j2000,
                                                ORvc_cartesian, tSSi, short=.FALSE.)
! Get direction of the local vertical
  arLp = ORvc_Unit(stateVc%x(1:3) - tSSi%x(1:3))
! Restrict velocity to XY geodetic plane
  tSSix(4:6) = tSSix(4:6) - arLp * ORvc_DotPr( tSSix(4:6), arLp )
! Compute Earth curvature radius in the plane intersected by the S/C velocity! Notice that the frame conversion are static for this computation
! Velocity in the plane tangent to the ellipsoid
  tVi%epoch = stateVc%epoch
  tVixx(1:3) = stateVcxx(4:6) - arLp * Orvc_DotPr( stateVcxx(4:6), arLp )

CALL ATcb_VecTrans( ORvc_j2000, ORvc_cartesian, tVi,

ORvc_earthFixed, ORvc_cartesian, tVef, short=.TRUE. )
! Topocentric matrix
  rCosLat = COS(tGeo%x(2))
 rSinLat = SIN(tGeo%x(2))
```



 Code:
 GMV-GMESPOD-TN-0027

 Date:
 18/11/2019

 Version:
 1.7

 ESA contract:
 4000108273/13/1-NB

 Page:
 11 of 23

```
rCosLon = COS(tGeo%x(1))
  rSinLon = SIN(tGeo\%x(1))
! East vector
  arTopoMat(1,1) = -rSinLon
  arTopoMat(1,2) = rCosLon
arTopoMat(1,3) = DBc_zero
! North vect ro
  arTopoMat(2,1) = -rSinLat * rCosLon
arTopoMat(2,2) = -rSinLat * rSinLon
  arTopoMat(2,3) = rCosLat
! Up vector
  arTopoMat(<mark>3,1</mark>) = rCosLat * rCosLon
  arTopoMat(3,2) = rCosLat * rSinLon
arTopoMat(3,3) = rSinLat
! Azimuth of this velocity w.r.t north (plane inclination)
  tVtopo%x(1:3) = MATMUL(arTopoMat, tVef%x(1:3))
  rAzim = ATAN2( tVtopo%x(1), tVtopo%x(2) )
! Support variables to speed the computation up
  rCosAz = COS( rAzim )
rSinAz = SQRT( DBc_one – rCosAz ** 2 )
  rCosLat = COS( tGeo%x(2) )
  rSinLat = SQRT(DBc_one - rCosLat ** 2)
  rFact = SQRT( ( DBcb_rEquator * rCosLat )**2 * ( crRp * rSinLat )**2 )
! Radius of curvature

rRmer = ( DBcb_rEquator * crRp )**2 / rFact**3

rRnor = DBcb_rEquator**2 / rFact
  rRadius = DBc_one / ( ( rCosAz**2 / rRmer ) + ( rSinAz**2 / rRnor ) )
! Escalate Velocity of the satellite with curvature radius
  arVssp = tVi%x(1:3) * rRadius / ( rRadius + rHeight )
! Correct with surface velocity in the XY plane
  tSSix(4:6) = arVssp - tSSix(4:6)
! Complete T'R'L'
  arRp = ORvc_Unit(tSSi_x(4:6))
  arTp = ORvc_Unit(ORvc_CrossPr( arRp, arLp ))
  arLlr = ORvc_Unit( arLp - Orvc_DotPr(arLp,arT)*arT )
  eAngle(1) = ASIN(ORvc_DotPr( arLp , arT ))
  eAngle(2) = ASIN(ORvc_DotPr( arLlr , -arR ))
eAngle(3) = ASIN(ORvc_DotPr( arRp , -arT ))
  CALL AMat_EulerAngToMat ( eAngle, '213', a )
END SUBROUTINE AMat_AtoTpRpLpfromTRLSen
```

Figure 2-3: Implementation from TRL to T'R'L' frame of reference



GMV-GMESPOD-TN-0027 18/11/2019 1.7 4000108273/13/1-NB

Page: 12 of 23

3. CONFIGURATION OF SATELLITE AND POD INSTRUMENTS

3.1. CENTRE OF GRAVITY (COG) AND MASS

The mass and location of the CoG at BOL in deployed configuration is provided in Table 3-1. The source is the mass history file provided by S-3 FOS (ESOC).

Table 3-1: Mass and CoG of Sentinel-3

Key	From Mass History file	
Mass	1129.648 kg	
CoGx	+1.4890 m	
CoGy	+0.2170 m	
CoGz	+0.0090 m	

The evolution of mass and location of the CoG is provided in the mass history file (s3a.mhf, s3b.mhf), provided as input from the Sentinel-3 FOS. For a description of the file see section 4.1.

3.2. GNSS ANTENNAE

The source of the following information is [RD.1].

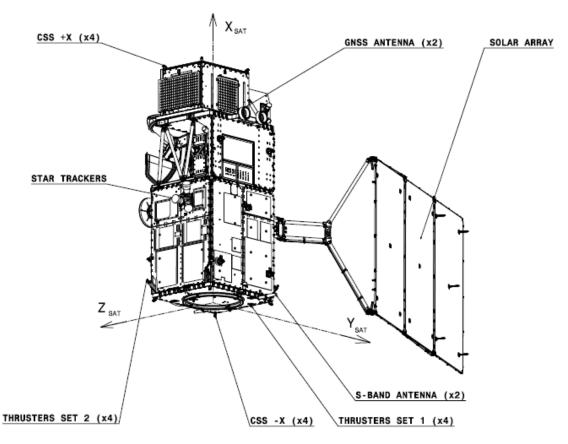


Figure 3-1: GNSS antenna location

The following tables show the **origin and orientation** of the GNSS-1 (Table 3-2) and GNSS-2 (Table 3-3) Antenna Reference Frames according to [RD.1]:



Page:

GMV-GMESPOD-TN-0027 18/11/2019 1.7

> 4000108273/13/1-NB 13 of 23

Table 3-2: Origin and orientation of GNSS-1 antenna

		S/C Reference Frame		
		X sat Y sat Z sat		
	Mech. Mounting ref. Point (mm)	2838.50	-242.5	-797.65
GNSS-1	Ref Frame Origin (mm)	2881.00	-190.0 (S3A) -200.0 (S3B)	-794.00
	X GNSS	0	1	0
	Y GNSS	1	0	0
	Z GNSS	0	0	-1

Table 3-3: Origin and orientation of GNSS-2 antenna

		S/C Reference Frame		ne
		X sat	Y sat	Z sat
	Mech. Mounting ref. Point (mm)	2838.50	157.50	-797.65
GNSS-2	Ref Frame Origin (mm)	2881.00	210.00 (S3A) 200.00 (S3B)	-794.00
	X GNSS	0	1	0
	Y GNSS	1	0	0
	Z GNSS	0	0	-1

The Y component of the reference frame origin of S-3A has been modified by 1 cm after the analysis reported in [RD.7]. Instead of modifying the centre of mass history file, which is provided by the Sentinel-3 flight operations centre, the origin of the reference frame is modified.

The **PCO values** (Phase centre offset) w.r.t. antenna reference frame according to the manufacturer is the following:

Table 3-4: PCO values for GPS antennas (design values)

Key	X/North (mm)	Y/East (mm)	Z/Up (mm)
GNSS-1	0.0	0.0	97.0
GNSS-2	0.0	0.0	97.0

Despite these values being provided by the manufacturer according to [RD.1], the following have been estimated in the POD processing after the experience with Sentine-1A and -2A, and produce more consistent results. They are the ones currently used in POD.

Table 3-5: PCO values for GPS antennas (used in POD)

Key	X/North (mm)	Y/East (mm)	Z/Up (mm)
GNSS-1	0.0	0.0	68.0



Code: Date:

Page:

Version: ESA contract:

GMV-GMESPOD-TN-0027 18/11/2019 1.7 4000108273/13/1-NB

14 of 23

3.3. DORIS ANTENNA

The source of the following information is [RD.1].

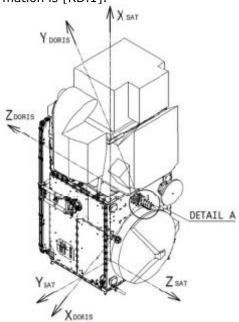


Figure 3-2: DORIS antenna reference axes

The following table shows the **origin and orientation** of the DORIS antenna reference frame:

Table 3-6: Origin and orientation of DORIS antenna

		S/C Reference Frame		
		X sat	Y sat	Z sat
DORIS	Origin (mm)	1569.3	73.0	755.0
	X DORIS	-0.382683	0.923880	0.0
	Y DORIS	0.923880	0.382683	0.0
	Z DORIS	0.0	0.0	-1.0

The antenna centre of phase offsets are the following:

Table 3-7: DORIS antenna centre of phase offset

		Antenna Reference Frame		Frame
		Х	Υ	z
DODYG	Offset @ 0.4 GHz (mm)	0.0	0.0	-158
DORIS	Offset @ 2.0 GHz (mm)	0.0	0.0	-312



Code: Date: Version:

ESA contract: Page:

GMV-GMESPOD-TN-0027 18/11/2019

4000108273/13/1-NB 15 of 23

1.7

3.4. LASER RETRO REFLECTOR (LRR)

The source of the following information is [RD.1].

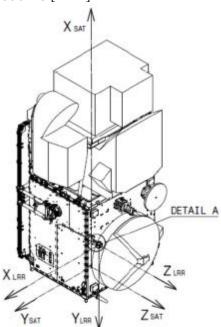


Figure 3-3: LRR reference axes

The following table shows the **origin and orientation** of the LRR antenna reference frame including corrections applied after mounting on the spacecraft:

Table 3-8: Origin and orientation of LRR instrument

		S/C Reference Frame		
		X sat	Y sat	Z sat
LRR	Origin (mm)	1134.030	637.905	801.18
	X LRR	0	+1	0
	Y LRR	-1	0	0
	Z LRR	0	0	+1

As regards the centre of phase offset, it varies between 16.25 and 23.13 mm depending on the zenith angle and culmination, according to the manufacturer [RD.1]. However, it was argued during the POD QWG #3 held at GMV on 30^{th} May - 1st June 2016 that the corrections proposed in that reference cannot fully represent the expected behaviour of the LRR [RD.4] since they are only elevation-dependent, while the Laser Retro Reflector array design (shown in Figure 3-4) clearly shows a strong azimuth dependency. Given that the same LRR was used for CryoSat-1/2 and PROBA-2/V (details in [RD.6]), it was proposed to use the same range correction (shown in Figure 3-5).



Code: GMV-G
Date:
Version:
ESA contract: 400
Page:

GMV-GMESPOD-TN-0027 18/11/2019 1.7 4000108273/13/1-NB 16 of 23



Figure 3-4: LRR array

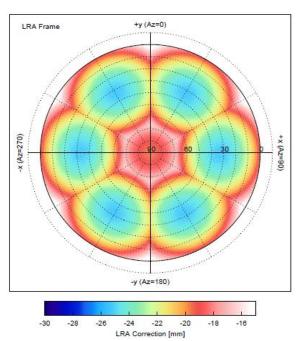


Figure 3-5: Elevation-Azimuth range correction proposed for Sentinel-3 based on CryoSat-1/2 and PROBA-2/V analysis (extracted from [RD.6])



Page:

GMV-GMESPOD-TN-0027 18/11/2019 1.7

> 4000108273/13/1-NB 17 of 23

3.5. SRAL ANTENNA

The source of the following information is [RD.1].

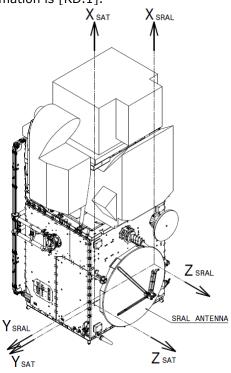


Figure 3-6: SRAL reference axes

The following table shows the **origin and orientation** of the SRAL antenna reference frame:

Table 3-9: Origin and orientation of SRAL instrument

		S/C Reference Frame		
		X sat	Y sat	Z sat
SRAL	Origin (mm)	721.14	-540.158	625.0
	X SRAL	+1	0	0
	Y SRAL	0	+1	0
	Z SRAL	0	0	+1

The SRAL antenna phase centre, expressed in SRAL frame of reference with respect to SRAL Origin, is given in the following table:

Table 3-10: Origin and orientation of SRAL antenna centre of phase

	SRAL Reference Frame		
	X SRAL	Y SRAL	Z SRAL
Centre of Phase (mm)	-38.1	540.2	-60.1



Code: Date: Version:

GMV-GMESPOD-TN-0027 18/11/2019 1.7

ESA contract: 4000108273/13/1-NB Page: 18 of 23

4. NAPEOS FORMAT SPECIFICATION

4.1. SENTINEL MASS HISTORY FILE FORMAT

FOS provides the mass and centre of gravity evolution in an XML format. This information is converted into a NAPEOS file with the following format:

Table 4-1: Format of mass history file

Key	Туре	Description
Year	I4,X	Year
Month	I2,X	Month
Day	I2,X	Day
Hour	I2,X	Hour
Minute	I2,X	Minute
Seconds	F5.3,X	Seconds
Mass	F9.3,X	Mass of the satellite (kg)
CoG_x	F8.5,X	Location of the x component of the CoG with respect to the Satellite Reference Axis (meters)
CoG_y	F8.5,X	Location of the y component of the CoG with respect to the Satellite Reference Axis (meters)
CoG_z	F8.5,X	Location of the z component of the CoG with respect to the Satellite Reference Axis (meters)

Example:

4.2. SENTINEL MANOEUVRE FILE FORMAT

FOS provides the manoeuvre file with the following format (NAPEOS based):

Table 4-2: Format of the manoeuvre file (header)

Key	Туре	Description
Time	A23, 1X	File update time as: YYYY/MM/DD-HH:MM:SS.SSS
Satellite ID	I3, 50X	ESOC satellite ID (268 for S3A and 269 for S3B)

Table 4-3: Format of the manoeuvre file (body)

Key	Туре	Description
Epoch	A23, 4X	Burn start or stop time (UTC), as: YYYY/MM/DD-HH:MM:SS.SSS
Acceleration	D15.8	First component of acceleration in km/s2
Acceleration	D15.8	Second component of acceleration in km/s2
Acceleration	D15.8	Third component of acceleration in km/s2
Flag	I5	Record flag. If >0, this is a manoeuvre start record. If 0, it is a manoeuvre end



Code: GMV-GMESPOD-TN-0027
Date: 18/11/2019
Version: 1.7
ESA contract: 4000108273/13/1-NB
Page: 19 of 23

Кеу	Туре	Description
		record.
		On a start record:
		 value 1 indicates that the components are radial, along-track and cross- track respectively
		- value 2 that they are along the J2000.0 X-, Y- and Z- axes respectively

Example:

2016/03/04-13:01:03.498 268 2016/02/22-09:29:35.000 -0.32319361D-10-0.56919703D-06 0.0000000D+00 1 2016/02/22-09:30:06.623 -0.32319361D-10-0.56919703D-06 0.0000000D+00 0 2016/02/22-12:10:00.000 -0.33487538D-09-0.56910436D-06 0.0000000D+00 1 2016/02/22-12:10:31.629 -0.33487538D-09-0.56910436D-06 0.0000000D+00 0

4.3. SENTINEL-3 OUTAGES NAPEOS FORMAT

The outages file is computed based on the existing gaps in the GPS L0 inputs combined with the manoeuvre file information. This information is converted into a NAPEOS file with the following format:

Table 4-4: Outages file format description (header)

Key	Туре	Description
Epoch	Epoch, a23	File last update epoch as YYYY/MM/DD-HH:MM:SS.SSS
File Title	String, a12	OUTAGES FILE
ESOC ID	Integer,i3	Satellite ESOC ID (268 for S3A and 269 for S3B)

Table 4-5: Outages file format description (body)

Key	Туре	Description
Epoch	Epoch, a23	Outage start epoch as YYYY/MM/DD-HH:MM:SS.SSS
Epoch	Epoch, a23	Outage end epoch as YYYY/MM/DD-HH:MM:SS.SSS
Outage type	String, a3	Type of outage. It may be: input gap (GAP), manoeuvre (MAN) or a combination of both (MIX)

Example:

2018/04/18-03:10:06.000 OUTAGES FILE 268
2000/01/01-00:00:00.000 2016/04/27-04:43:04.000 GAP
2016/04/28-16:44:34.000 2016/04/29-10:44:14.000 GAP
2016/04/29-15:39:26.000 2016/04/29-15:41:07.000 MAN
2016/05/03-12:51:38.000 2016/05/03-12:53:19.000 MAN
2016/05/05-15:03:47.000 2016/05/06-07:55:35.000 GAP
2016/05/09-14:36:29.000 2016/05/09-23:59:59.000 MIX



Page:

GMV-GMESPOD-TN-0027 18/11/2019 1.7 4000108273/13/1-NB

20 of 23

5. SATELLITE DESCRIPTION

5.1. SPACECRAFT GEOMETRICAL MODEL

The following figures show a view of geometry of the satellite in deployed configuration (extracted from [RD.3]):

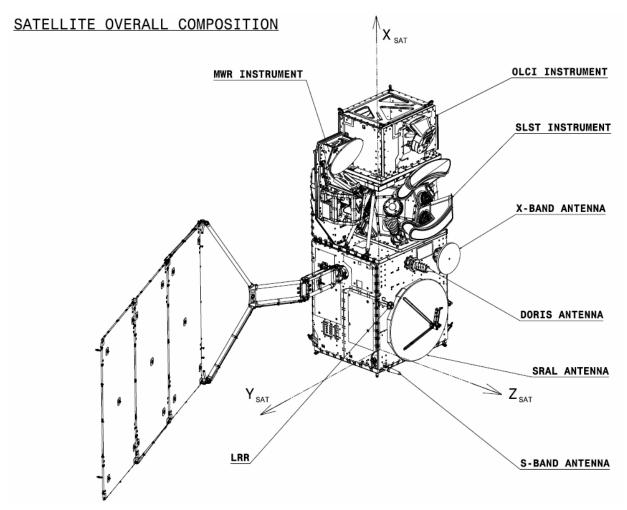


Figure 5-1: Sentinel-3 geometry (side oriented toward Earth)



 Code:
 GMV-GMESPOD-TN-0027

 Date:
 18/11/2019

 Version:
 1.7

ESA contract: 4000108273/13/1-NB Page: 21 of 23

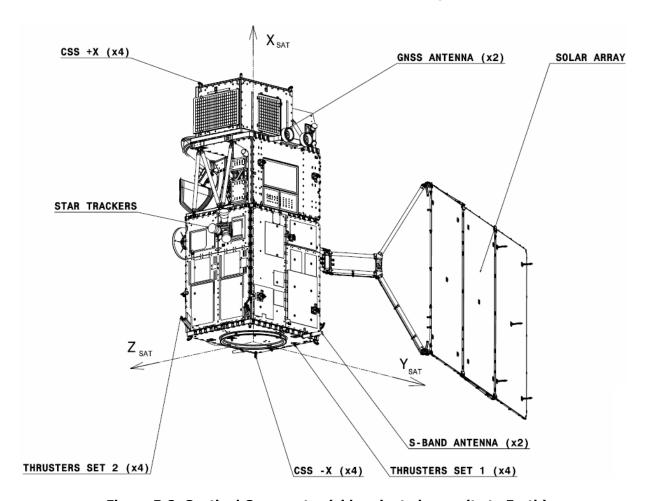


Figure 5-2: Sentinel-3 geometry (side oriented opposite to Earth)

The resulting projected areas are summarized in the following table (from [RD.1]):

Projected area [m²]					
Deployed configuration					
3.244					
6.058					
16.576					
Without Solar Array Wing					
2.84					
5.41					
6.10					

The overall area of the 3 Panels conforming the Solar Array is 10.50 m².

5.2. SOLAR ARRAY

The **Solar Array** is inclined with respect to the Ys axis with an angle of 24° as illustrated in the following figure (Ys mentioned as Ysat in the figure). In nominal operation, the Solar Array Wing rotates around the Ys axis. The rotation angle value is estimated and controlled by the AOCS.



 Code:
 GMV-GMESPOD-TN-0027

 Date:
 18/11/2019

 Version:
 1.7

 ESA contract:
 4000108273/13/1-NB

 Page:
 22 of 23

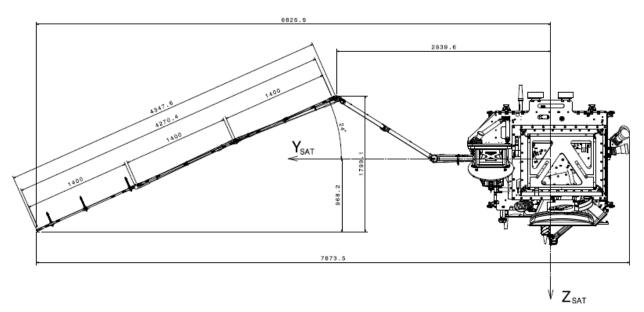


Figure 5-3: Solar Array geometry

5.3. THERMO OPTICAL SURFACE PROPERTIES

The following table lists the spacecraft surface properties in both the visible and the infra-red spectrum (from [RD.1]).

Table 5-1: Spacecraft surface properties in visible spectrum

	Satellite side	Solar Absorptance	Specular Solar Reflectance	Diffuse Solar Reflectance
SVM, PIM and Instruments (without Solar Array Wing)	-X	0.84	0.08	0.08
	+X	0.85	0.07	0.07
	-Y	0.60	0.35	0.05
	+Y	0.69	0.26	0.06
	-Z	0.63	0.31	0.05
	+Z	0.75	0.10	0.15
Solar Array	Cells	0.82	0.18	0.00
	Back	0.81	0.00	0.19

Table 5-2: Spacecraft surface properties in IR spectrum

	Satellite side	Emissivity	Specular IR Reflectance	Diffuse IR Reflectance
SVM, PIM and Instruments (without Solar Array Wing)	-X	0.71	0.15	0.15
	+X	0.72	0.14	0.14
	-Y	0.73	0.18	0.09
	+Y	0.72	0.17	0.11
	-Z	0.73	0.17	0.10
	+Z	0.74	0.12	0.13
Solar Array	Cells	0.69	0.31	0.00
	Back	0.73	0.00	0.27



 Code:
 GMV-GMESPOD-TN-0027

 Date:
 18/11/2019

 Version:
 1.7

 ESA contract:
 4000108273/13/1-NB

 Page:
 23 of 23

END OF DOCUMENT