CryoSat-2

Precise Orbit Context

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Change Record

Date	Issue	Page	Change
02 Dec 2002	1.0	all	Initial issue for CryoSat-1
12 Dec 2002	1a	all	Correction of typos (none in the numerical values)
16 Feb 2007	2.0	all	Update of CryoSat-1 document in order to reflect changes due to the CryoSat-2 spacecraft and orbit

Table of Contents

1 SCOPE

This document provides a preliminary set of information to be used for the definition of a test orbit for DORIS instrument onboard CryoSat-2. This orbit is consistent with the test data sets generated in the context of simulated SIRAL data products.

The information provided in this document is representative of the eventual in-flight conditions and configuration and is primarily intended to provide a consistent baseline for simulations and analysis. The document will be updated prior to launch in order to provide the most accurate information available at that time.

2 SATELLITE DESCRIPTION

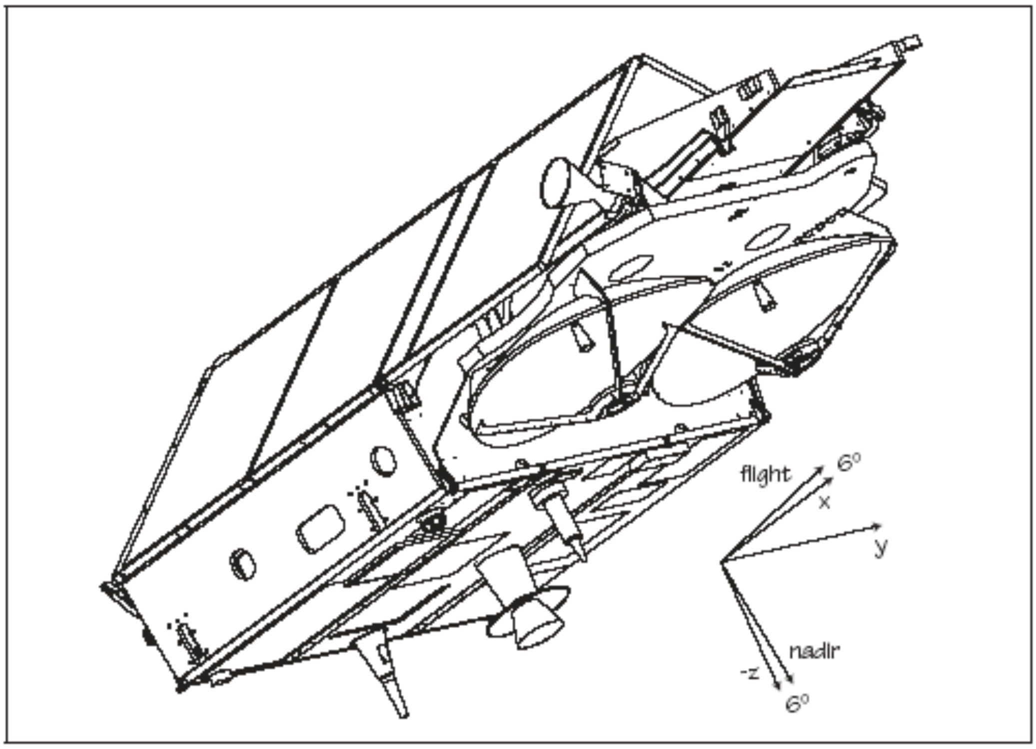
2.1 Satellite Reference Frame

A view of the CryoSat-2 satellite, indicating the satellite reference frame is provided in Figure 1. The satellite flies in a “nose-down” attitude, inclined at 6º to the positive x-axis. The nadir direction is inclined 6º from the negative z-axis.

The origin of the satellite reference frame is at the centre of the satellite mounting plane on the launch vehicle.

There are no moving parts.

Figure 1 - The CryoSat-2 satellite, shown without the thermal control material, which will be used to wrap the large antennas and their support structure. The satellite reference frame is shown as well as the directions of flight and nadir. Note that for the z-axis the negative axis is shown in order to show the offset of the nadir direction.



2.2 Mass Properties

CryoSat-2 has been designed so that the centre of mass corresponds to the centre of the single, spherical fuel tank. The fuel is gaseous nitrogen, which will uniformly fill the tank. CryoSat-2 has no moving parts.

Consequently the centre of mass *will not move* during the satellite lifetime. Nevertheless, the standard format of manoeuvre report issued by the Flight Operations Centre at ESOC includes an estimate of the centre of mass position and the remaining satellite mass following every manoeuvre.

The location of the centre of mass, and the satellite mass, are provided in Table 1.

Table 1 - CryoSat-2 mass properties at beginning of life (BOL), and the nominal mass after the acquisition of the nominal orbit following separation from the launcher. This Nominal Mass shall be used for the DORIS orbit simulation.

x (mm)	*y* (mm)	*z* (mm)	BOL Mass (kg)	Nominal Mass (kg)
1657 +/- 5	13 +/- 5	15 +/- 5	735.0 +/- 22.4	721.1 +/- 14.4

2.3 Attitude Control

The attitude control law for CryoSat-2 is earth pointing, with the following characteristics:

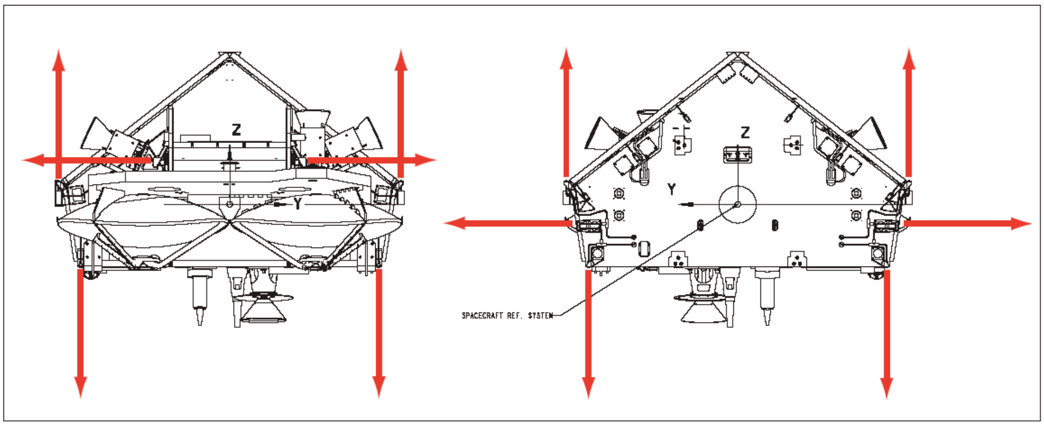
- the flight direction is 6º from the positive *x*-axis, as shown in Figure 1;
- the direction to the local normal to the WGS84 ellipsoid is 6º from the negative *z*-axis, as shown in Figure 1;
- the *y*-axis is orthogonal to the satellite flight direction (not the ground track, i.e. no yaw steering).

The attitude control system makes use of the magneto-torquers to provide control torques to the satellite. These are supported by use of the small attitude control thrusters to maintain the attitude dead-band. The thrusters are aligned so that all provide thrust orthogonal to the flight direction, and are operated in pairs with the intention to provide a pure torque with no residual acceleration. However due to manufacturing tolerances it is likely that small mismatches will occur which will cause small residual accelerations in either the cross-track or radial direction. The thrusters have the following characteristics:

- thruster force: 10.4 mN (1.3 bar thrusters inlet pressure)
- expected mismatch: 5%
- thruster pulse duration: 50 ms
- approx. number of pulses per orbit: 50
- mass flow: 14.2 mg/sec

The location of the thrusters is shown in Figure 2.

Figure 2 - Positions of the CryoSat-2 attitude control thrusters, and direction of thrust (shiwn as red arrows), all of which are orthogonal to the flight direction. Combinations of thrusters are used to provide torques around the satellite axes.



2.4 Satellite Surfaces

Preliminary information on the satellite surface areas and thermo-optical properties are provided here. They have been derived directly from the satellite thermo-mechanical design, making a number of approximations. These values will be used as a reference set until the development of a specific macro-model has been completed.

The surface properties are given in Table 2 for the solar spectrum and Table 3 for the infrared spectrum.

Table 2 - CryoSat-2 surface properties in the visible spectrum

Surface	+x	-x	+y	-y	+z	-z
Area (m^2)	2.515	2.515	5.114	5.114	8.882	8.882
Specular Reflectivity	0.063	0.047	0.048	0.040	0.015	0.132
Diffuse Reflectivity	0.093	0.096	0.066	0.066	0.056	0.085
Absorptivity	0.844	0.857	0.887	0.894	0.929	0.784

Table 3 - CryoSat-2 surface properties in the Infrared spectrum

Surface	+*x*	-*x*	+*y*	-*y*	+*z*	-*z*
Area (m^2)	2.515	2.515	5.114	5.114	8.882	8.882
Specular Reflectivity	0.023	0.015	0.017	0.014	0.005	0.054
Diffuse Reflectivity	0.175	0.182	0.124	0.127	0.110	0.150
Absorptivity	0.802	0.803	0.859	0.859	0.885	0.796

In addition to the interaction of the satellite with incident radiation it is also necessary to take account of the force due to thermal dissipation arising from the on-board equipment. All of this thermal radiation is from the z-surface. The power dissipation is dependent on the instrument operations around the orbit.

For the reference case an **average power dissipation of 285 W** (TBC) shall be assumed.

2.5 Reference Points

The reference points for the various equipments and instruments on CryoSat-2 are given in Table 4.

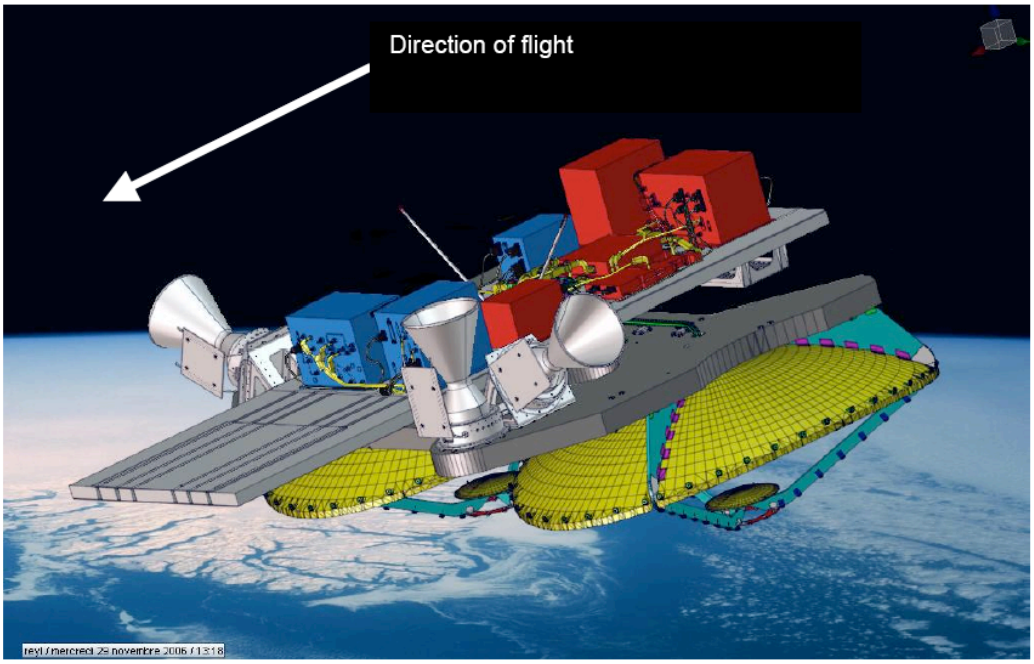
Table 4 - Reference points on the CryoSat-2 satellite (in the satellite reference frame)

	x (mm)	*y* (mm)	*z* (mm)	*Ø* (deg)
Centre of Mass	1657.0	13.0	15.0	n/a
SIRAL Antenna 1	2803.3	585.0	41.5	6º
SIRAL Antenna 2	2803.3	-585.0	41.5	6º
DORIS 2 GHz	1851.4	-200.0	-758.3	6º
DORIS 400 MHz	1834.5	-200.0	-597.2	6º
LRR (optical centre)	1808.5	-935.0	-450.0	6º

2.5.1 SIRAL Antennas

The SIRAL instrument has two antennas. The layout of SIRAL-2 with respect to the flight direction is shown in Figure 3. In nominal operation the transmitter is connected to the Antenna 1 (left hand antenna w.r.t. flight direction). In the event of a failure in the transmit electronics in this chain then the operation is switched to the redundant radar and the transmitter is connected to the right hand antenna (Antenna 2).

Figure 3 - View of the nose of CryoSat-2 showing the installation of the nominal (red) and the redundant (blue) radar systems plus antennas (yellow+green) mounted on the thermo-elastically stable antenna bench (grey). In nominal configuration the transmitter is connected to the left hand antenna (w.r.t. flight direction).



In Low Resolution Mode (LRM) and SAR mode the single receive chain is normally connected to Antenna 1. In the event of a failure in the receive electronics in this chain then the Antenna 2 will be used. The Mission Control Centre and the User Service Centre will notify such an event.

In SARin mode both antennas are used for receive.

The locations provided in Table 4 refer to the apex of the primary reflectors. Other reference points, previously used by other projects, such as the phase centre of the aperture plane, are not conveniently defined for the elliptical SIRAL antennas.

The antennas are inclined by 6º with respect to the satellite reference plane in order to point towards the nadir.

2.5.2 DORIS

The centre of phase for both the 2GHz and the 400 MHz channel is provided. CryoSat-2 has two DORIS receivers and both are connected to the same antenna.

The antenna is inclined by 6º with respect to the satellite reference plane in order to point towards the nadir.

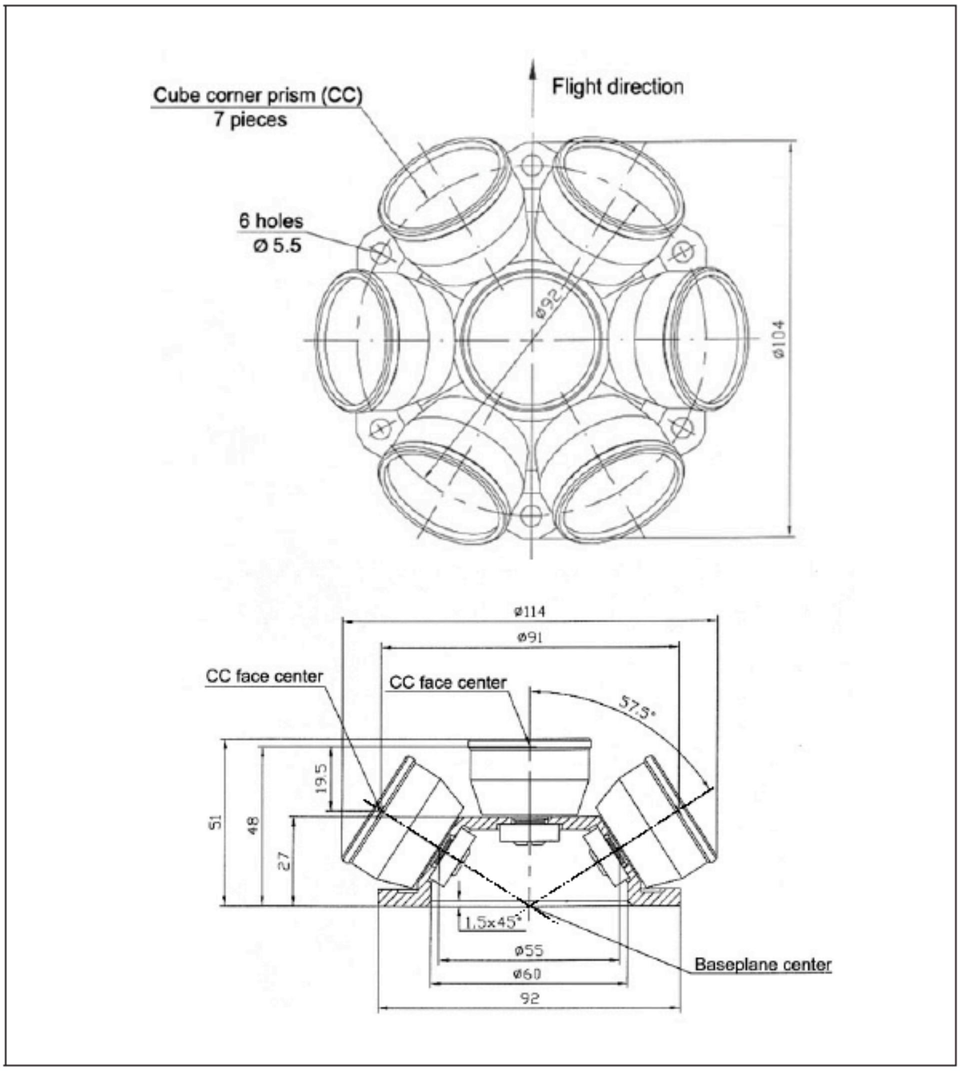
2.5.3 Laser Retroreflector

The laser retroreflector is shown in Figure 1.

The optical centre coincides with the centre of the interface plane to the satellite.

The laser retroreflector is mounted on an interface plate inclined by 6º with respect to the satellite reference plane in order to point towards the nadir.

Figure 4 - The CryoSat-2 laser retroreflector.



3 ORBITAL PARAMETERS

3.1 CryoSat-2 reference orbit

The reference orbit used for CryoSat-2 simulations is an arc of 3 revolutions at an arbitrary date. It is defined as three revolutions staring from the following ascending node:

- Absolute orbit number: 48
- Relative orbit number: 4145
- Repeat cycle: 369 days
- Cycle Length: 5344 orbits
- Longitude of ascending node crossing: 309.369092 deg
- MLST of ANX: 2010-07-04T11:50:18.425118
- TAI: 2010-07-04T15:13:24.600938
- UTC: 2010-07-04T15:12:51.600938
- UT1: 2010-07-04T15:12:51.100938
- MLST drift: -179.208556 sec/day

The times, positions and velocities defining the state vector at this ascending node, as well as the previous one, absolute orbit 47, are given in Table 5.

Table 5 - State vector of the CryoSat-2 reference orbit (Absolute Orbit 48), and the previous orbit, at the ascending node. The reference frame used is the IERS Terrestial Reference Frame.

Absolute Orbit	47	48
Relative Orbit	4144	4145
TAI	2010-07-04T13:34:11.106918	2010-07-04T15:13:24.600938
UTC	2010-07-04T13:33:38.106918	2010-07-04T15:12:51.600938
UT1	2010-07-04T13:33:37.606918	2010-07-04T15:12:51.100938
x (m)	+6393455.132	+4503445.343
y (m)	-3087017.929	-5488618.064
z (m)	+0000000.000	+0000000.000
$\dot{x}$ (ms^{-1})	-0346.795979	-0607.173822
$\dot{y}$ (ms^{-1})	-0695.836821	-0485.588594
$\dot{z}$ (ms^{-1})	+7490.017013	+7490.017013

A file containing the ascending node state vectors for an extended set of orbits starting from the absolute number 38 to 53 is available. This file is an XML format, and is named:

CS_TEST_MPL_ORBPRE_*TDB*T*TDB*_*TBD*T*TBD*_*TBD*.EEF

3.2 DORIS orbit simulation

An orbit maintenance manoeuvre will be simulated, occurring more than 3 orbits after the initial state vector (i.e. after the end of the CryoSat-2 reference orbit simulations arc of 3 revolutions).

The details of the orbit maintenance manoeuvre are shown below.

- ∂v: 0.03m/sec
- increase of semi-major axis: 30 meters

The exact times of the of the DORIS orbit simulation including the orbit maintenance manoeuvre as used during the TMD4 performance test of the DORIS instrument are shown in Table 6.

Table 6 - DORIS TMD4 performance test scenario times including the orbit maintenance manoeuvre.

	TAI	Time Difference
Start DORIS orbit simulation	2010-07-04 13:34:10	
Begin TMD4 simulation scenario	2010-07-04 22:00:00	+ 8.5 h
1st DORIS converged	2010-07-05 01:45:00	+ 3h 45min
Begin of orbit maintenance manoeuvre	2010-07-05 02:00:00	+ 15 min
End of orbit maintenance manoeuvre	2010-07-05 02:05:00	+ 300 sec
DORIS full performance	2010-07-05 03:43:20	+ 1 orbit (100 min)
End TMD4 simulation scenario	2010-07-05 10:00:00	+ 12h after begin
Stop DORIS orbit simulation	2010-07-05 14:27:30	+ min. 1d after start

4 ASSUMED ENVIRONMENTAL CONDITIONS

For the orbit simulation a reference set of environmental and earth parameters are defined. These are intended to be representative of the conditions at the time of the reference orbit.

4.1 Earth Parameters

4.1.1 Pole Position

The values of the 2006-07-04 (MJD 53920) shall be used for the full DORIS orbit simulation:

- u_{pole} : 0.128894 arcsec
- v_{pole} : 0.296220 arcsec

4.1.2 Time Reference

The following values are defined in the CryoSat-2 Reference Orbit, described in Section 3, "Orbital Parameters":

- UT1 – UTC : - 0.5 sec
- TAI – UTC : + 33 sec

The same values shall be used for the full DORIS orbit simulation.

4.1.3 Gravity

The following earth gravity field shall be used:

- EIGEN GL045 GRACE 78x78

The following gravitational parameters for the sun and moon shall be used:

- GM_{sun} : $0.13271243774248 \times 10^{21}$ Nm^2kg^{-1}
- GM_{moon} : $0.4902798928650 \times 10^{13}$ Nm^2kg^{-1}

Ocean tides, solid earth tides and planetary perturbations shall not be taken into account.

4.2 Non-gravitational Forces

4.2.1 Air Drag

The air drag shall be calculated with the model MSIS-200. For the solar flux and K_p the values of 1999-07-04 shall be taken, in order to be more representative of the solar conditions in July 2010.

4.2.2 Radiation Pressure

The solar radiation pressure shall be taken into account, including modelling of any satellite eclipses. The solar constant shall be assumed to be

- C_{sun} : $0.45605000 \times 10^{-5}$ Nm^{-2}

No modelling of infrared or earth albedo effects shall be included in the DORIS reference orbit.