CryoSat-2 Quaternion Products: file format specifications

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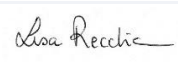
	L. Recchia – Aresys	
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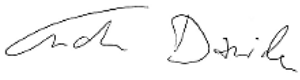
Approved by	D. Giudici – Aresys	

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Summary

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1. Document Overview

1.1. Scope

This document describes the product structure of the attitude quaternion AUX_PROQUA products generated by the Cryosat Star Tracker Processor.

1.2. Acronyms

Aresys	Advanced Remote Sensing Systems
EOCFI	Earth Observation Customer Furnished Item
PDS	Payload Data Segment
XML	eXtensible Markup Language

1.3. Reference Documents

[RD1] PE-TN-ESA-GS-0001 Earth Explorer Ground Segment File Format Standard v1.4

[RD2] C2-TN-ARS-GS-5153 IPF_STR_PROC Product Format Specification issue 2.0 19 June 2018

[RD3] EXP-MA-DMS-GS-0001 Earth Explorer Mission CFI Software Conventions Document v3.7.5

2. AUX_PROQUA file format specification

2.1. Processed Quaternions Files for CryoSat-2 (AUX_PROQUA)

2.1.1. Mission applicability

This document describes the AUX_PROQUA Quaternions file generated for the CryoSat-2 mission.

2.1.2. Description

This file contains the attitude Processed Attitude computed by the CryoSat-2 PDS based on the attitude quaternions computed on-board by the Star Trackers and provided to the PDS within the CryoSat-2 PDGS STR Level 0 Products.

The 3 CryoSat-2 Star Trackers provide attitude in the STRxATT L0 products. The STRxATT L0 products contain raw (untouched) quaternions. Considering the current configuration for EOCFI used in the CryoSat PDS, if there is a gap greater than 120 seconds, the processing of the Star Tracker L0 files fails and the attitude for the corresponding time interval is set as Degraded-Modelled.

For the computation of the quaternions it is furtherly indicated that data have been generated starting **from the Corrected Mispointing Angles (Roll, Pitch, Yaw)** which consider the known biases of the sensors w.r.t. the nominal Satellite reference frame.

The Quaternions are calculated in the Geocentric Mean of 2000 Inertial Coordinate Frame.

The Geocentric Mean of 2000 Inertial Reference Frame is defined as a parallel translation of the BM2000 solar reference frame to the centre of the Earth, being the BM2000 defined as “The centre of this reference frame is the barycentre of the Solar System. The x-y plane coincides with the predicted mean Earth equatorial plane at the epoch J2000.0, and the x-axis points towards the predicted mean vernal equinox. The latter is the intersection of the mean equator plane with the mean ecliptic, and the ecliptic is the orbit of the Earth around the Sun. The z-axis points towards north”.

In line with the above, in the CryoSat-2 PDS the attitude and quaternions data are computed using the EE-CFI 3.x version.

In summary, the following detail specifications have been retained for the quaternions file generation:

[SPEC-01] Quaternion products will contain the rotation angles (as quaternions) between the satellite fixed reference frame and the Inertial Earth centered frame defined according to the Geocentric Mean of 2000 (J2000). The satellite fixed reference frame is defined as in the following figure:

a. satellite fixed frame is centred at the centre of mass of the CryoSat platform;
b. x_s is directed from the from the reference frame centre of origin in the direction of the real antenna bore-sight;
c. z_s is directed from the origin and parallel with the direction vector adjoining the rx only antenna reference point to the tx only antenna reference point and orthogonal to x_s;
d. y is determined by the cross product $y_s = x_s \times z_s$.

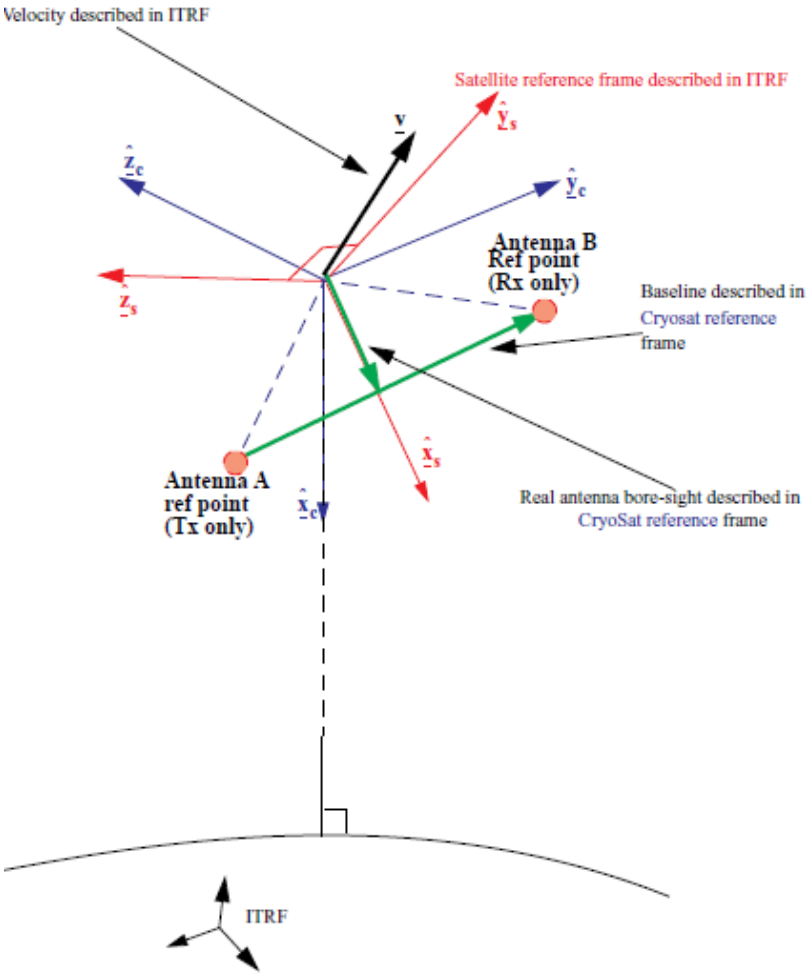

Fig.1 CryoSat Satellite Reference Frame

[SPEC-02] Quaternion product file will contain the Quaternions computed from the one Star Tracker (out of the three Star Trackers mounted on the spacecraft) which is considered the optimal one at that moment.

[SPEC-03] Quaternion product file will provide Quaternions at 1Hz sampling rate and obtained after applying moving average with a window length equal to 5 seconds.

[SPEC-04] One Quaternion product file per-day will be produced with validity coverage of about 26.5 hours, i.e. subsequent products will be partially overlapped.

[SPEC-05] Quaternion product file will be generated at best effort and no timeliness requirements will be given.

[SPEC-06] The format of Quaternion product files will be XML based and compliant with Earth Observation Mission CFI software.

[SPEC-07] The content of the Quaternion products will be computed using library functions from branch 3.X of Earth Observation Mission CFI software.

2.1.3. Dissemination

The file is made available to the users of CryoSat-2 by the CryoSat-2 PDS in the Cal-Val ftp server and it is used for geodesy and POD specialised users.

2.1.4. Data Latency/Coverage

The processed quaternions files are generated by the PDS during precise attitude processing.

The processing delay and timeliness are related to the CryoSat-2 TLM_STRHK_ files delivery (typically 6 hours after reception of last data).

The validity coverage is the same as the CryoSat-2 Orbit files: each file covers about 26.5 hours (one complete day, with about two hours with the previous and 23 minutes with the next consecutive files).

Files frequency generation: one file per day. Files are delivered within 2.5 days after data acquisition.

The attitude information is provided every 1 second.

2.1.5. Accuracy

The accuracy of the computed attitude shall be better than:

- 1 arc-second RMS in pitch and yaw
- 5 arc-second RMS in roll

2.1.6. Data Volume

21 Mbytes uncompressed per product file with 1 new product file generated every day.

2.1.7. Naming Convention

The applicable file naming convention is defined in the Section 4.1 of the Earth Explorer Ground Segment File Format Standard [RD1].

In particular the first 19 characters are fixed for this product, while the other fields are the Validity_Start, Validity_Stop and File_Version as defined in Tab.1 below.

Example: CS_OFFL_AUX_PROQUA_YYYYMMDDTHHMMSS_YYYYMMDDTHHMMSS_BXXX

2.1.8. Data Structure and Definition

The Processed quaternions files follow the Earth Observation EE File Format Specification and the Tailoring of the CryoSat-2 STR File Format Specification defined in [RD2].

When no specific tailoring is described, the standard EE FFS directly applies.

Each Processed quaternions File consists of one Earth Explorer Format XML file with extension .EEF, which is disseminated as a tar, g-zipped package.

The .EEF contains a Header section and a Data-Block section.

The Header is structured in two sections:

- Fixed Header
- Variable Header

To be noted that in CryoSat-2 TAI is used in the data block.

The schema SCHEMA_ATT.xsd describes the format of this file. The schema is attached to this document in Section 2.1.13.

2.1.9. XML Fixed Header Section

XML Tag Name (Level 1)	XML Tag Name (Level 2)	Value	Description
File_Name			As defined in Section 2 without the extension.
File_Description		Processed quaternions File	
Notes		Variable	Free Text
Mission		CryoSat	
File_Class		Variable	Consistent with file class in Section 2
File_Type		AUX_PROQUA	Same as File Type in Section 2
Validity_Period			
	Validity_Start	Variable	UTC time consistent with Validity Start Date in Section 2. Format: UTC=yyyy-mm-ddThh:mm:ss
	Validity_Stop	Variable	UTC time consistent with Validity Stop Date in Section 2. Format: UTC=yyyy-mm-ddThh:mm:ss
File_Version		D001	The value of the

			File_Version field is composed by the Baseline ID (e.g. D) and a numeric code that starts from 001.
Source			
	System	PDS	A string with 3 characters. The System field value must be equal to the File Name Site Centre field value as defined in section 2
	Creator	IPF_STR_PROC	Corresponds to the facility deployed on the Site Centre that generated the file
	Creator_Version	Variable	Version of the service software generating the product
	Creation_Date	Variable	Date of creation. Format: UTC=yyyy-mm-ddThh:mm:ss

Tab.1 Processed quaternions File – Fixed Header

2.1.10. Variable Header Section

No variable header present.

2.1.11. Data Block Section

The data block format is ASCII xml.

XML Tag Name Level 1	Type	Description
Attitude_File_Type	string	The attitude file type: Sat_Attitude

Attitude_Data_Type	string	It defines the type of attitude data: Quaternions
Max_Gap	Unit=”s”	Maximum gap detected in the file, i.e. maximum amount of seconds between two consecutive sets of quaternions, increased by a fixed amount of 0.5s.
Quaternion_Data	Structures: see tables below	Structure for the list of quaternions

Tab.2 Processed quaternions File – Data Block

XML Tag Name	Type	Unit	Description
Inertial_Ref_Frame	string		Reference frame: Geocentric Mean of 2000 (GM2000). This reference frame is defined as EO CFI v3.x frame w.r.t. CryoSat-2 satellite frame using the following convention: X_CFI = - Y_CS2 Y_CFI = - X_CS2 Z_CFI = - Z_CS2
List_of_Quaternions	count=”n”		List of Quaternions

Tab.3 - Processed quaternions File – Quaternions Data

XML Tag Name	Type	Unit	Description
Quaternions	Structure (see table and note below)		Set of quaternions for a given time representing the transformation between Earth-Centred-Earth-Fixed and satellite attitude frame. It is recommended to write quaternions with 9 decimal digits.

Tab.4 Attitude Restituted File – List of Quaternions Data

XML Tag Name	Type	Attribute	Description
Time	string	ref=”TAI”	Date for the quaternions. The date format is CCSDS-A with reference and microseconds

			(TAI=yyyy-mm-ddThh:nn:ss.uuuuuu)
Q1	real		Quaternion
Q2	real		Quaternion
Q3	real		Quaternion
Q4	real		Quaternion

Tab.5 Attitude Restituted File – Quaternions

XML Tag Name	Type	Attribute	Description
Quality	String		Quality flag indicating the quality status of the product. Possible values: NOMINAL DEGRADED-MODELLED See next section for a complete definition of each possible value

Tab.6 Attitude Restituted File – Quality flag

Note: The following quaternions definition, consistent with EO CFI v3.x conventions, has been used (see Sect 7.2.1 of the Earth Explorer Mission CFI Software Conventions Document [RD3]):

$$Q1 = e_x \, sin(\Theta|2)$$
$$Q2 = e_y \, sin(\Theta|2)$$

$$Q3 = e_z \, sin(\Theta|2)$$
$$Q4 = cos(\Theta|2)$$

where (e_x, e_y, e_z) are the direction cosines of the rotation axis and θ is the rotation angle.

Then (Q1, Q2, Q3) corresponds to the vector part of the quaternion and Q4 is the scalar part of the quaternion.

2.1.12. Quality flags

As part of the CryoSat-2 processing chains, each of the products needs to be quality flagged. The definition of these quality flags is based on the monitoring of specific metrics available at the time of generation of the corresponding product.

The thresholds to define a product as degraded may be fine tuned during the processor commissioning phase.

The metrics to be monitored together with the corresponding value of the quality flag are described next for the product Processed quaternions File:

- Default quality flag value (Value: NOMINAL)
- Use of a model due to the lack of quaternions data (Value: DEGRADED-MODELLED).

When the processing of STRxATT L0 products fails, the datarecord is not written in the output file. As a consequence, the product will contain only valid record and the time will be not necessarily evenly sampled.

2.1.13. Example of a File

```
<Earth_Explorer_File>
 <Earth_Explorer_Header>
  <Fixed_Header>
   <File_Name>CS_OFFL_AUX_PROQUA_ 20191102T215523_20191104T002321_D001</File_Name>
   <File_Description>Processed quaternions File</File_Description>
   <Notes></Notes>
   <Mission>CryoSat</Mission>
   <File_Class>OFFL</File_Class>
   <File_Type>AUX_PROQUA</File_Type>
   <Validity_Period>
    <Validity_Start>UTC=2019-11-02T21:55:23</Validity_Start>
    <Validity_Stop>UTC=2019-11-04T00:23:21</Validity_Stop>
   </Validity_Period>
   <File_Version>D001</File_Version>
   <Source>
    <System>PDS</System>
    <Creator>IPF_STR_PROC</Creator>
    <Creator_Version>02.00</Creator_Version>
```

```
    <Creation_Date>UTC=2019-11-04T20:04:46</Creation_Date>
   </Source>
  </Fixed_Header>
  <Variable_Header>
  </Variable_Header>
 </Earth_Explorer_Header>
 <Data_Block type="xml">
  <Attitude_File_Type>Sat_Attitude</Attitude_File_Type>
  <Attitude_Data_Type>Quaternions</Attitude_Data_Type>
  <Max_Gap unit="s">1.0</Max_Gap>
  <Quaternion_Data>
   <Inertial_Ref_Frame>GM2000</Inertial_Ref_Frame>
   <List_of_Quaternions count="93601">
    <Quaternions>
     <Time ref="TAI">TAI=2019-11-02T21:55:23.000000</Time>
     <Q1>-0.253047899698</Q1>
     <Q2>-0.436975295404</Q2>
     <Q3>0.861003275641</Q3>
     <Q4>-0.060767680550</Q4>
     <Quality>NOMINAL</Quality>
    </Quaternions>
    <Quaternions>
     <Time ref="TAI">TAI=2019-11-02T21:55:24.000000</Time>
     <Q1>-0.253170898025</Q1>
     <Q2>-0.436496641014</Q2>
     <Q3>0.861204656334</Q3>
     <Q4>-0.060841751171</Q4>
     <Quality>DEGRADED-MODELLED</Quality>
    </Quaternions>
…
   </List_of_Quaternions>
  </Quaternion_Data>
 </Data_Block>
</Earth_Explorer_File>
```