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DOCUMENT

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NOTE ON CHRIS ACQUISITION PROCEDURE AND IMAGE GEOMETRY

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1 BACKGROUND

The aim of this document is to clarify the acquisition procedure CHRIS on-board the PROBA satellite. It provides a detailed description of the acquisition procedure and summarises the implications for the geometrical properties of the CHRIS images.

This document may be considered an update to the previous memo on Azimuth and Zenith View Angle calculations drafted by ESA and circulated by Sira Ltd to CHRIS PIs on 15/07/2004. Based on the recommendations in the memo, format 4.1 of the CHRIS HDF image product was updated on ?? to include Azimuth and Zenith View angle information for the image centre pixel.

CHRIS HDF format Format 4.1 includes the following information on image acquisition geometry

- Image centre times (ICT)
- Minimum Zenith Angle)MZA)
- Fly-by Zenith Angle (FZA)
- Azimuth Zenith Angle (AVA)
- Zenith View Angle (ZVA)

An illustration of the acquisition geometry and the definition of the angles involved is provided in Appendix 1.

Revision 1 of this document is based on the results of a meeting on 15/01/2005 between EOP-SMS and TEC-SP to address open issues regarding image acquisition recently highlighted by CHRIS PIs.

2 CHRIS ACQUISITION PROCEDURE

The CHRIS acquisition procedure *is based a total observation time interval Tobs* which is calculated on-board based on the following parameters:

- ϕ which is defined based on a 55º acquisition cone θ centred on the test site as illustrated in Fig 1.
- Target longitude and latitude (lon, lat)
- Target height (h)
- Angular velocity of the PROBA platform ω

Tobs defines the beginning of the 1st scan to the end of the 5th (and final) scan is determined by

$$Tobs = \phi/\omega$$

The estimates of ϕ and ω are made at a time Δt=390 s prior to the start of the first image acquisition using instantaneous on-board values of the moment, i.e. the result of the filtering of the on-board GPS data, *i.e. Tobs is frozen 390s prior to the acquisition maneuver.* The estimation methodology is

1) ϕ is assumes a circular orbit with a fixed distance to the spacecraft equal to the semi-major axis of the orbit. The semi-major axis is the estimated value on-board. To determine the location of the target centre a spherical earth is assumed with the radius defined by the centre of the earth to target. The target's geographical latitude and longitude are transformed into geocentric coordinates. The transformation geodetic→ geocentric accounts properly for the earth flattening. The altitude is then measured above the WGS84 geoid.

2) ω is *estimated from actual PROBA orbit data*, i.e. the true angular velocity at $\Delta t=390$

Once Tobs is fixed, the timing of the remaining acquisition maneuvers are by definition fixed and can be subdivided into

- i) scan time Tsc = 20s within which the imaging is performed [1].
- ii) slew period Tsl = 12.5s between each scan
- iii) margin periods Tmar added to both sides of the scan to damp transients occurring between slew period and the scan period.

The total observation period is made up of 5 scans, 4 slew periods and 8 margin periods (the margin periods before the 1st scan and after the 5th scan are considered outside Tobs) as illustrated in Fig 2. The scan times Tscan are evenly distributed across Tobs. Tmar is the only free variable and is chosen so that the total time adds up to Tobs. All Tmars are equal. As Tobs is calculated based on the actual angular rate of the orbit ω, the centre times C1 to C5 vary slightly over time as function of orbit height and corresponding changes in ω.

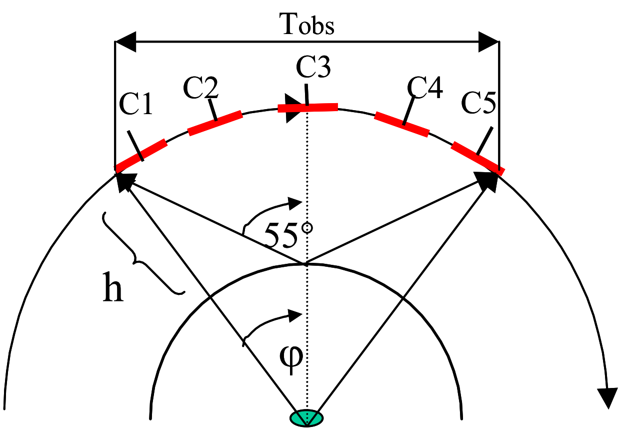


Fig1: Illustration of acquisition geometry. The red lines indicate image acquisitions and C1 to C5 the image centre times. **N.B. C1 and C5 do not correspond to the start and end of the observation time.**

[1] Tsc can be further subdivided into period of light integration = 10s and non-light integration = 10s. However the total time spent looking directly at the targeted scene is 20s.

Tobs =
Tsc+Tmar+ → 1st acquisition
Tsl+Tmar+Tsc+Tmar+ → 2nd acquisition
Tsl+Tmar+Tsc+Tmar+ → 3rd acquisition
Tsl+Tmar+Tsc+Tmar+ → 4th acquisition
Tsl+Tmar+Tsc → 5th acquisition

Fig2: Illustration of the image acquisition sequences including scan time (Tsc), slew period (Tsl) and margin periods (Tmar).

The spacecraft is oriented such the instrument line-of-sight is pointing towards the target at all time. This definition leaves one degree of freedom open; the rotation around the Line-of-sight (LOS). PROBA has adopted a convention to fully define the rotation matrix from the orbital frame (roll-pitch-yaw) to the frame defining the attitude of the spacecraft while imaging. Instead of a general sequence of three rotations, only two are used.

First, a pitch rotation is made to bring the pitch-yaw plane onto the target. Then a roll rotation (the new roll) is made to bring the LOS towards the target. This strategy effectively assumes a flat earth. The projection of the instrument slit on the ground is a straight line perpendicular to the ground track when looking straight down towards nadir. It would still be a line perpendicular to the ground track after the two above rotation if the earth were flat. However, the earth sphere effectively distorts the line.

The scanning motion is super-imposed to the above maneuver by targeting a moving point on the earth instead of target always the centre of the image. This point is moving over the area to image in a plane parallel to the orbital plane, effectively rotating back and forth around the orbital axis, "buried" in the earth. In order to keep the same scanning direction for all 5 images, the rotation axis is also frozen shortly (c.f freeze time above) before the beginning of the acquisition and maintained throughout. This compromise keeps the direction of scan constant on earth at the expense of scanning always exactly parallel to the ground track.

3 A NOTE ON THE UNCERTAINTIES IN CHRIS POINTING

As with all satellite imaging instruments, sources of uncertainty in CHRIS/PROBA pointing exist and lead to misalignments of the images with respect programmed pointing. Typical sources of error include

- Alignment (instrument and spacecraft)
- Datation, i.e. timing (error in time translate into errors on the computed earth rotation, hence on pointing)
- Limitation in the PROBA on-board feedback loop used to maintain maximum pointing accuracy during the acquisition (residual calibration errors on wheel axis and inertia ratio)

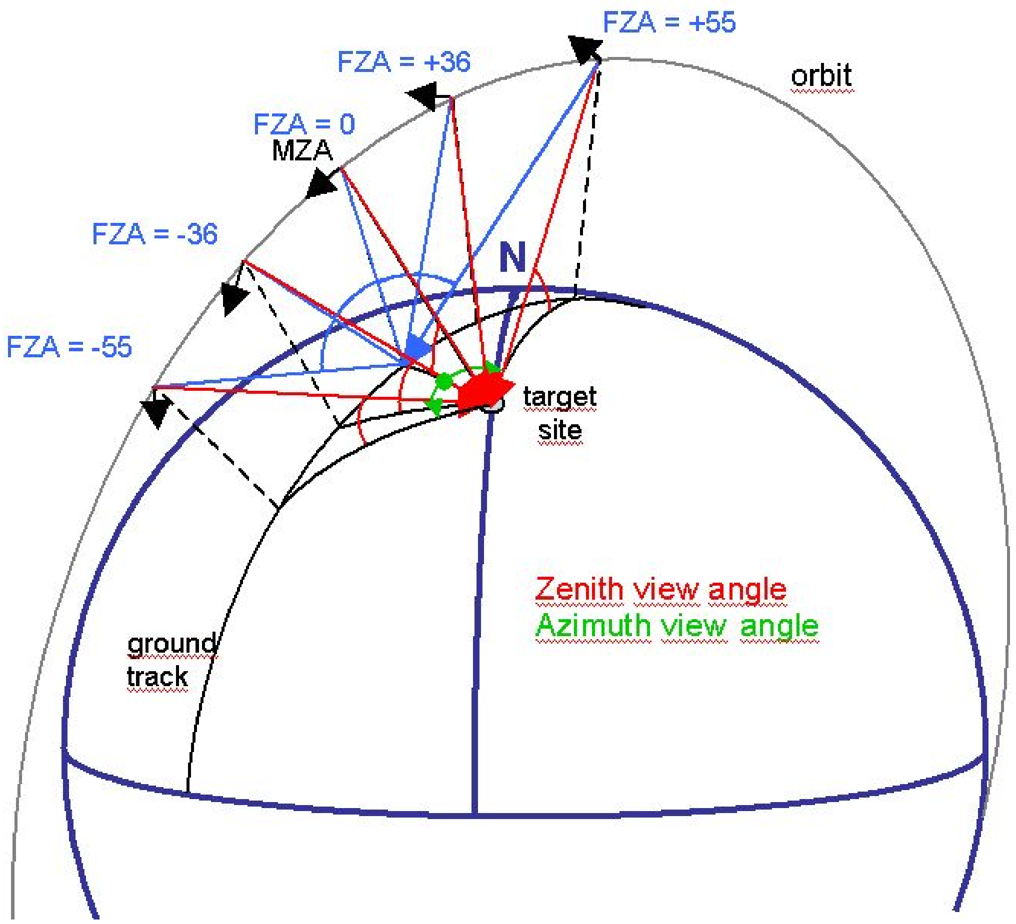
At satellite level, PROBA also makes an estimate of pointing errors based on the feedback loop and transmits this information to the ground as error quaternions.

It is important to note that the mispointing of the acquisitions observed on the ground is the cumulative uncertainty including all sources of error for CHRIS/PROBA. The best estimates of pointing errors under the current nominal operations of the PROBA platform are provided by systematic comparisons between expected and actual pointing on the ground. An example of such feedback is given in Appendix 2. Feedback on mispointing, especially if collect over time and in a systematic way, i.e. separately for all incidence angles and using different test sites, may provide the basis for tuning the acquisition methodology and improve geometric coregistration of the individual images in an image set. Important information to be included in such reporting are the test site lat and lon, and observed delta longitude, delta latitude for each of the 5 images.

4 APPENDIX 1

Image geometry diagram illustrating

- Minimum Zenith Angle (MZA)
- Fly-by Zenith Angle (FZA)

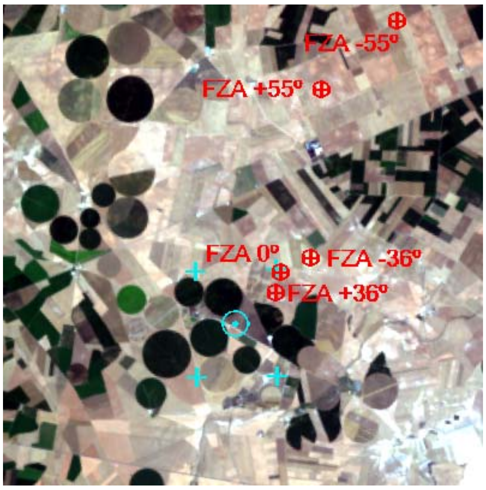


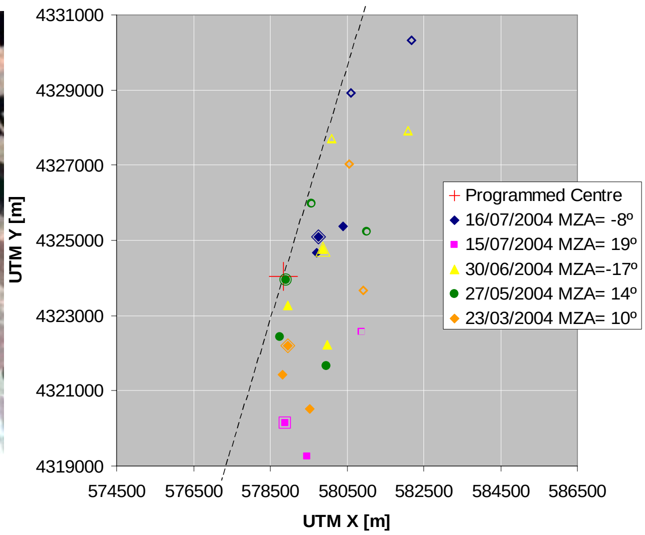
(courtesy of Luis Alonso, Jose Moreno, University of Valencia, Valencia, Spain)

5 APPENDIX 2

(Feedback provided by Luis Alonso, University of Valencia, Spain)

Below there are two graphs, the left one shows the position of the images centres acquired the 16/07/2004; the blue circle indicates the programmed image centre, and the blue crosses indicate de limit of a ±0.01º area (the precision of the centre coordinates). To the right a graph shows the position of the image centres for all the Barrax acquisitions during 2004. The programmed centre is the red cross, the image centre of the 0º acquisitions are distinguished by symbols with an outer frame ⊙, the ±36 are filled symbols ●, and the ±55 are empty symbols O. The inclination of the orbit at the given latitude is displayed as a black dashed line, used as a reference (we are aware that the subsatellite track will be at that position only in a perfect nadir overpass).





Looking at this diagram, it can be appreciated that ±36 acquisitions are always grouped near the 0º acquisition, and ±55 are always grouped and displaced to the north, in some cases the displacement can go up to 4.5km.