

Radiometric features and ground processing for high-resolution Earth observation satellite Bayer matrix-based images like CO3D

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Abstract

Matrix detectors and colour filters arrays are more widely used for satellites and rover missions in the past years. Recently, four CO3D (from "Constellation Optique 3D" in french) satellites equipped with COTS matrix Bayer sensor were launched and calibrated. Both the sensor sampling distinctive features and the new Step & Stare guidance mode are leading to new calibration and processing paradigms. In this paper, we delve into techniques dedicated for such Bayer matrix-based system, mainly but not limited to high-resolution (HR) Earth-observation (EO) satellite missions. We first describe dedicated techniques for in-orbit radiometric performance assessment like signal-to-noise ratio (SNR) and modulation transfer function (MTF). Then we address ground processing dedicated to Bayer acquisitions. Finally, we demonstrate the validity of our approach with CO3D in-orbit measurements. We also apply the radiometric ground processing on real images and provide a comparison with Pléiades-HR imagery, demonstrating the many benefits of the CO3D mission and all its novelties. CO3D in-orbit testing (IoT) is still ongoing eight months after launch, the in-flight performances are not presented in this paper due to confidentiality agreement.

1. Introduction

The four CO3D ("Constellation Optique 3D") satellites developed by Airbus Defense & Space (ADS) in partnership with the French space agency (CNES) were launched on July, 25th 2025 (Lebègue et al., 2020, 2026). This High Resolution (HR) Earth Observation (EO) optical mission is dedicated to the generation of a global 1 m resolution Digital Surface Model. Images are acquired in visible and near infra-red (NIR) spectral bands with a 50 cm Ground Sampling Distance (GSD), thanks to monochromatic and Bayer pattern-based matrix sensors, as shown in Figure 1. The CO3D satellites feature several technological innovations, including a new observation mode, called Step and Stare. Each satellite uses its matrix detector to shoot images (Stare) and pave the area of interest with scenes of about 7km x 5km. The spacecrafts' outstanding agility allows them to quickly reposition between successive shooting (Step) with remarkable short tranquilization time.

The acquisition process relies directly on aliased high-resolution red, green and blue images, rather than on a highly sampled panchromatic band and separated colour bands. Radiometric performances assessment requires dedicated techniques as well. Ground processing is designed to accommodate those innovations and comply with the performance requirements of automated global production (Melet et al., 2020, 2026). The algorithms are not exclusively dedicated to HR Earth Observation and could be useful for any mission based upon Bayer matrix: low-cost low-resolution cubesat satellites and planetary rovers for instance.

In Section 1, we present radiometric performance assessment techniques dedicated to Bayer matrix-based images, in the frame of HR-EO satellites. Those include noise evaluation, instrument refocus and MTF assessment. Unlike previous CNES missions which were all based on push-broom acquisition, CO3D required novel approaches and developments.

Section 2 presents new Bayer on-board and ground processing chain. It details the overall CO3D processing chain presented by Languille et al. (2023) over radiometric processing. Only the novelties compared to Cucchetti et al. (2021) are detailed.

Section 3 relies on CO3D data to demonstrate the presented approach. As the 9-month IoT is still on-going and due to confidentiality agreement, only limited results are presented. We nonetheless show results after ground processing and demonstrate CO3D quality by displaying visual comparison with Pléiades-HR PAN-sharpened images.

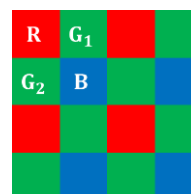


Figure 1. Bayer colour filter array (CFA) – Bayer (1975)

2. Performance assessment

The traditional triplet of radiometry covers Signal-to-noise Ratio (SNR) assessment, Modulation Transfer Function (MTF) evaluation and absolute radiometry calibration. The absolute radiometric calibration -which allows the conversion of digital counts into physical quantities- is performed after ground processing and thus does not require Bayer dedicated processing. Details about CO3D absolute radiometric calibration can be found in Buffe et al. (2026).

2.1 Noise and radiometry

Assessing the noise model requires multiple acquisitions over dark areas (with no light signal) to evaluate the temporal and spatial distribution of the dark signal. The signal-to-noise ratio (SNR) is evaluated by tracking uniform areas in images and measuring signal variation at different radiances.

2.1.1 Noise model

The typical sources of Earth-observation instrument radiometric and sampling noise comprise dark signal and its drift, quantification noise, electro-magnetic compatibility, read-out noise, shot noise and straylight (both dependent on the input signal L_{LSB} in LSB). Considering performance after ground equalization, one must also consider both photo response and dark signal non-uniformities (PRNU & DSNU) residues. When taken all together and combined, the noise model has a standard deviation σ_{noise} given in LSB by:

$$\sigma_{noise} = \sqrt{a^2 + bL_{LSB} + (PRNU_{residue} \cdot L_{LSB})^2} \quad (1)$$

One can measure the additive part a^2 of the noise in $L_{LSB} = 0$ acquisition's conditions. Those hypotheses are met for an EO satellite during night-time and over areas without light source, commonly over oceans far from coasts.

With a single acquisition, one can compute the spatial noise variance across all the pixels: $a_{spatial}^2$. As Bayer matrix-based acquisitions do not exhibit a temporal evolution, multiple acquisitions are necessary to assess the temporal variation of the instrument additive noise. Considering a stack of acquisitions in similar conditions, the evolution of the variance of small patches across the time series provides the temporal noise variance $a_{temporal}^2$.

2.1.2 Signal-to-Noise Ratio empirical assessment

The instrument Signal to Noise Ratio (SNR) validation is performed on the many images acquired during commissioning and does not require dedicated programming. It nonetheless requires both uncompressed (or nearly lossless compressed images) and equalized acquisitions to retrieve the true instrument performance and separate pixel-to-pixel response inhomogeneity from spatial noise.

Due to the varying spectral response across the Bayer R/G/B wavelengths, an independent assessment must be made for each colour plane. However, due to the common optics and sensor's electronics, the three colour planes share a common noise model and thus the same SNR, expressed as a function of LSB, as radiance may differ between the bands. As the green band has twice the number of pixel and SNR is computed at Bayer macro-pixel resolution, a $\sqrt{2}$ factor is applied as signal increases in square root of the number of repetitions.

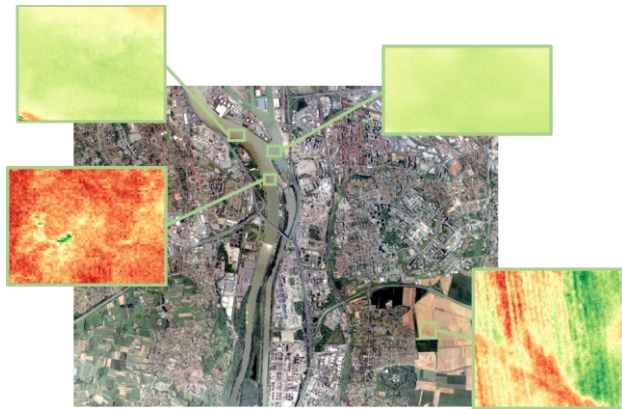


Figure 2. Simulated CO3D image with four patches automatically extracted for SNR evaluation. The patches only display the corresponding green band. Among the extracts, only one (*Top right*) is suitable for spatial noise assessment since the

others have local landscape variation invisible on the down-sampled image used for patch extraction.

An automated process detects relatively uniform areas within the various images. Figure 2 shows some detected patches on a simulation. The Signal to Noise Ratio is computed for each patch by dividing the scenery spatial average value (μ) with the standard deviation (σ) of the signal over the considered image patch.

$$SNR = \frac{\mu}{\sigma} \quad (2)$$

Uniform landscape such as calm water surfaces or snowy areas may provide more usable patches (with greater areas), but any locally uniform landscape is workable. To limit memory consumption and increase processing speed, the initial uniform area detection is performed on low resolution images (typically 1/16th of the full resolution). Due to this down sampling, some scenery high frequency variation and inhomogeneity might outwit the detection step and provide an erroneous or at least underestimated SNR data point. The resulting scatter plot of the combined assessment is a pessimist estimate of the instrument' SNR as shown in Figure 3. Only the best values are kept to assess true SNR with a confidence given by the coefficient of variation (CV) between the bands. It is defined as the ratio of the standard deviation of the three colour bands SNR at a chosen radiance over its mean. Due to the sample size (3 channels), we use the unbiased estimator $\hat{c}_V^*$ given by

$$\hat{c}_V^*(SNR) = \left(1 + \frac{1}{12}\right) \frac{\sigma_{\{SNR\}_{R,G,B}}}{\mu_{\{SNR\}_{R,G,B}}} \quad (3)$$

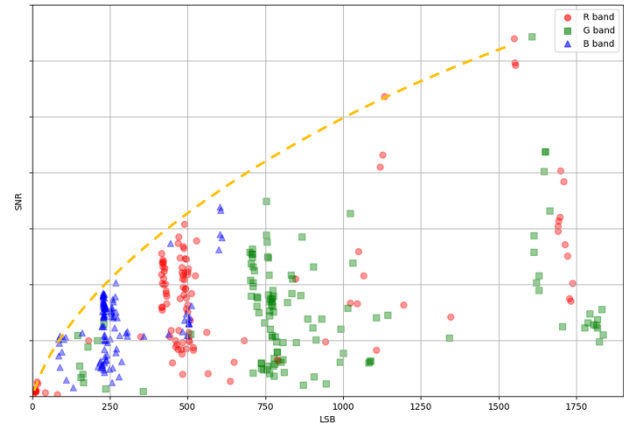


Figure 3. Unfiltered scatter plot of SNR evaluation on the single CO3D simulated image of Figure 2 with a diverse landscape. The estimated SNR curve (in dashed yellow) is already visible with a few dozen extracted patches. Due to the method pessimistic approach, many extracted patches under-estimate the SNR.

2.2 Focus and resolution

Even if an instrument is precisely aligned on the ground, the combined effects of launch shocks, vibration and the space environment may cause changes to its optical focusing. Therefore, refocusing the instrument is one of the first activities to be conducted once in orbit. As with any optical system, the process of satellite imaging can be considered as a low-pass filter, defined by its modulation transfer function (MTF). MTF is the 2D Fourier transform of the satellite point spread function (PSF).

Lucas et al. (2024) describes how the PSF combines through convolution instrument static effects (optical degradation linked to the instrument wavefront error and sensor attenuation) with dynamic contributors (motion blur, platform vibration, guidance):

$$\begin{aligned} MTF_{sat} &= MTF_{static} \cdot MTF_{dynamic} \\ \Leftrightarrow PSF_{sat} &= PSF_{static} * PSF_{dynamic} \end{aligned} \quad (4)$$

Dynamic effects are variable, depending on acquisition angles, platform stability whereas static contributor may only slightly vary between acquisitions, neglecting thermoelastic variation. An independent evaluation of both static and dynamic terms is necessary to precisely derive the satellite's performance.

Measuring the instrument edge response on ground patterns helps to evaluate MTF. Evaluation shall be performed on each band independently, after ground equalization. In order to limit data alteration, no pixel interpolation shall be performed: as a result, the green band is separated into two sub-bands assessed separately. Such a measurement provides quite reliable MTF estimates, but only for frequencies lower than a quarter of the sampling frequency f_s due to the Bayer sensor sparse sampling. In addition, ground-target based estimation are biased by the acquisition condition (depointing, platform stability, atmosphere) adding external contributors to the intended static MTF measurement.

Star-based MTF measurements allow a more precise retrieval of the instrument's characteristics (Lucas et al., 2023) for each spectral band. Using well-known spectral and point-like targets (e.g. stars or lasers), chromatic instrument effects can be derived. Assuming stars are point sources, such acquisitions directly provide satellite PSF's images. Considering inertial guidance and long tranquilization time prior acquiring, one may consider negligible dynamic effects. Single star images have the same frequential limit at $\frac{f_s}{4}$: Multiple successive acquisitions of the same target enhance the available frequential information. If there is enough data, it is possible to reconstruct a super-resolved (SR) PSF as illustrated by Figure 4. Each colour plane is treated independently, the two greens providing twice the number of frames to stack. There are many SR libraries (shift-and-add, drizzling), but PSFr (Birrer et al., 2022) provided better results than others. Besides, Ding et al. (2022) successfully used it on James Webb Space Telescope data.

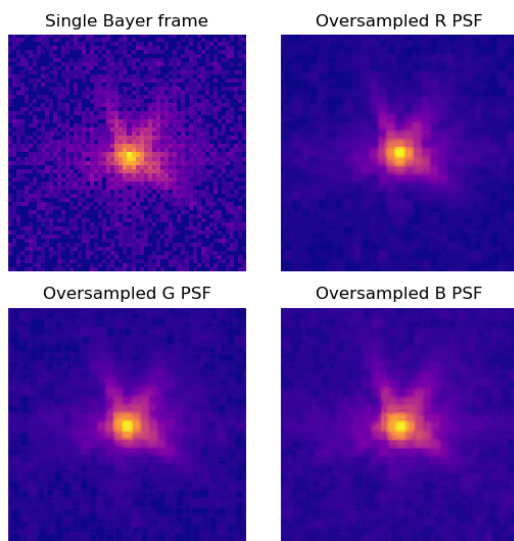


Figure 4. CO3D simulation of a single Bayer frame of a star acquisition (Top left) and 4 times over-sampled red (Top right) green (Bottom left) and blue (Bottom right) PSF reconstruction after stacking 10 frames based on PSFr.

Phase diversity technique (Latry et al., 2017) goes one step further, allowing detailed instrument characteristics to be retrieved like optical aberration and instrument Wavefront Error (WFE). Lucas et al. (2023) provide the detailed process for a Bayer sensor, which is a specific case of the patent registered by Lucas et al. (2026).

3. Radiometric ground processing

We present the most recent image processing chain for Bayer-based missions, developed by ADS for onboard use and by CNES for ground-based use. This includes high-resolution Earth observation satellites and is also envisaged for other missions, such as CubeSats and planetary rovers (Cucchetti et al., 2021, Th  ret et al., 2024). Depending on computational capacity and transmission bandwidth, the onboard chain may be simplified.

Figure 6 shows the overall on-board and ground processing chain. This provides more information on radiometry than presented by Languille et al. (2023). Furthermore, we only discuss the steps that were not developed by Cucchetti et al. (2021), namely on-board/on-ground equalisation, defective pixel interpolation, spectral processing, and Bayer-dedicated restoration.

3.1 Compression & decompression

Cucchetti et al. (2021) provides a detailed account of fixed-quality compression and its application to Bayer acquisitions. First, a noise variance-stabilizing transform (VST) is performed to produce a constant noise variance output prior to spectral decorrelation using a Karhunen–Lo  ve transform (KLT) which also delivers constant variance noise since KLT is a linear transform with fixed coefficients. KLT delivers 4 1m subsets with constant variance noise which are independently compressed with fixed quality wavelet Compression algorithm. Encoding then takes place on board after a discrete wavelet transform (DWT). The images may be previously normalized on-board to reduce inter-pixel variation and compression bandwidth. The initial ground processing consists in reverting the compression, with the additional step of noise restoration needed before denoising to recover the original noise distribution significantly corrupted by compression step. Figure 5 shows the ground combination of decorrelated bands to recreate the Bayer Image.

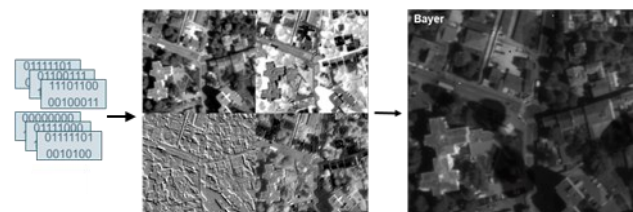


Figure 5. Reconstruction of the Bayer image on the ground after decompression and combination of the four spectrally decorrelated bands

3.2 Radiometric processing

3.2.1 Equalization

Bayer matrix-based acquisitions do not display a temporal dimension; time is no longer a constraint when creating 2D data, enabling a new paradigm of acquisitions that exploit this available dimension (e.g. summing acquisitions, videos...). This also prevents the direct computation of temporal evolution (e.g. summing columns with an along-track slow motion).

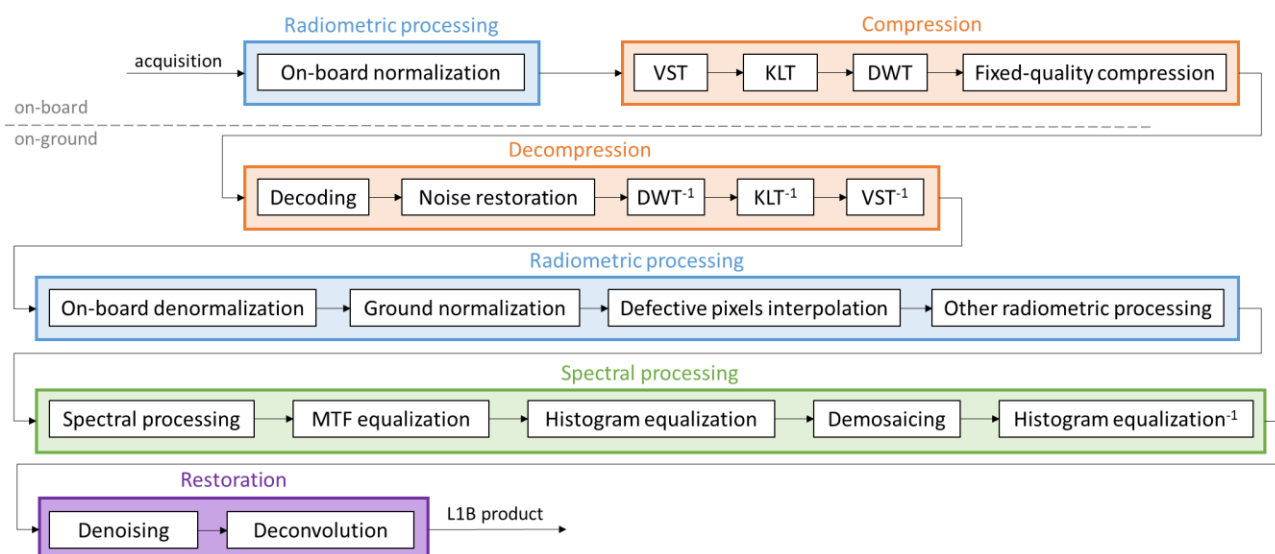


Figure 6. Block diagram of the overall Bayer processing chain. Each block colour represents common processing aspects.

Detector normalization is less critical for Bayer acquisition compared to push-broom, as there are no stripes. However, wrong equalization tables would create grid effect due to pixel-to-pixel gain difference and let visible defocused particles on the sensor protective cover over pseudo-uniform areas.

With agile push-broom systems, one could pilot the target to align sensor axis with ground speed like AMETHIST guidance (Théret et al., 2006), acquiring with every pixel the exact same scenery. The equalization process of a matrix sensor with Step&Stare guidance requires acquisitions over uniform areas. In the frame of HR imagery, even pseudo-uniform sites like desert or Antarctica display local non-uniformity. A specific guidance to blur landscape might help removing landscape residues.

3.2.2 Noisy and defective pixel interpolation

The harsh space environment (radiation, temperatures and ionised particles) can degrade system performance, particularly the response of sensors. Over time, some pixels may malfunction and require correction on the ground to minimise the impact on images. In particular, a single faulty pixel can affect all its neighbours due to the demosaicing process. The following types are expected: dead pixels, white pixels in the dark, non-linear response pixels and noisy pixels. Acquisitions of uniform landscapes (bright and dark) like the one used for equalisation might help to identify them.

The faulty pixels are interpolated on each colour band separately. Agglomerated pixels are managed through an iterative process: first, pixels with the highest number of healthy neighbours are interpolated. Then, the number of neighbours available for interpolation is assessed again, and this process is repeated. Interpolation can be as simple as taking the mean of the neighbours, or it can rely on a more complex approach, such as pseudo-Hamilton-Adams interpolation based on local image gradients (Cucchetti et al., 2021).

3.3 Spectral processing

Bayer sensors provide sparse images of each colour plane, so an interpolation process, known as demosaicing, is required to recover information at the sensor's native resolution. Low-computational-cost algorithms based on the Hamilton-Adams interpolation scheme are used for HR satellite image processing (Cucchetti et al., 2021).

During the recovery of colour planes, the red, blue and green channels are non-convolutionally mixed. Any other known instrumental effects should be corrected before this step, while each colour plane is still independent. These corrections may include realignment to compensate for any instrument and processing spectral deregistration. MTF normalisation shall also be applied before merging to equalize sharpness across the sub-plane as shown in Figure 7.

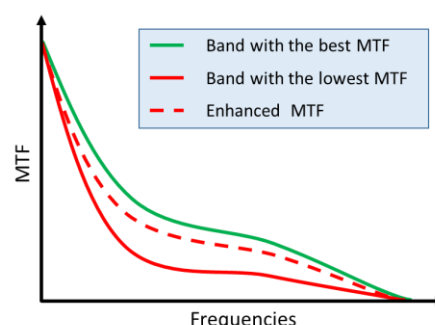


Figure 7. Principle of MTF equalization before demosaicing which aims to enhance the bands lower MTF to (or close to) the others' level.

Indeed, shorter wavelengths are more impacted by achromatic optical aberration than longer ones. On the contrary, diffraction MTF increases with the band frequency. In case of difference between bands, the demosaicing output of the best band is therefore degraded by the interpolation spectral mixing because of the lower other band MTF.

Additional processing, such as radiometric histogram stretching, can improve the demosaicing process and reduce chromatic artefacts. Aligning the sub-bands radiometry eases the interpolation process, reduce chromatic artifacts and improves edge restitution. The inverse transform shall be applied after demosaicing to store the original radiometry; therefore, the overall transform shall be a bijection.

First, we rely on an initial histogram matching look-up table (LUT) computed by any good signal processing library, to match red and blue histogram with the green one (considered as the reference band). Those LUT are however not bijective.

Therefore, we perform a linear regression limited to the LUT smoothest part. To ease the implementation and reduce computation cost, this method creates a non-optimal transform at very low and high luminance but ensure both an artifact-free bijective and optimal transform for a vast majority of the pixels. Table 1 shows the quantitative improvement on PSNR, RMSE and SSIM based on simulations.

	PSNR	RMSE	SSIM
HA	15.493	0.1564	0.219
Stretch + HA + stretch ⁻¹	15.520	0.1558	0.223

Table 1. Demosaicing PSNR, RMSE and SSIM with only HA interpolation or with an additional histogram stretching step. Performance is evaluated on a simulated 5x7km CO3D scene. The best value is in bold.

3.4 Restoration

In optimised systems, the MTF value is low at the Nyquist frequency, resulting in blurry raw images. Restoration (Latry et al., 2012) involves denoising and deconvolution, which enables control over the final noise level and recovery of image sharpness. Usual denoising technique involves NL-Bayes algorithm implemented by Lebrun et al. (2013) applied to a single band. Bayer dedicated demosaicing and denoising algorithm (Guillaume et al., 2025) can take advantage of the CFA pattern, with combined denoising of the three colour bands.

4. Application to CO3D Images

4.1 In-orbit performance assessment

4.1.1 Noise in darkness

In-flight calibration relies on burst acquisitions: each image product consists of dozens of frames acquired successively. Multiple acquisition at night over the Atlantic, Pacific and Indian ocean are combined to retrieve the instrument noise model (both spatial and temporal). The evaluation performance is expressed here as the coefficient of variation (CV) defined across thousands of measurements, hence the use of the regular estimator $\widehat{c}_v(a_{temporal}^2)$. It is defined as the ratio between standard deviation σ and mean value μ :

$$\widehat{c}_v(a_{temporal}^2) = \frac{\sigma_{a_{temporal}^2}}{\mu_{a_{temporal}^2}} \quad (5)$$

The same technique and metric are used to derive NIR temporal noise model. The spatial noise is assessed with an unbiased estimator $\widehat{c}_v^*(a_{spatial}^2)$ between the three red / green / blue bands results:

$$\widehat{c}_v^*(a_{spatial}^2) = \left(1 + \frac{1}{12}\right) \frac{\sigma_{\{a_{spatial}^2\}_{R,G,B}}}{\mu_{\{a_{spatial}^2\}_{R,G,B}}} \quad (6)$$

$\widehat{c}_v(a_{temporal}^2)_{CO3D1,2,3,4} VIS$	1.28%
$\widehat{c}_v(a_{temporal}^2)_{CO3D1,2,3,4} NIR$	1.40%
$\widehat{c}_v^*(a_{spatial}^2)_{CO3D1,2,3,4} VIS$	2.35%

Table 2. CO3D temporal and spatial noise estimation variation averaged across the four satellites.

Table 2 shows only a small dispersion of the results as well as a similar retrieval performance between Bayer VIS and NIR sensors, hence demonstrating the method performance. Across all satellites, the relative deviation between spatial and temporal noise estimation is lower than 3%.

4.1.2 Signal to noise ratio

SNR in-flight empirical assessment is performed on any landscape with automatic processing. Figure 8 provides two examples of uniform sceneries acquired by CO3D. The average coefficient of variation between the four satellites in regard of the SNR specification is given in Table 3.



Figure 8. Examples of CO3D acquisitions used for SNR computation. Large calm water surfaces (Left) and snowy areas (Right) provide reliable estimates at low and high luminance.

	Red	Green	Blue
$\widehat{c}_v^*(SNR)@L_{CO3D1,2,3,4}$	2.16%	1.02%	1.16%

Table 3. CO3D SNR estimation variation per spectral band averaged across the four satellites.

4.1.3 Refocusing and MTF assessment

CO3D refocusing system is based on thermal control of the telescope's primary mirror. The observation of stars at various mirror temperature settings introduces different imaging states of the same target that help phase diversity retrieval. CO3D BURST acquisition mode allows to retrieve nearly simultaneously dozens of images, providing numerous observations of the same target.

This also allows simpler metrics like PSF full width at half maximum (FWHM) to be derived. It is a measure of the resolving power of an instrument: sharpest system has a narrower PSF and a lower FWHM. Expressed as a function of defocus, it roughly follows a quadratic function. This provides a good estimate of the temperature at best focus without the need of complex computation. PSF FWHM is measured on each extracted colour plane, then averaged across the frames of each burst. Figure 9 provides an illustration of CO3D measurements.

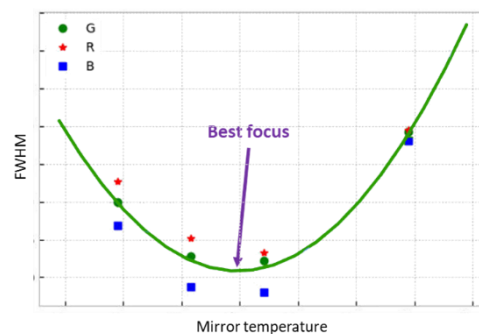


Figure 9. CO3D PSF FWHM measurements for the three colour bands as a function of thermal control setting. The green line shows the quadratic best fit for the green channel.

Even if CO3D MTF assessment relies on phase diversity, ground targets are regularly acquired during the IOT phase (as illustrated by Figure 10) to quickly monitor the system's health. Figure 11 provides an example of a single CO3D star acquisition and the simulated image based on phase diversity optical aberration estimation.

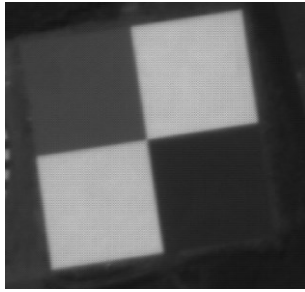


Figure 10. Bayer image of the Baotou (China) knife-edge target acquired by CO3D

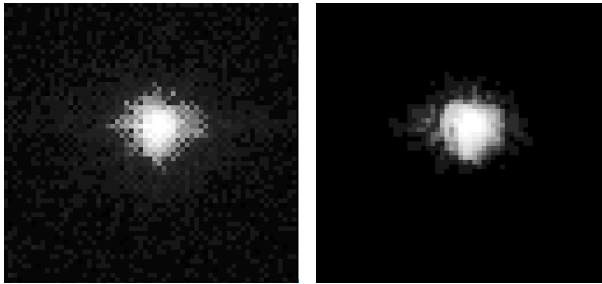


Figure 11. A single frame from a star acquisition (VIS sensor, bayer image) of Epsilon Virginis (HIP 63608) (*Left*) and the green band simulation based on PSF reconstruction (*Right*).

4.2 Radiometric ground processing

4.2.1 Equalization

The motivation to update the gain and offset tables is manifold: the pixel response may evolve over long term, thus updating the gain table is necessary. Furthermore, the sensor local response can be affected by particle contamination lying on the detector or on optics close to it. These particles are prone to move during launch making the correction with prelaunch tables inefficient. The update of gain tables allows to correct these effects. Finally, acquisition in darkness enables defective pixels to be identified and monitored.

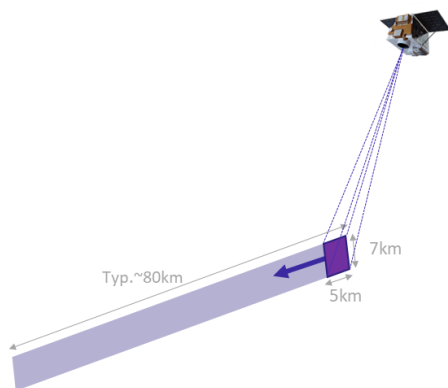


Figure 12. CO3D drifting summation acquisition process. Typically ~100 images are acquired successively on a 80km-long strip and directly summed on-board.

The mechanism for creating the offset/gain correction tables is based on acquisitions carried out in a drifting mode, with several images summed over landscapes that are as uniform as possible illustrated by Figure 12. Careful data management is necessary to avoid any saturation. Equalization tables are directly computed on-board based on those summed acquisitions. Indeed, uploading two (gain & offset) 150 million pixels tables for each satellite is not possible.

New equalization tables were produced during CO3D IoT summing long drifted acquisitions over the Antarctic (for gain table) and oceans at night (offset). An example of such table is provided by Figure 13

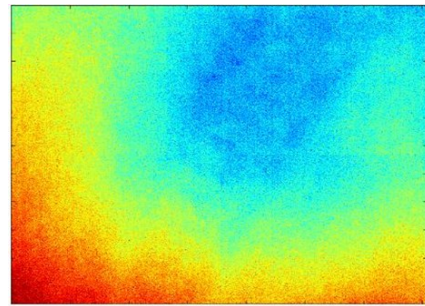


Figure 13. One of CO3D gain tables measured on ground prior to launch

During operations, the instrument withstands violent shocks which might lead to some contamination displacement. Indeed, there are some very light and shallow dusts on the sensor box cover. Those only degraded signal transmission by less than 1% but are unfortunately visible over uniform surfaces. Nonetheless, the new tables perfectly correct these artefacts.

4.2.2 Bayer demosaicing

Figure 15 displays the result of CO3D colour interpolation step on a scene, improved by colour histogram stretching. The stretch law applied on the image is illustrated by Figure 14.

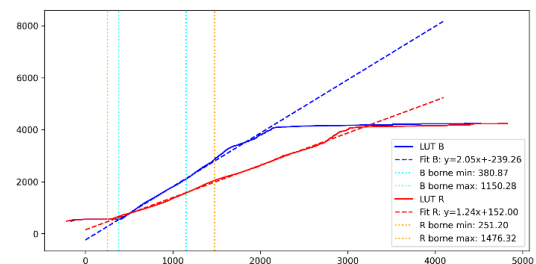


Figure 14. Red and blue histogram stretching LUT and the computed linear bijective transform associated to the CO3D acquisition of Figure 15 and Figure 16.

4.2.3 Restoration

Figure 16 shows CO3D restoration process. The denoising step is based on Non-Local Bayes denoising adapted to Bayer matrix (Guillaume et al., 2025) with a third step ensuring spectral coherence and limiting chromatic artifacts. The deconvolution process relies on filters generated thanks to the star-based MTF and is performed on each band independently, with a dedicated management of specular saturation.

4.3 Comparison with Pléiades-HR imagery

More than a decade later, CO3D provides 50 cm colour imagery just like Pléiades HR, with fundamentally different instruments and acquisition processes. Pléiades relies on a panchromatic band, acquired at 70 cm (equivalent to CO3D green band in terms of native resolution) and PAN-sharpening of multispectral push-broom images acquired at 2.8 m a final resampling to 50 cm. After processing, both missions provide R/G/B imagery with 50 cm ground sampling distance. Scenery details are similar between the two. CO3D Bayer provides more natural and sharper colour information as illustrated in Figure 17.

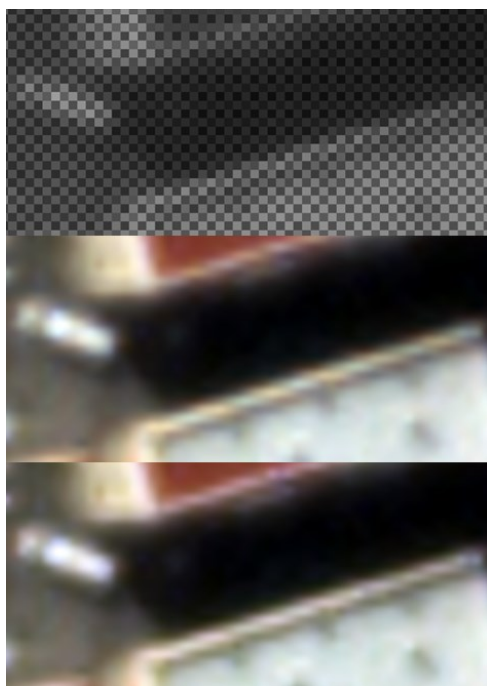


Figure 15. CO3D Bayer image (*Top*) of Cadix, after demosaicing without histogram stretching (*Center*) and with histogram stretching (*Bottom*), zoom x50. Without histogram matching, colour artifact (yellow and blue stripes) appear on building and bright cars edges.

CO3D also benefits from a low-noise rolling-shutter matrix sensor and a well-tuned variable integration time management, having a good SNR in dark areas like shadows. This is of prime importance for the 3D mission, to improve reconstruction in urban areas.

5. Conclusion

In this paper we presented performances assessment and calibration techniques dedicated to Bayer matrix sensor. These techniques were successfully applied during the CO3D commissioning phase. Furthermore, we examined the Bayer processing chain and demonstrated how the radiometric qualities of the output products compare to Pléiades reference imagery.

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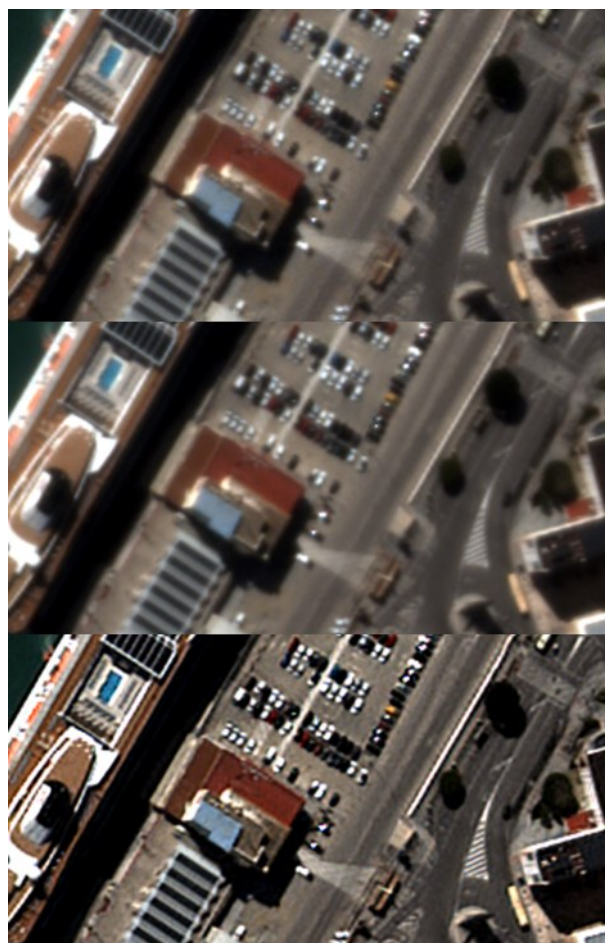


Figure 16. CO3D acquisition over Cadix harbour. After demosaicing (*Top*), denoising (*Center*) and deconvolution (*Bottom*). s

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Figure 17. Comparison of restored CO3D (Left) and PAN-sharpened Pléiades-HR (Right) acquisitions on Cadix harbour (Top) and Casablanca Mosque (Bottom). Cadix acquisitions have less than a week time-delay. Despite the more favourable sun illumination for Pléiades over Casablanca Mosque, there is more signal in the shadows with CO3D. CO3D also has better spectral separation between colours. PHR images have a red halo around the edges, which is more pronounced in bright areas (such as around boats), and the colours are also more diffuse.

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