## Proba – V 11th Quality Working Group (QWG): Summary Report

The 11th Proba-V QWG took place via WebEx on 25th - 26th Jun 2020

| **Partecipants:** | | | |
|---|---|---|---|
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## Objectives of the meeting

The main discussion points for the QWG meeting #11 are recalled:

1. *Mission Status:* the FG and GS status after more than 7 years in space is excellent and the primary objective of ensuring continuity to VGT data series bridging the gap to S3 was fully met. To prevent impact of orbital drift on the consistency of the long-term archive, it was decided to discontinue the operational mission by 30 June 2020; as from July 2020 the new experimental phase will start with a limited commitment on real-time delivery. During the meeting, the mission status is reviewed with focus on calibration and data quality as well as on anomalies and performances expectation for the mission extension.
2. *Mission Experimental Phase*: the new experimental phase will start on July 2020, the initial focus will be on acquiring data over Africa and Europe and preparing for the operations and exploitation of the Proba-V Companion Cubesat (PV-CC); the launch of the first PV-CC, carrying onboard a VNIR sensor identical to Proba-V, is expected for April 2021. During the meeting, the extension scenario is presented, the proposals for Science and Cal/Val experiments reviewed and the Cal/Val and Exploitation plan for the PV-CC mission discussed.
3. *Algorithms Baseline for C2*: the development and validation of the NN cloud screening are completed and the relevant module is ready for the processing. The development of the new AC scheme is on-going in close collaboration between HYGEOS and VITO. During the meeting, the progress status, the integration tests, and validation results are reviewed. As a result of the discussion the baseline is fine-tuned and consolidated, and the reprocessing plan agreed.
4. *Continuity*: the validation activities for the transition to Sentinel-3 are on-going, their status is reviewed during the meeting. CGLS products will be continued with Proba-V until June 2020 and starting from July 2020 all NRT production of biophysical variables will be based on Sentinel-3 input data. S-3 based products will be initially released in demonstration mode and in parallel a QA will be carried out to assess their quality. As soon as a give product will reach a good quality status it will be delivered in operational mode.

## Flight and Ground Segment Status

The overall performances of the platform and sensor are excellent and very stable with a platform availability between 99,1% and 99.9% for the last 9 months. All performance parameters are well within the requirements, the system is very stable with no sign of degradation.
The Flight Segment status is reviewed, here below the main indicators:

- *LTDN predictions:* 09:23 AM are reached in June 2020, as expected
- *Platform Status:* during this period, the platform was very stable. Two issues on GPS with consecutive TLE selection were observed and potential impact on geometric quality is discussed.

The main activities on the platform are summarized here below:

- *Geometric error investigation:* starting from November 2019 an increased amount of geometric errors was observed; an extensive analysis was performed, and updates of star tracker SW were applied. The analysis of the errors and their impact on data availability was refined by VITO and it is available at the following web site (https://www.vito-eodata.be/missingpixels/). In addition, monthly dumps of Star Tracker images are now performed to continuously monitor performance.
- *Preparation to Experimental Phase:* the activity will start in July 2020 and 3 X-band contacts per day will be executed. The acquisitions will be over Africa and Europe, the new LSM will be provided by VITO. Concerning preparation to PV-CC mission, ESA will coordinate discussion with all relevant partners to review operational GS readiness. A TC will be organized for this purpose during July 2020, involving ESRIN, REDU, ESTEC and ASL.

- *AOCS:* performances are far better than requirement, the overall status is excellent.
- *Power Budget:* largely positive and stable showing no apparent degradation of the solar arrays nor power distribution system
- *Thermal performances:* excellent thermal performances of radiator and optical bench are confirmed
- *Decompression errors:* the number of decompression errors is currently low. VITO has performed a better classification of the error events: an initial analysis was performed manually, and the outputs are detailed in the VITO report.
- *Ground segment status:* the satellite and ground segment operations are running nominally. ESA/REDU centre supported all planned passes, the data downlink was shared between Kiruna, Alaska, and Inuvik stations with 10 X-band passes per day. From the first of July 2020 onwards only 3 X-band passes per day will be planned, and the proposed strategy is to schedule two passes after the REDU morning passes and one before the REDU evening pass.

## Radiometric and Geometric calibration

The vicarious calibration results show a potential impact of temperature change, camera and band dependent: this increasing trend is not considered in the ICP files and it is being investigated how to correct for it in the C2 reprocessing. The proposed way forward is to select a second-degree polynomial model in function of date for each camera/band that correct the long-term temperature change but not the seasonal variation.
The radiometric accuracy and multi-temporal stability of the Lybia-4 Rayference Calibration Reference (LRCR), which was acquired with 3 different radiometers (VGT1/VGT2/Proba-V), is carefully assessed as a first step for the SPAR@MEP ESA project. The first results of Proba-V data harmonisation are presented: the Proba-V calibration is very accurate, in the order of 3%, at the same level of more sophisticated sensors, having an on-board calibration device. No statistically significant departures are observed for the measured radiometry when compared to the simulation, except for the BLUE band and left camera, where deviations are in the order of 4-5%. Polar plots also show a dependency on azimuthal configuration, with clear differences between forward and backscattering, which is not observed in MODIS. This may point to potential polarisation sensitivity.
An overview of the Proba-V geometric accuracy is presented: the *absolute accuracy* is excellent (<100m for all cameras) and well within goal requirements, with no sign of degradation. The last update of geometric coefficients dates to Sept 2016 demonstrating the stability of the platform pointing system. The *absolute location error* varies along the mission showing a seasonal pattern with slightly degraded performances in wintertime and a clear improvement in absolute accuracy during 2020. This improvement has been ascribed to the update of the on-board star-tracker SW performed during Jan 2020. The *inter-band accuracy* is very good and largely within the requirements. The inter-band errors per spectral bands are always below 70m for the three cameras. The *multitemporal accuracy* is also well within the specifications with about 89% of compliance to the requirement for the VNIR bands and 95% for the SWIR.

## Mission Experimental Phase

The extension proposal agreed between ESA and BELSPO during the Mission Board meeting in March 2020 is presented. Starting from the 1st July 2020, Proba-V will enter the experimental phase during which the following scenarios will be implemented:
• Systematic acquisitions (3 X-band passes per day) over Africa and Europe with central and side cameras. The choice of this region of interest was triggered by requests of key users, in particular UC Louvain, who is strongly interested in further exploiting Proba-V acquisitions, over Africa in particular, to demonstrate their value for complementing S-2 imagery in a number of regional application with main focus on agriculture ad land cover. This choice was also welcomed by VITO.
• On-request acquisitions for Cal/Val and Science purposes, this includes in particular continuing vicarious calibration acquisitions over PICS, DCC, Moon and oceans. The MVA experiment will be descoped owing to the limited overlapping region verified in past test. The night-time acquisitions show a strong impact of noise and the possibility to effectively sense the faint urban light signal is very unlikely. A super-resolution experiment is described and proposed: the idea of the experiment is to turn the platform around the yaw axis by certain angle (45-60 degree) in order to oversample the same pixel on ground with multiple near coincident measurements. The 60 degrees is considered the best option, since it ensures over-sampling the same pixel on-ground with 3 adjacent detectors, potentially leading to a large gain in the information content and resolution of the considered target at sub-pixel scale. In addition, VITO proposed to execute moon daily calibration acquisitions covering a full lunar cycle. The derived daily data might be very interesting for the validation of a new lunar irradiance model being developed at VITO to improve the existing ROLO model. The QWG members are encouraged to take this opportunity for proposing new experiments.
• Start of companion mission in synergy with the first VNIR Cubesat PV-CC (TMA identical to Proba-V) that will compensate and progressively expand Proba-V observations capabilities. The current launch estimate is April 2021. The QWG need to proactively contribute to this mission phase by proposing and consolidating a Cal/Val and Mission Exploitation Plan in synergy with Proba-V. An investigation is currently on going at VITO in collaboration with ESTEC to estimate overlapping orbits between the two satellites and to test PDGS workflow with PV-CC source packets.

In addition, it was also suggested to test the cloud algorithm approach developed at University of Valencia, using transfer learning from Proba-V to PV-CC. This could be a good demonstration of such approach and should be considered as part of the Exploitation Plan. The cross calibration and the harmonization between two different satellites will be an important topic to be addressed during this phase and it should be detailed within the Cal/Val plan.

## Algorithm Baseline Definition for C2

The development and validation of the NN cloud screening are basically completed: the NN at 100 m was trained by University of Valencia, implemented in the VITO infrastructure, and successfully validated by Brockmann Consult. The final algorithm is a single globally tuned NN model, which does not require ancillary data and multitemporal information.
The results of validation phase are reported and show by far better cloud detection results than in C1, especially in terms of decreasing of false positives, in particular 40% improvement is observed in C2 in terms of reduction of commission errors. The quality of the new cloud mask is likely providing the best possible accuracy considering the limited spectral coverage and the lack of thermal bands. The cloud shadow mask was assessed showing a medium quality, as it often under-estimates the cloud height and therefore the mask is not covering all parts of the shadow area. This limitation might be improved in a potential evolution of the C3 baseline.
The new AC scheme is based on an advanced SMAC version with re-computed LUT including a much larger ensemble of aerosol mixtures (148) and using an ancillary dataset for AOD. The validation methodology is built on the protocols prototyped in the frame of ACIX. It consists in validating the TOC products obtained using different aerosol input data against in-situ reference synthetic data obtained using as input AERONET atmospheric state and 6S accurate atmospheric correction RTM. The comparison is performed over 48 AERONET sites covering different biomes, locations, and meteorological conditions. With respect to the input data, two options are being considered: MERRA-2 and CAMS both based on Atmospheric Global Re-analysis datasets suitable for a reprocessing exercise. In both cases, a derived AOD climatology will be generated. A first validation exercise has been done for the year 2018 and for the single Proba-V pixel closest to the AERONET site. MERRA-2 hourly data was used as ancillary data and the regressions plots for all sites and bands are presented. The validation exercise will be completed by end of July 2020.
The SMAC AC prototype was successfully installed on the Proba-V operational processing environment. The integration tests showed high memory consumption mostly due to loading of the global DEM in memory. HYGEOS in collaboration with VITO is investigating the problem and a fix of the issue is being implemented by restraining the size of the DEM to the region of interest of the processed segment.
During the discussion on C2 baseline, it was addressed the need of providing uncertainty information into the final TOC products. The advanced AC module already implements this feature, by running multiple execution of SMAC using a Monte-Carlo approach to propagate uncertainties in the input data into the output products. However, currently there is no pixel-based uncertainty at TOA level, but only an average value per band and per camera estimated with vicarious approaches. Furthermore, the reprocessing infrastructure is not ready to handle and allocate an additional layer in the TOC products for C2 reprocessing, since this will have a significant impact on the overall PDGS infrastructure. At this point, the possibility to provide pixel-based uncertainties in the TOC products need to be postponed to a future baseline (C3), for which the impact on PDGS side needs to be carefully assessed. The provision of pixel-based uncertainties at TOA level could be considered also as part of C3 evolution. It is therefore suggested for the time being to add a switch in the SMAC algorithm and disable for C2 both the Monte-Carlo computation and the provision of per-pixel uncertainty in TOC.
Despite the fact that per-pixel uncertainty cannot be provided in C2, it would be very important to attach to the TOC products a Quality Indicator (QI) providing information on the reliability of the AC, especially in case of large aerosol loading or for large viewing/illumination angles, where the SMAC parameterization is known to be less accurate. Currently the status map is full and there is no space for such QI, however VITO is keen to investigate on potential solution and propose a way forward for C2.
Finally, a potential list of upgrades to be included in future C3 baseline will be proposed and reviewed by the QWG during future meetings so that to progressively consolidate the list and prepare the ground for the C3 baseline definition. The expected time frame to consolidate and start working on these improvements will cover the next 2-3 years.

## Continuity

The overall availability of Proba-V data was good and ensured the NRT operations at CGLS during the whole operational mission life. From the first July 2020 onwards all NRT production of biophysical variables will be based on Sentinel-3 input data initially in demonstration mode with limited commitment on the quality. In parallel to the switch a QA of S3-based products will start, a given product will start to be disseminated in operational mode as soon as it will reach the required quality level, QA will start with NDVI product. The new workflow will focus on NRT production at 300m based on Sentinel-3 L1c data; the NRT production at 1km will be discontinued, a user tool will be provided allowing downscaling S3 products. The Albedo products at 1km will be no longer produced in CGLS but will continue in C3S based on Sentinel-3. Lastly, the Water Bodies products will continue until September 2020 with Proba-V, starting from October onwards it will be generated using as input Sentinel-2 data. The activities for the next period include the quality assessment and consolidation of S3 biophysical products and their final dissemination. The alignment between PROBA-V C2 products at 300m and the S3 biophysical

products will be also verified to have consistency in the time series. To this end, early access to one-year of Proba-V C2 reprocessing is requested by CGLS as soon as they are available.

The latest SYN L2 IPF was delivered and implemented in operations in June 2020; the results of validation on SYN L2 products are presented and discussed. The quality assessment of SYN AOD performed by direct comparison to AERONET shows a slight overestimation, which is reflected in the derived surface reflectance. An additional inter-comparison exercise between the SYN and MODIS Normalized Surface Reflectances (BRDF corrected) shows a good agreement. Assessment of the consistency between SYN-VGT and Proba-V products is currently on-hold at VITO. The need to apply the SLSTR calibration factors to S3 L1C CGLS processing chain is discussed, it was demonstrated that these factors have an impact on SYN-AOD and SDR retrieval. The SLSTR correction factors were supposed to be officially released after the S3VT Meeting, originally planned on Mar 2020, which was eventually postponed to Dec 2020 due to the pandemic. On the other hand, there is good confidence on the amount of such correction, as confirmed by various independent analysis made by different calibration experts. The results of this assessment were summarised in a TN, which will be circulated within the Proba-V QWG.