Project:	Copernicus Sentinel-1, -2, -3 and -6 Precise Orbit Determination Services
Meeting:	CPOD – Quality Working Group #12
Date:	13 - 15 June 2023
Place:	Technichal University Delft, Delft, The Netherlands
Secretary:	H. Peter / PosiTim UG

ATTENDEES

Name/Company/Signature	Name/Company/Signature
Pierre Féménias (PF) / ESA-ESRIN	Urs Hugentobler (UH) / TUM (13+14 June)
Carlos Fernández (CF) / GMV	Patrick Schreiner (PS) / GFZ
Jaime Fernández (JF) / GMV	Anton Reinhold (AR) / GFZ
Heike Peter (HP) / PosiTim	Alexandre Couhert (AC) / CNES
Francisco Sancho (FS) / EUMETSAT	John Moyard (JM) / CNES
Marc Fernández (MF) / GMV (14+15 June)	Torsten Mayer-Gürr (TMG) / TUG
Filomena Catapano (FC) / ESA-ESRIN	Barbara Süsser-Rechberger (BSR) / TUG
Pieter Visser (PV) / TU DELFT	Stefan Winkler (SW) / Airbus (13 June)
Wim Simons (WS) / TU DELFT	Ka Ban (KB) / Airbus
Oliver Montenbruck (OM) / DLR	Kevin Gutsche (KG) / Airbus
Martin Wermuth (MW) / DLR	Jose van den IJssel (JI) / TUD
Daniel Arnold (DA) / AIUB (online)	Sebastiano Padovan (SP) / EUMETSAT (online)
Miguel Munoz de la Torre (MMT) / GMV (online)	Bingbing Duan (BBD) / TUM (online)
Sonia Lara (SL) / GMV (online)	Hugues Capdeville (HC) / CLS (online)
Javier Berzosa (JB) / GMV (online, 14+15 June)	Frank Lemoine (FL) / GSFC-NASA (online, 13 June)
Eva Terradillos (ET) / GMV (online)	Shailen Desai (SD) / JPL-NASA (online, 13+14 pm)
Luning Bao (LB) / GMV (online)	Cyril Kobel (CK) / AIUB (online)
Berthyl Duesmann (BD) / ESA-ESTEC (online)	Georgia Katsigianni (GK) / CNES (online)
Eléonore Saquet (ES) / CNES (online)	Adrian Banos-Garcia (ABG) / CNES (online)
Francesco Gini (FG) / ESA-ESOC (online)	José Carlos Rodriguez (JCR) / ILRS (online, 14 pm)

Attachments

Annex01: 01_Copernicus_POD_QWG12_20230613_15_agenda_final
Annex02: 02_QWG12_GMV_Status of the Copernicus POD Service
Annex03: 03_QWG12_ESA_Status of current missions and upcoming Sentinel C&D satellites
Annex04: 04_QWG12_Airbus_Presentation from Airbus
Annex05: 05_QWG12_CNES_Status CNES processing
Annex06: 06_QWG12_PosiTim_Sentinel-6 yaw attitude bias
Annex07: 07_QWG12_PosiTim_S-6 PODRIX Galileo tracking – marginal state

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Annex08: 08_QWG12_DLR_presentation_slides
Annex09: 09_QWG12_TUG_Presentation from TU Graz
Annex10: 10_QWG12_TUD_SwarmTrackingLoops
Annex11: 11_QWG12_TUM_PhaseS6A_ALGO
Annex12: 12_QWG12_PosiTim_S-1 outgassing event
Annex13: 13_QWG12_GMV_Status of the EOF<->SP3 converter for COAH
Annex14: 14_QWG12_GMV_Recommendation to switch to COST-G FSM operationally
Annex15: 15_QWG12_CNES_SLR station range bias correction based on LEO missions
Annex16: 16_QWG12_ILRS_ILRS station range bias generation
Annex17: 17_QWG12_GMV_Testing on L5 with GNSS products based on L1&L5
Annex18: 18_QWG12_GMV_Testing on Galileo HAS
Annex19: 19_QWG12_GMV_Review of AIs and recommendations

Agenda	Distribution List
(details see Annex01 attached) 1. Welcome and purpose of meeting, logistics 2. Status Copernicus POD Service 3. Status current Sentinel and future C&D satellites 4. Presentation from Airbus 5. Status CNES processing 6. Sentinel-6 yaw attitude bias 7. S-6 PODRIX Galileo tracking – marginal state 8. S-6 half-cycle slips 9. Presentation from TU Graz 10. High solar activity – tracking look adaptations 11. S-1C tracking scheme – recommendation for future C/D satellites 12. S-1 outgassing event 13. Status of the EOF<->SP3 converter for COAH 14. Recommendation to switch to COST-G FSM operationally 15. SLR station range bias correction based on LEO missions 16. ILRS station range bias generation 17. Review of AIs and recommendations 18. Testing on L5 with GNSS products based on L1&L5 19. Testing on Galileo HAS	Attendees + copernicuspod@gmv.com + carolina.nogueiraLoddo@eumetsat.int + nuno.miranda@esa.int + ferran.gascon@esa.int + jerome.bouffard@esa.int + hilary.wilson@eumetsat.int + muriel.pinheiro@esa.int + steffen.dransfeld@esa.int + franck.borde@esa.int + Olivier.colin@esa.int + franck.desbouillons@esa.int + alessandra.boungiorno@esa.int + jordi.farres@esa.int + berenice.guedel@esa.int + kate.symonds@esa.int + valentina.boccia@esa.int + luisella.giulicchi@esa.int + denise.dettmering@tum.de + nzelensk@umd.edu + flavien.mercier@cnes.fr + s3mpc-stm-coord@groupcls.com + s3.stm@eumetsat.int

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Agreements, declarations, actions

Copernicus POD QWG#12 and CPOD operations summary

General:

- The software switch from NAPEOS to ***FocusPOD*** end of January 2023 went very smoothly. No impact on the accuracy of the products could be noticed. The timeliness could significantly be reduced, which is especially visible for the NRT products.
- The increasing solar activity impacts the tracking performance mainly over the geomagnetic poles. The carrier phase noise increases due to this. Receiver tracking loop adaptations are recommended to minimize the impact of the increasing solar activity. (see Annex08 and Annex10 and Recommendation #11)

Sentinel-1:

- Sentinel-1A CPOD Service operations are running nominally. The increasing solar activity impacts the PREORB product due to the large uncertainty in the prediction of the solar flux indices.

Sentinel-2:

- Sentinel-2A & -2B CPOD Service operations are running nominally.

Sentinel-3:

- Sentinel-3A & -3B CPOD Service operations are running nominally.

Sentinel-6:

- Sentinel-6A CPOD Service operations are running nominally. The inconsistency of 14 mm in y-direction between PODRIX and TRIG results can be removed by adding a yaw bias of 0.43 deg to the attitude quaternions. (see Annex06)

Welcome and purpose of meeting, logistics (PF, CF, PV)

Status Copernicus POD Service (CF)
(details see Annex02 attached)

EGP (External GNSS provider) reference signal change:
CF: The EGP reference signal change is due to the harmonisation of reference signals across different projects by the EGP. It has to be adopted within the CPOD Service (if tests turn out positive).
OM: With selection of 7Q for Galileo it could be difficult to get phase bias for integer ambiguity resolution (IAR)
JF: Currently NRT and STC processes are still ambiguity float.

Latest RSR results:
WS: For the latest RSR a radial offset of 7mm has been found for S-6 In the TUD processing using the new S-6 PCV map. Processing is still based on IGS14 (JPL delivering orbit and clock products has not yet switched to IGS20).
OM: IGS14/IGS20 scale difference is very probably cause of the radial offset.

CPOD tools EOF-SP3 converter:
FL: SP3 might not be the best choice for orbit result exchanges due to the cut at 1 mm resolution in the format. What about ORBEX format?
OM: ORBEX is a good but very general format, which can handle a lot of different contents. Full implementation to read it is very difficult. ORBEX is not (yet) widely accepted. Best option is to move the decimal point in the SP3 by one position for LEO orbit positions and velocities. This is still compliant with the format description in terms of the length of the data fields and leads to 0.1 mm resolution.

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Recommendation #41:
(details see Annex20)
The Copernicus POD QWG recommends that the EOF-SP3 converter uses the F14.7 format for writing LEO satellite positions in SP3. This would avoid issues with the 1 mm resolution.

COAH and SOL (Sentinels online):
TMG: Documentation on SOL is fine to get started with POD.
OM: COAH website (GNSS data hub) is not very user-friendly. Download of single products is fine, but for POD a whole bunch of products is needed. Better documentation and example scripts (e.g., as it is available for PODAAC) for downloading several files in one run would be very helpful.
BSR: Confirmation that download of a bunch of files from COAH is not easily possible and needs a lot of manual interaction.

AI on ESA (QWG012-ESA-AI-001):
ESA to check with COAH about having a public API for the GNSS hub (to allow for batch download of files with a script) as it is available for the science hub.

AI on ESA and EUMETSAT (QWG012-ESA-AI-002): (AI is also connected to discussion on geocenter motion modelling, see below)
ESA and EUMETSAT to contact Copernicus Services and altimetry data users using the S-3 and S-6 orbit products about their specific needs (CoN, CoM frame) and to request test analysis with different product series, e.g., CNES, CPOD, COMB. Length of data set to be agreed.
Note: There is an AI on GMV (MRR#5-GMV-AI-001) from the Monthly Meeting on 16 June 2023:
GMV to produce a TN explaining the changes related to the geocenter motion and their potential impact on the orbital products.
This TN will be the basis for ESA and EUMETSAT to get in contact with the Copernicus Services and altimetry data users.

Recommendation #42:
(details see Annex20 attached)
The CPOD QWG recommends to provide the combined orbit products from the RSRs for all satellites on the GNSS hub of the COAH.

FL: What is the latency of the COMB orbit products? They might be used for SLR station calibration.
CF: COMB is produced for the RSRs, every four months, so not very suitable for short-term calibration. There are other orbit products with shorter latencies which could be better suited for this purpose.

AI on GMV (QWG012-GMV-AI-001):
GMV to provide list of available S-3 and S-6 orbit products with their corresponding latencies to ILRS (FL + ILRS Central Bureau) to be possibly used for SLR station monitoring.

<u>Status Sentinel C/D satellites</u> (PF):
(details see Annex03 attached)
The support and the quick reaction of the CPOD team and QWG for understanding and solving the S-1A leaking event in October 2022 is very much appreciated.
Lowering of Sentinel-1B has started. As soon as the satellite is below the “Starlink envelope” the rest of the fuel will be used to lower the satellite as much as possible. Then it will be passivated meaning that all instruments are switched off, solar arrays are moved out of the sun, and batteries are disconnected.

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OM: 25y re-entry altitude of more than 600 km is questioned. Natural reentry from that altitude is expected to be longer than 25 years.
BD: Once S-1B is passivated the Ballistic coefficient is being assessed, in order to have the best 25y altitude for S-1A (and S-1C and S-1D).

FL: ILRS tracking requests for new missions and planned tandem phases should be submitted early enough (> 0.5-1 year before launch) to guarantee readiness of the ILRS and its SLR stations.

Presentation from Airbus (SW,KB,KG):
(details see Annex04 attached)
CRISTAL:
Two PODRIX, LRA, no DORIS
CF: POD processing included in ground processing?
KB: Not yet
KB: How can we as platform provider give support for POD?
=> all mechanical, thermal and geometrical information of the platform, measurement of offsets of all sensors after integration, proper documentation
FL: Are the thrusters used for reaction wheel offloading?
SW: No reaction wheel offloading by thrusters. It is done by magnetotorquers.
FL: Yaw flips are very useful for disentangling antenna offset mismatches. Thermal studies on the satellite should be done beforehand so that CRISTAL could fly flipped by 180 degrees for four days at a time, because this allows to calibrate the POD instruments.
KB: Yaw flips are possible on CRISTAL.
AC: What are the POD requirements for CRISTAL?
KB: POD requirements are not coming from Airbus. The requirements are available on system level.
OM: The POD requirements are probably like those from CryoSat.
MW: Amount of fuel is more than 10% of the satellite wet mass. Are there measures about the distribution of the fuel within the tanks? What about CoM changes due to this?
KB: Tanks are heritage from Sentinel-6 design. Clever distribution of fuel within tanks.

Orbit determination:
OM: Batch filter might be better than back- and forward filtering.

Sentinel -6:
Status of CNES processing (JM)
(details see Annex05 attached)
HP: Which new time-variable gravity field model is planned for the new POE-G standards?
AC: EIGEN-GRGS RL05 because of availability of EIGEN-GRGS before GRACE era. The latter is needed for reprocessing of the older satellite missions.

CNES S-3 and S-6 orbits are delivered in the CoM (Center of Mass) frame with an explicit modelling of the geocenter motion (self-estimated model). This is the cause for the annual and semi-annual signal in the orbit differences between CNES and other QWG orbits.

General discussion on geocenter motion modelling:
Geocenter motion modelling is a heavily discussed topic in the POD community. According to the current IERS Conventions only center of mass corrections based on ocean tide information (and associated sub-daily, daily etc. time scales) had to be applied for the transformation between CoN (Center of Network, e.g. ITRF2014) and CoM (Center of Mass) frame. With the new ITRF2020 an official geocenter motion model (annual and semi-annual signals) has now been published. The ITRF2020 geocenter motion model now allows for a harmonized modelling

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by different groups. However, the IGS ACs agreed to not apply this new model (neither the associated seasonal ground deformation model) in their GNSS orbit and clock processing.
AC: With the current POE-F standards, CNES still uses a special (IGS14-based) CNES/CLS orbit and clock solution and is adopting their geocenter motion model via a correction to the GNSS clocks (details see Couhert et al.2020, https://doi.org/10.1029/2019JB018293).
OM and TMG: An easy way to realize a proper LEO POD solution in the CoM frame would be to apply (next to the transformation into inertial system) both the new ITRF2020 geocenter motion model (with annual and semi-annual periods) and the center of mass corrections from the ocean tide information (with "short-periodic" contributions) to the IGS AC orbit solution of the GNSS satellites. This enables a consistent modeling of orbital dynamics and observations in an inertial CoM system. Before saving the LEO positions in the SP3 file both corrections have to be applied in reverse direction to obtain the LEO orbit in the CoN (Center of Network) frame. The CoN frame would be the preferable and unambiguous frame to deliver the Sentinel orbits for the RSRs. It has to be checked with the altimetry data users which orbit reference (CoM or CoN) they expect to get from the POD provider. At minimum, this should be clearly stated so that they could translate the orbits in CoM or CoN properly afterwards (see also QWG012-ESA-AI-002 and MRR#5-GMV-AI-001 above).
CF/AC: Clarification about the geocenter motion model applied to the CNES orbits and how to handle this correctly in the RSR comparisons.
CF: It has to be checked with the QWG members if all can provide their orbit solutions in CoN frame.

AI on GMV+CNES (QWG012-GMV-AI-002):
GMV and CNES to clarify about the geocenter motion model applied to the CNES orbits and agree on the standard for the operational CPOD products.

AI on CNES (QWG012-CNES-AI-001):
CNES to check if a simple transformation of their S-3 and S-6 orbits from CoM to CoN can be done without doing a full determination of the orbits again.

AI on GMV (QWG012-GMV-AI-003):
GMV to prepare a memorandum on the handling of the geocenter motion in the different QWG orbit solutions in the context of the RSRs.

S-6 yaw attitude bias – way forward (HP)
(details see Annex06 attached)
Test data set analysis confirms that an attitude correction of -0.43 deg in yaw leads to more consistent orbit solutions from the PODRIX and the TRIG data. The y-offset of 14 mm disappears when considering this in the attitude products.
Information about the issue will be forwarded to PLSO (Post-Launch Support Office) to try to find an explanation or a solution on platform side.
For POD the S-6 attitude quaternions are planned to be corrected in the attitude product available for the POD QWG and in the PROQUA product, which is made available on the COAH GNSS hub.

AI on GMV (QWG012-GMV-AI-004):
GMV to apply the -0.43 deg yaw bias to Sentinel-6A processed quaternions for POD and to the PROQUA product (made available on COAH).

AI on POSITIM (QWG012-PTIM-AI-001):
PosiTim to provide information on the S-6 yaw bias to PLSO (Kate Symonds) for clarification.

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S-6 PODRIX Galileo tracking - marginal state (HP)
(details see Annex07 attached)
Unacceptable high number of cycle slips in carrier phase passes of Galileo satellites in marginal state ("SISA=NAPA") is seen as a PODRIX tracking problem, which has to be solved by Beyond Gravity (former RUAG). Ground stations do not show such a behaviour. Fixing of the PODRIX tracking in marginal state should be pured irrespective of any efforts of the Galileo project to reduce/minimze the occurrence of marginal state in the constellation.

Recommendation #43:
(details see Annex20 attached)
The CPOD QWG recommends to contact Beyond Gravity (RUAG) to make sure that PODRIX receiver tracks Galileo satellites in marginal state without resetting the carrier phase ambiguities.

S-6 half cycle slips (MW)
(details see Annex08 attached)
List of days, which are affected by PODRIX frontend related half cycle slips, will be distributed to check the impact in the QWG member solutions. Based on the outcome further actions might be necessary. This could be the correction of the half-cycle slips at RINEX generation step, but it will be difficult to do this in an automated way.

AI on ALL (QWG012-ALL-AI-001):
ALL to check if receiver frontend related half-cycle slips in S-6 PODRIX data impact the IAR process.

Presentation from TU Graz (TMG)
(detail see Annex09 attached)
TUG orbit processing:
S-3A&B: Inconsistent results with COMB detected in radial direction. Cause is still under investigation.
JF: Already tested to include Sentinels/LEOs in network solution to estimate GNSS orbit and clocks?
TMG: No, no large impact expected and the problem with different sampling rates (stations: 30 sec, LEOs: 10sec or 1sec) would have to be solved.

Initiative to provide ocean tide models in unique format (ICGEM):
HP: The initiative is very much appreciated, because the current situation with different file formats and different formulation for different ocean tide models prevents to switch to newer models or to even test different models.
OM/CF: A solution to provide the ~40 individual files (one per tidal constituent) within one file would be preferable.
TMG: ICGEM format does not allow for this and it is not foreseen to change the format because of this. The number of files is not seen as a problem.

High solar activity – tracking loop adaptations? (MW)
(details see Annex08 attached)
In contrary to Swarm and GOCE, increased carrier phase RMS or increased differences between reduced-dynamic and kinematic orbits are only observed over the geomagnetic poles and not or only few around the geomagnetic equator.

Impact of Swarm tracking loop adaptations (JvI)
(details see Annex10 attached)

Recommendation (Reinforcement and rephrasing of Recommendation #11):

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(details see Annex20 attached)
The CPOD QWG recommends to change as quick as possible the bandwidth of the semi-codeless P(Y) carrier phase tracking loops on L2 from 0.5 Hz to 1 Hz for the Sentinel GPS receivers (Sentinel-1,-2,-3).

We are currently in the time of increasing solar activity. A tracking loop adaptation would help to decrease the carrier phase tracking noise over the geomagnetic poles. An increased carrier phase noise impacts the processing performance and the quality of the IAR. Quick adaptation within weeks or very few months is needed, because the tracking problems are fully related to the solar activity.
The overall noise of the carrier phase will slightly increase by the wider tracking loops, but the positive impact during high solar activity is seen as the higher benefit than the slightly increased carrier phase noise during low solar activity.

S-1C tracking scheme – recommendation for future C/D satellites (Discussion)
Sentinel-1C will have the same default tracking configuration as Sentinel-6A (GPS-IIA,GPS-IIR: **L1,L2P(Y)**; GPS-IIRM,GPS-IIF,GPS-IIIA: **L1,L2C**; Galileo: E1,E5a)
The CPOD QWG agrees to have this default tracking configuration also on future C/D satellites. It has to be secured that the receiver does not automatically switch to L1,L5 tracking for the new generation of GPS satellites as soon as the L5 signal becomes healthy. This would cause major problems for POD, because then signal combinations with L1+L2 and L1+L5 would be tracked for the respective groups of GPS satellites and require joint processing in the POD S/W.

FG: S-6 GPS L2C data still show slightly worse performance than GPS L2P(Y). Request to do again ground tests with receivers of future Sentinel satellites and to get access to these ground test data.
OM: L2C test data from S-3B at the beginning of the mission and about five days of L2C tracking with the TRIG receiver could help to check L2C performance as well.

Observed S-6 phase drift (BBD)
(details see Annex11 attached)

Recommendation (reinforcement and rephrasing of Recommendation #29):
(details see Annex20 attached)
Existing recommendation:
The CPOD QWG recommends to use ground characterisation of the GNSS receivers to select nominal+redundant before the launch. In addition, the CPOD QWG recommends to do signal simulation tests of the different receivers to get information about the phase differences (L2P(Y) vs. L2C).
Add-on:
The CPOD QWG again requests ground testing and access the corresponding data of the GNSS receivers of upcoming missions to learn about the tracking performance and to get information about the phase differences between L2P(Y) and L2C.

Recommendation (Rephrasing of Recommendation #30):
(details see Annex20 attached)
The CPOD QWG recommends to keep the current default configuration (GPS-IIA,GPS-IIR: **L1,L2P(Y)**; GPS-IIRM,GPS-IIF,GPS-IIIA: **L1,L2C**; Galileo: E1,E5a) for future C/D missions. It has to be secured that the receiver does not automatically switch to L1,L5 tracking for the new generation of GPS satellites as soon as the L5 signal becomes healthy.

S-1 "outgassing" event (HP)
(details see Annex12 attached)

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FG on behalf of S-1 FD at ESOC: Big thank you again to the CPOD Service and the QWG for the quick reaction and support to find the cause of the disturbances on Sentinel-1A.

AI on GMV (QWG012-GMV-AI-005):
GMV to contact S-1 FD team to get assistance for further investigations on POD side on the S-1A leaking event.

Status of the EOF<->SP3 converter for COAH (MF)
(details see Annex13 attached)

Recommendation to switch to COST-G FSM operationally (CF)
(details see Annex14 attached)
No objection from the CPOD QWG to switch to COST-G FSM operationally.

Future S-3 STC and NTC orbit products – CNES vs. CPOD, GPS-only or GPS+DORIS
Discussion see agenda item "Status CNES processing"

SLR station range bias correction based on LEO missions – way forward (AC)
(details see Annex15 attached)
JF/CF: Estimation of SLR station range biases for RSRs based on single satellites only is not optimal. Other sources for the station range bias would be preferable. As a first step the station range biases will be estimated based on the combined orbits of all three satellites (S-3A, S-3B and S-6A).
OM: SLRF2020 or at least ITRF2020 coordinates should be used, because SLRF2014 coordinates yield worse residuals and coordinates would have to be co-estimated.

ILRS station range bias generation (JCR)
(details see Annex16 attached)
ILRS data handling file (DHF) should be tested for SLR validation of LEO orbits.

AI on GMV (QWG012-GMV-AI-006):
GMV to compare the SLR station range biases from the ILRS DHF (if available) to existing range biases (e.g., from RSRs)

Liaising with European/ESA ILRS stations (Discussion)

Recommendation #44:
(details see Annex20 attached)
The CPOD QWG recommends to include future ESA SLR stations fully into the ILRS. New stations complementing the current geographic distribution are particularly encouraged.

S-3A/S-3B GNSS tracking (L2P(Y) availability) in view of planned tandem phases with S-3C/S-3D (Discussion)
According to the latest US Federal Radionavigation Plan L2P(Y) will at least be available until 2029. In view of the planned launch dates of S-3C and S-3D it should, therefore, be no problem.

Testing on L5 with GNSS products based on L1&L5 (CF)
(details see Annex17 attached)

Testing on Galileo HAS (CF)
(details see Annex18 attached)

Next meeting

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TUM has agreed to host the next Copernicus POD QWG meeting in Munich, Germany.

Review of AIs and recommendations from previous meetings and new AIs and recommendations
(details see Annex19 and Annex20 attached)

Action items:

QWG003-POS-AI-003: The AI will be moved to GMV. GMV plans to try out the orbit combination approach based on Variance Component Estimation (VCE) in the near future. A TN will be compiled about these tests.
QWG011-ALL-AI-003: Still open, because inconsistencies were found in the TUG solutions.
QWG011-ALL-AI-002: To be closed.
QWG011-ALL-AI-001: To be closed.

Recommendations status:

QWG#1 Recommendation #3: The sentence “If possible, such a test is recommended to be performed on Sentinel-1B (if decommissioned)” has been removed.
QWG#2 Recommendation #7: Comment: A technical note (GMV-CPOD-TN-0037 “Elements needed for LEO POD”) has been circulated to ESA in 2021. TN will be re-checked for additional requirements, e.g., information on thermal behaviour. Then the TN will be circulated to the QWG for review.
QWG#3 Recommendation #11: Rephrasing: The CPOD QWG recommends to change as quick as possible the bandwidth of the semi-codeless P(Y) carrier phase tracking loops on L2 from 0.5 Hz to 1 Hz for the Sentinel receivers (Sentinel-1, -2, -3). It is recommended to test the changes first on Sentinel-2 which has (1) not so critical accuracy requirements and (2) has the possibility to test it on the redundant receiver while keeping the main receiver in normal operations (see Recommendation #21). Such a parallel run of the main and redundant receiver should be kept for at least three full days (0:00-24:00). After successful testing the bandwidth should be changed with highest priority for Sentinel-3 (highest accuracy requirements), followed by Sentinel-1 (lowest altitude), and with lowest priority for Sentinel-2 on the main receivers.
QWG#3 Recommendation #14: To be closed
QWG#7 Recommendation #21: Comment: To be combined with QWG#3 Rec#11. Parallel runs of main and redundant receiver on Sentinel-2 could be used to easily test the change of the bandwidth of the tracking loops.
QWG#7 Recommendation #22: To be closed, because it is not needed for B units considering P(Y) tracking being possible (up to 2029) beyond the life time of the B units.
QWG#9 Recommendation #29: Re-inforcement of existing recommendation.
Add-on: The CPOD QWG again requests ground testing and access the corresponding data of the GNSS receivers of upcoming missions to learn about the tracking performance and to get information about the phase differences between L2P(Y) and L2C.
QWG#9 Recommendation #30: Rephrasing: The CPOD QWG recommends to keep the current default configuration (GPS-IIA,GPS-IIR: **L1,L2P(Y)**; GPS-IIRM,GPS-IIF,GPS-IIIA: **L1,L2C**; Galileo: E1,E5a) for future C/D missions. It has to be secured that the receiver does not automatically switch to L1,L5 tracking for the new generation of GPS satellites as soon as the L5 signal becomes healthy.
QWG#10 Recommendation #31: Still open.
QWG#10 Recommendation #32: Still open. Add-on: It was done for Swarm as well and improved the tracking and POD performance. This would not only be the case for Sentinel-6 but also for Sentinel-1, -2, and -3.
QWG#10 Recommendation #33: Still open.
QWG#10 Recommendation #34: Still open. Rephrasing: The CPOD QWG recommends to perform yaw flip manoeuvres for any upcoming mission with stringent orbit accuracies like Sentinel-3 or Sentinel-6.
QWG#11 Recommendation #35: To be closed

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QWG#11 Recommendation #36: Sentence “For Sentinel-6A a corresponding paper exercise would be needed to look for the 14 mm discrepancy in the Y-component of the TRIG-PODRIX baseline” has been removed. It is clarified that this recommendation is valid for any future mission in need of POD.
Add-on: The recommendation is also valid for all future missions.
QWG#11 Recommendation #37- #40 : Still open

List of new action items

QWG012-ESA-AI-001 (2023/12/31):
ESA to check with COAH about having a public API for the GNSS hub (to allow for batch download of files with a script) as it is available for the science hub.

QWG012-ESA-AI-002 (2023/12/31):
ESA and EUMETSAT to contact Copernicus Services and altimetry data users using the S-3 and S-6 orbit products about their specific needs and to request test analysis with different product series, e.g., CNES, CPOD, COMB. Length of data set to be agreed.

QWG012-GMV-AI-001 (2023/12/31):
GMV to provide list of available S-3 and S-6 orbit products with their corresponding latencies to ILRS (FL + ILRS Central Bureau) to be possibly used for SLR station monitoring.

QWG012-GMV-AI-002 (2023/12/31):
GMV and CNES to clarify about the geocenter motion model applied to the CNES orbits and agree on the standard for the operational CPOD products.

QWG012-CNES-AI-001 (2023/12/31):
CNES to check if a simple transformation of their S-3 and S-6 orbits from CoM to CoN can be done without doing a full determination of the orbits again.

QWG012-GMV-AI-003 (2023/12/31):
GMV to prepare a memorandum on the handling of the geocenter motion in the different QWG orbit solutions in the context of the RSRs.

QWG012-GMV-AI-004 (2023/12/31):
GMV to apply the -0.43 deg yaw bias to Sentinel-6A processed quaternions for POD and to the PROQUA product (made available on COAH).

QWG012-PTIM-AI-001 (2023/12/31):
POSITIM to provide information on the S-6 yaw bias to PLSO for clarification.

QWG012-ALL-AI-001 (2023/12/31):
ALL to check if receiver frontend related half-cycle slips on S-6 PODRIX data impact the IAR process.

QWG012-GMV-AI-005 (2023/12/31):
GMV to contact FD to get assistance for further investigations on POD side on the S-1 leaking event.

QWG012-GMV-AI-006 (2023/12/31):
GMV to compare the SLR station range biases from the ILRS DHF (if available) to existing range bias (e.g., from RSR).

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QWG012-GMV-AI-007 (2023/07/31):
GMV to prepare a TN gathering all CPOD QWG recommendations.

List of new Recommendations:

Recommendation #41:
The Copernicus POD QWG recommends that the EOF-SP3 converter uses the F14.7 format for writing LEO satellite positions in SP3. This would avoid issues with the 1 mm resolution.

Recommendation #42:
The CPOD QWG recommends to provide the combined orbit products from the RSRs for all satellites on the GNSS hub of the COAH.

Recommendation #43:
The CPOD QWG recommends to contact Beyond Gravity (RUAG) to make sure that PODRIX receiver tracks Galileo satellites in marginal state without resetting the carrier phase ambiguities.

Recommendation #44:
The CPOD QWG recommends to include future ESA SLR stations fully into the ILRS. New stations complementing the current geographic distribution are particularly encouraged.

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