

Project:	Copernicus Sentinel-1, -2, -3 and -6 Precise Orbit Determination Services
Meeting:	CPOD – Quality Working Group #11
Date:	21 - 23 June 2022
Place:	University of Bern, Bern, Switzerland
Secretary:	H. Peter / PosiTim UG

ATTENDEES	
Name/Company/Signature	Name/Company/Signature
Pierre Féménias (PF) / ESA-ESRIN	Xinyuan Mao (XM) / AIUB
Carolina Nogueira Loddó (CNL) / EUMETSAT	Pieter Visser (PV) / TU DELFT
Jaime Fernández (JF) / GMV	Wim Simons (WS) / TU DELFT
Heike Peter (HP) / PosiTim	Javier Berzosa (JB) / GMV
Francisco Sancho (FS) / EUMETSAT	Oliver Montenbruck (OM) / DLR
Carlos Fernández (CF) / GMV	Martin Wermuth (MW) / DLR
Adrian Jäggi (AJ) / AIUB	Urs Hugentobler (UH) / TUM
Daniel Arnold (DA) / AIUB	Bingbing Duan (BD) / TUM
Francesco Gini (FG) / ESA-ESOC	Patrick Schreiner (PS) / GFZ
Werner Enderle (WE) / ESA-ESOC	Anton Reinhold (AR) / GFZ
Rolf Dach (RD) / AIUB (part time)	
Ulrich Meyer (UM) / AIUB (Tue 21)	
Flavien Mercier (FM) / CNES (online)	Sebastiano Padovan (SP) / EUMETSAT (online)
John Moyard (JM) / CNES (online)	Berthyl Duesmann (BD) / ESA-ESTEC (online)
Alexandre Couhert (AC) / CNES (online)	Hugues Capdeville (HC) / CLS (online)
Maria Salas (MS) / GMV (online)	Marc Fernández (MF) / GMV (online)
Eva Terradillos (ET) / GMV (online)	Sonia Lara (SL) / GMV (online)
Luning Bao (LB) / GMV (online)	Miguel Angel (MA) / GMV (online)
Franck Borde (FB) / ESA-ESTEC (online, 22+23)	Georgia Katsigianni (GK) / CLS (online, Tue 21)
Frank Lemoine (FL) / GSFC-NASA (online, 21+22 pm)	Cyril Kobel (CK) / AIUB (online, Wed 22)
Shailen Desai (SD) / JPL-NASA (online, Tue 21 pm)	

Attachments
Annex01: 01_Copernicus_POD_QWG11_20220621_23_agenda_final.pdf
Annex02: 02_QWG11_GMV_Status of the Copernicus POD Service.pdf
Annex03: 03_QWG11_GMV_Review of AIs and recommendations.pdf
Annex04: 04_QWG11_AIUB_COST-G gravity field models for LEO POD.pdf
Annex05: 05_QWG11_AIUB_IGS-repro3 - ITRF2020 update, changes w.r.t. ITRF2014.pdf
Annex06: 06_QWG11_PTIM_GPSIII_meanpole.pdf
Annex07: 07_QWG11_EUM_Sentinel-6 CPOD QWG#11- Mission Status.pdf

Annex08: 08_QWG11_GMV_S6A CPOD Service.pdf
Annex09: 09_QWG11_CNES_Status Sentinel 6A MF processing at CNES.pdf
Annex10: 10_QWG11_JPL_Sentinel-6 Precise Orbit Determination using TriG Tracking Data.pdf
Annex11: 11_QWG11_GSFC_GSC POD Update.pdf
Annex12: 12_QWG11_DLR_Sentinel-6A TRIG-PODRIX Cross Calibration.pdf
Annex13: 13_QWG11_DLR_Observations on S6A RINEX files.pdf
Annex14: 14_QWG11_TUD_Sentinel_STC_POD_TUDelft2022.pdf
Annex15: 15_QWG11_AIUB_Update on SLR Bias Determination Study.pdf
Annex16: 16_QWG11_Leeds_S1AB_offset_analysis.pdf
Annex17: 17_QWG11_AIUB_Estimation of PCO corrections for Sentinel satellites.pdf
Annex18: 18_QWG11_PTIM_Sentinel-6A MF satellite macro model - Status report of investigations.pdf
Annex19: 19_QWG11_CNES_Sentinel-6 Solar radiation pressure model.pdf
Annex20: 20_QWG11_TUD_Sentinel Altimeter Cross-over Analysis.pdf
Annex21: 21_QWG11_DLR_Results from tandem phase of Sentinel-3A and -3B.pdf
Annex22: 22_QWG11_ESA_Sentinel Status June 2022.pdf
Annex23: 23_QWG11_GMV_Additional LRR on CRISTAL mission.pdf
Annex24: 24_QWG11_GMV_Presentation on use of GPS L1-L5 for future missions.pdf
Annex25: 25_QWG11_Poster_ESA_LPS_Transponder_Analysis_Mertikas_20_May_2022.pdf

Agenda	Distribution List
(details see Annex01 attached)	Attendees
1. Welcome and purpose of meeting, logistics	+ copernicuspod@gmv.com
2. Status Copernicus POD Service	+ pierre.potin@esa.int
3. Review of AIs and Recommendations from previous meetings	+ ferran.gascon@esa.int
4. COST-G gravity field models for LEO POD	+ anja.stromme@esa.int
5. ITRF2020 update, changes w.r.t. ITRF2014	+ hilary.wilson@eumetsat.int
6. Topics related to ITRF2020 update	+ muriel.pinheiro@esa.int
7. Sentinel-6 MF mission activities at Eumetsat	+ steffen.dransfeld@esa.int
8. CPOD Service – RINEX files, NRT orbits, etc.	+ betlem.rosich@esa.int
9. CNES – Status of processing	+ Olivier.colin@esa.int
10. JPL – TRIG processing	+ franck.desbouillons@esa.int
11. GSFC – DORIS+SLR orbit solutions	+ alessandra.boungiorno@esa.int
12. Comparison TRIG – PODRIX	+ jordi.farres@esa.int
13. Sentinel-6 RINEX file issues	+ berenice.guedel@esa.int
14. TUD – STC orbit solutions for validation	+ kate.symonds@esa.int
15. AIUB/CNES/DLR/POSITIM – SLR bias estimation study	+ valentina.boccia@esa.int
16. Sentinel-1: Feedback on orbit reprocessing	+ luisella.giulicchi@esa.int
17. Estimation of PCO corrections for Sentinel satellites	+ denise.dettmering@tum.de
18. Sentinel-6A MF satellite macro model - Status report of investigations	+ nzelensk@umd.edu
19. Sentinel-6 Solar radiation pressure model	+ s3mpc-stm-coord@groupcls.com
20. Sentinel Altimeter Crossover analysis	+ s3.stm@eumetsat.int
21. Results from tandem phase of S-3A and S-3B	
22. Status Copernicus missions – plans for C/D	
23. HPCM CRISTAL: additional LRRs for the active debris removal functionality	

24. Use of GPS L1/L5 for future missions?

Agreements, declarations, actions

Copernicus POD QWG#11 summary

Sentinel-1:

- Sentinel-1A & -1B CPOD Service operations are running nominally except that no S-1B SAR files (to extract the measured attitude) are received due to the S-1B anomaly on the SAR. This has no impact on the accuracy of the orbit products.

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.

Welcome and purpose of meeting, logistics (PF, AJ)

(details see Annex01a attached)

Status Copernicus POD Service (JF)

(details see Annex02 attached)

JF asks whether there are requests for further products on the Copernicus Open Access Hub (COAH):

- OM: Sentinel-6 RINEX files
- JF: It is agreed with EUMETSAT to publish S-6 products on COAH.
- HP: S-2 orbits would be needed from other POD groups (e.g., Technical University of Graz) to process the S-2 data with their s/w.

Recommendation #35:

The CPOD QWG recommends to provide Sentinel-2 NTC orbit products on COAH.

OM: COAH website is not very user-friendly. Download of single products is fine, but for POD a whole bunch of products are 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.

WE: Machine Learning: Is it foreseen to use Machine Learning for the quality control on orbit level only or also on observation level?

JF: So far, the experience has been reduced to use the output of the POD processing (estimated parameters, residuals, etc.) to assess the quality of the product computed. Its use on the observations directly has not been done.

PF: Comment on updated orbit accuracy and latency requirements for CPOD3: No degradation is expected from one CPOD contract to the next. Therefore, the new requirements are aligned to the current performance of the products.

WS: Is the new s/w based on zero- or double differences?

JF: Undifferenced processing.

PV: Is the s/w only capable to process GNSS data?

JF: Currently, GNSS as well as radar, optical and SLR measurements are supported, but other observation types will follow.

OM: Doubts on benefits from the RAW processing, because in the case of dual frequency processing it is mathematically equivalent to the current processing (ionosphere-free linear combination).

Review of AIs and recommendations from previous meetings

(details see Annex03 attached)

QWG010-ALL-AI-009: It is clear the impact on the clock, so there is no further action here. Proposed to close.

QWG008-ALL-AI-006: After the analysis of DLR, it is proposed to close.

Details on the recommendations listed at the end of the MoM.

COST-G gravity field models for LEO POD (UM)

(details see Annex04 attached)

AC: What is about time intervals before GRACE-FO? Are the models also available for dates before 2018? Would be needed for reprocessing.

UM: Currently the focus of the generation of these models is on the operational LEO POD, which means that only the GRACE-FO mission time is covered. Further investigations will follow to prolong the time intervals for which the models may be used.

JF: Before switching to the COST-G gravity field models also tests are needed to analyse the applicability for reprocessings of all Sentinel satellites, i.e. starting mid 2014 for Sentinel-1A.

OM: Can improvements from the COST-G gravity field models be seen in a reduction of the empirical parameters?

UM: This has been analysed, but there is no significant reduction present.

??: It is known that C20 coefficient estimate is weak in GRACE/GRACE-FO gravity field models. Is it replaced from other analysis, e.g. SLR?

UM: No. Analysis has shown that differences are caught up by empirical parameters.

AJ: C20 problematic might be relevant for GNSS orbit determination. This will be studied by a PhD student.

OM: What happens if GRACE-FO availability is ceased?

UM: There are groups working in models using different data to bridge the gap. Otherwise, we would have to rely on extrapolations.

ITRF2020 update, changes w.r.t. ITRF2014 (RD)

(details see Annex05 attached)

Before the switch to ITRF2020 a parallel processing for the generation of Earth Orientation Parameter (EOP) might also be possible. This has to be asked for from IERS.

The GNSS' PCO for GPS-III and Galileo are different for each frequency. This has an impact on the code and phase biases, which has to be generated consistently; otherwise, it will impact the MW combinations for ambiguity fixing. If the GNSS' PCOs are applied for the generation of the biases or not will be documented in the bias files in future (with the switch to ITRF2020).

QWG011-ALL-AI-001 (2022/12/31): To re-estimate the PCO and PCV maps of the GNSS antennas on-board the Sentinels, which is aligned to the ITRF2020.

Topics related to ITRF2020 update (HP)

(details see Annex06 attached)

OM: GPS III nadir angle extensions does not make sense based on the IGS14 ANTEX. It should be waited until IGS20 ANTEX is available.

AJ: AIUB/CODE has plans to estimate GPS PCVs based on IGS20 including GPS III nadir angle extension.

AC: Concerning the mean pole: When using the C21/S21 coefficients provided in a mean gravity field model, one should apply back consistently the pole tide correction that was removed when computing the mean gravity field model. This means using the same mean pole model.

OM: Concerning ITRF2020: It is not clear yet if IGS analysis centers will apply seasonal corrections to the station coordinates in their processing or not. This is agreed for the other services (ILRS, IDS) but IGS seems not to follow this. It will finally be decided next week at the IGS workshop. How should we (LEO POD groups) handle these differences in the ILRS vs. IGS products when doing SLR validation of the orbits.

AC: Concerning ITRF2020: An additional correction will be provided with this new release enabling either to deliver IGS solutions with respect to the center of mass of the Earth (seasonal terms) or with respect to the center of figure (as done until now). It will be decided soon at IGS if they will apply or not this correction when delivering their products. At least we will have this discussion with the CNES/CLS AC to provide the best solution for LEO altimeter satellites, which is with respect to the CM of the Earth, to be consistent with DORIS and SLR observations (corrected at station position level using the same CM ITRF2020 correction model).

Sentinel -6:

Sentinel-6 MF mission activities at Eumetsat (CNL)

(details see Annex07 attached)

CPOD Service – Status (JF)

(details see Annex08 attached)

CNES – Status of processing (JM)

(details see Annex09 attached)

Flip manoeuvre in July 2021 has not been during sun beta angle between 0° and 10°

GPS III PCV adjustment (nadir angle extension) has been done based on Sentinel-6 data.

JF: We will implement a change in the generation of the RINEX files to apply the temperature correction biases to the code signals, in order to allow a proper handling of the legacy and civil signals on Sentinel-6A.

JPL – TRIG processing (SD)

(details see Annex10 attached)

OM: Magnitude of Y-offset is dependent on constraints in the dynamical model.

GSFC – DORIS+SLR orbit solutions (FL)

(details see Annex11 attached)

Comparison TRIG – PODRIX (OM)

(details see Annex12 attached)

Y-component of baseline shows 14 mm discrepancy of observed values vs. design => not acceptable.

QWG011-ALL-AI-002 (2023/06/30): Action to investigate the Y-component bias of 14 mm on Sentinel-6A. To propose changes to the location of sensor if needed.

Recommendation #36:

The CPOD QWG recommends to revisit/recheck/remeasure the Sentinel-6B ARP (antenna reference point) coordinates from all POD sensors before launch to avoid problems with inconsistent ARP coordinates during POD processing. 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.

Sentinel-6 RINEX file issues (MW)

(details see Annex13 attached)

HP: How do the other groups handle the inconsistencies in the GPS L1C/L2C vs. L1P(Y)/L2P(Y) measurements in their ambiguity fixing procedures?

CPOD: No mixing of the signals in the ambiguity fixing.

AIUB: Estimating receiver code biases.

TUM: No mixing of the signals in the ambiguity fixing.

CNES: Removing observations from L1P(Y)/L2P(Y) satellites.

TUD: Removing observations from L1C/L2C satellites, because JPL products only support ambiguity fixing for L1P(Y)/L2P(Y) signals.

TUD – STC orbit solutions for validation (WS)

(details see Annex14 attached)

OM: ISB (inter-system bias) has to be estimated epoch-wise, because of the phase glitches of the receiver.

AIUB/CNES/DLR/POSITIM – SLR bias estimation study (DA)

(details see Annex15 attached)

CF: Is there interest to include the LEO-based station coordinate estimates into the SLR reference frame computations?

OM/DA: Several attempts to the ILRS did not trigger much interest from the ILRS community to look into the LEO-based station coordinate estimates or include LEOs into the SLR reference frame computations.

Copernicus Sentinel GNSS related data and user data-take and usage

Request from ESA to POD QWG: Which file format would be preferable for CryoSat quaternions, XML or NetCDF? ESOC and TUD (doing CryoSat POD): No specific recommendation, both formats have their advantages and disadvantages; plain ASCII file would be preferable.

Recommendation #37:

The CPOD QWG recommends to provide attitude files (quaternions) for any further satellite (not only Copernicus) in plain ASCII format in an agreed/simple format, e.g., CPOD Service quaternion format.

Sentinel-1 : Feedback on orbit reprocessing (HP)

(details see Annex16 attached)

Presentation was held on behalf of colleagues from University of Leeds

POD QWG: Hypothesis that the ARP modifications should not have been applied to both satellites is definitely wrong. Since the S1A/B offset varies in different SAR tracking modes the assumption is that the offset has its origin within the SAR.

Estimation of PCO corrections for Sentinel satellites (CK)

(details see Annex17 attached)

PCO offset estimates can be provided to the CPOD QWG for testing and verification in other POD s/w environments.

Sentinel-6A MF satellite macro model – Status report of investigations (HP)

(details see Annex18 attached)

DA: Recommended repeating analysis without estimation of CD.

CNES – Sentinel-6 Solar radiation pressure model (FM)

(details see Annex19 attached)

DORIS documentation will be updated to reflect the modifications in the satellite macro model.

BD: I am aware of a S6 transponder paper, where the transponder observes (radial) variations with the draconic harmonics (~57 days for S6) - if using the official S6 POD orbit. Paper is not yet published but ESA LP 2022 poster is available. Poster is only on Jason-3.

Poster is made available as Annex25.

FG: In addition to a CAD model more accurate optical and IR properties are needed. It has been observed for many satellites that the published properties have to be adapted in the processing to better fit to the models.

Recommendation #38:

The CPOD QWG recommends to get a proper CAD model and the optical and IR properties of the different elements in the satellite before the launch of future satellites (like for Sentinel-6). In addition, the thermal behaviour of the solar arrays, the radiators and the entire satellite are needed for proper radiation pressure modelling. The optical and IR properties of the different surfaces should be either measured directly on the satellite or on material samples to get better values.

Sentinel altimeter crossover analysis (PV)

(details see Annex20 attached)

Results from tandem phase of S-3A and S-3B (MW)

(details see Annex21 attached)

Processing confirms already seen and known (but partly not yet corrected) CoM/ARP inconsistencies.

QWG011-ALL-AI-003 (2023/06/30): To identify the origin of the inconsistencies between the CoM/ARP on Sentinel-3A & B and to propose new operational characterization.

Status Copernicus missions – plans for C/D (BD)

(details see Annex22 attached)

Baseline is to have two operational satellites per mission. During commissioning phase of a new satellite, three satellites (if possible) are operated for a proper transition to the new satellite. Decommissioned satellites are moved to parking orbits.

Recommendation #39:

The CPOD QWG recommends to make the GNSS data available to the user community from the decommissioned satellites in their parking orbits (if still running and available). The data are very valuable for various scientific applications, e.g., gravity field determination, ionosphere analysis and thermosphere studies.

HPCM CRISTAL: additional LRRs for the active debris removal functionality (JF)

(details see Annex23 attached)

Recommendation #40:

The CPOD QWG recommends to carefully revisit the design of the LRRs for space debris removal on future satellites. It should be taken actions to avoid tracking of the LRRs for space debris removal from SLR stations on Earth during routine operations.

Use of GPS L1/L5 for future missions? (JF)

(details see Annex24 attached)

OM will raise the request for GPS L1/L5 clock products at the upcoming IGS Workshop (27 June – 1 July) again.

Demo of focusPOD (JB)

Demonstration of new software package focusPOD developed at GMV

List of action items

QWG011-ALL-AI-001 (2022/12/31): To re-estimate the PCO and PCV maps of the GNSS antennas on-board the Sentinels, which is aligned to the ITRF2020.

QWG011-ALL-AI-002 (2023/06/30): Action to investigate the Y-component bias of 14 mm on Sentinel-6A. To propose changes to the location of sensor if needed.

QWG011-ALL-AI-003 (2023/06/30): To identify the origin of the inconsistencies between the CoM/ARP on Sentinel-3A & B and to propose new operational characterization.

Review of Recommendations from previous QWG meetings:

(List is available in Annex03)

QWG#1 Rec#3:

Rephrasing:

The CPOD QWG recommends the S-1 FD to develop a procedure to retrieve the CoM by analysing the torque resulting when using the out-of-plane thrusters. This test is recommended to be done during commissioning phase of Sentinel-1 C/D.

If possible, such a test is recommended to be performed on Sentinel-1B (if decommissioned).

QWG#3Rec#11:

There is no urgency on this recommendation. However, solar activity is increasing and if P(Y) tracking would be degraded for the lower Sentinels one should be prepared to react.

Rephrasing:

The CPOD QWG recommends to prepare a procedure to change the bandwidth of the GPS receivers as done on the Swarm satellites. If P(Y) tracking will be degraded due to increasing solar activity on the lower Sentinel satellites the bandwidth adaptation could quickly be done.

QWG#9 Rec#29:

Background for the rephrasing:

- The choice of nominal and redundant receiver on S-6 MF is sub-optimal due to the phase glitches occurring in the receiver frontend of the nominal receiver. Such phase glitches are nearly absent in the redundant receiver.
- The GPS L2P(Y) and L2C have a small phase offset, which could be measured in signal tests on the ground before launch of the satellite.

Rephrasing:

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).

List of new recommendations

Recommendation #35 (Open):

The CPOD QWG recommends to provide Sentinel-2 NTC orbit products on the COAH. Sentinel-2 orbit products on the COAH support further usage of the Sentinel-2 RINEX and quaternion data for POD from other groups and institutions.

Recommendation #36 (Open):

The CPOD QWG recommends to revisit/recheck/remeasure the Sentinel-6B ARP (antenna reference point) coordinates from all POD sensors before launch to avoid problems with inconsistent ARP coordinates during POD processing. 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.

Recommendation #37 (Open):

The CPOD QWG recommends to provide attitude files (quaternions) for any further satellite (not only Copernicus) in plain ASCII format in an agreed/simple format, e.g., CPOD Service quaternion format.

Recommendation #38 (Open):

The CPOD QWG recommends to get a proper CAD model and the optical and IR properties of the different elements in the satellite before the launch of the satellite (like for Sentinel-6). In addition the thermal behaviour of the solar arrays, the radiators and the entire satellite.

Recommendation #39 (Open):

The CPOD QWG recommends to make the GNSS data available to the user community from the decommissioned satellites in their parking orbits (if still running and available). The data are very valuable for various scientific applications, e.g., gravity field determination, ionosphere analysis and thermosphere studies.

Recommendation #40 (Open):

The CPOD QWG recommends to carefully revisit the design of the LRRs for space debris removal on future satellites. It should be taken actions to avoid tracking of the LRRs for space debris removal from SLR stations on Earth during routine operations.