

<b>Project:</b>	Copernicus Sentinel-1, -2 and -3 Precise Orbit Determination Services
<b>Meeting:</b>	CPOD – Quality Working Group #8
<b>Date:</b>	26 and 27 June 2019
<b>Place:</b>	DLR, Oberpfaffenhofen
<b>Secretary:</b>	H. Peter / PosiTim UG

## ATTENDEES

Name/Company/Signature	Name/Company/Signature
Pierre Féménias (PF) / ESA-ESRIN	Stefan Hackel (SH) / DLR
Jaime Fernández (JF) / GMV	Daniel Arnold (DA) / AIUB
Heike Peter (HP) / POSITIM	Pieter Visser (PV) / TU DELFT
Michiel Otten (MO) / ESA-ESOC	Wim Simons (WS) / TU DELFT
Martin Wermuth (MW) / DLR	Cyril Kobel (CK) / AIUB
Emilio J Calero (EC) / GMV	Berthyl Duesmann (BD) / ESA-ESTEC
Bingbing Duan (BD) / TUM	Franck Borde (FB) / ESA-ESTEC
Francesco Gini (FG) / ESA-ESOC	Yago Andrés (YA) / EUMETSAT
Andrea Nardo (AN) / EUMETSAT	Patrick Schreiner (PS) / GFZ
Only on Wednesday:	
John Moyard (JM) / CNES	Javier Berzosa (JB) / GMV
Flavien Mercier (FM) / CNES	Denise Dettmering (DD) / DGFI-TUM
Rolf König (RK) / GFZ	René Zandbergen (RZ) / ESA-ESOC

## Attachments

- Annex01: 01\_Copernicus\_POD\_QWG8\_2018062627\_agenda\_final.pdf
- Annex02a: 02a\_QWG08\_ESRIN\_Sentinels-Status.pdf
- Annex02b: 02b\_QWG08\_ESRIN\_CPOD\_Procurement2.pdf
- Annex03: 03\_QWG08\_GMV\_StatusCPODService.pdf
- Annex04: 04\_QWG08\_CNES\_copernicus\_cnes\_status.pdf
- Annex05a: 05a\_QWG08\_ESOC\_POD\_MO.pdf
- Annex05b: 05b\_QWG08\_GFZ\_Copernicus\_POD\_QWG\_190626.pdf
- Annex06a: 06a\_QWG08\_GMV\_Single-receiver ambiguity fixing.pdf
- Annex06b: 06b\_QWG08\_AIUB\_Ambigity\_Fixing.pdf
- Annex06c: 06c\_QWG08\_TUM\_Bingbing\_POD\_QWG\_8th.pdf
- Annex07: 07\_QWG08\_GMV\_Reprocessing of Sentinels orbits at CPOD.pdf
- Annex08a: 08a\_QWG08\_DLR\_Sentinel-3\_SLR.pdf
- Annex08b: 08b\_QWG08\_CNES\_Copernicus\_cnes\_comparisons.pdf
- Annex09: 09\_QWG08\_Sentinel\_3AB\_POD\_TUdelft2019.pdf
- Annex10: 10\_QWG08\_AIUB\_CK\_Oberpfaffenhofen.pdf
- Annex11a: 11a\_QWG08\_GMV\_CPOD\_Proposal for different S-1 orbit validation in RSRs.pdf
- Annex11b: 11b\_QWG08\_S1A\_S1B\_status\_Hpeter.pdf
- Annex11c: 11c\_QWG08\_AIUB\_S1\_ARP.pdf
- Annex11d: 11d\_QWG08\_TUD\_Sentinel\_1AB\_POD\_TUdelft2019.pdf

Annex11e: 11e\_QWG08\_TUM\_PCO\_Bingbing\_POD\_QWG\_8th.pdf

Annex12: 12\_QWG08\_ReviewRecommendations.pdf

Annex13: GMV-GMESPOD-MEM-0033\_v1.0\_S1orbitaccuracy.pdf

Agenda	Distribution List
<p>(details see Annex01 attached)</p> <ol style="list-style-type: none"> <li>1. Welcome and purpose of meeting</li> <li>2. Status of Copernicus Sentinel missions</li> <li>3. Status Copernicus Service</li> <li>4. Status S-3 processing at CNES</li> <li>5. Introducing topics to be discussed</li> </ol> <p>POD groups and other contributions</p> <ol style="list-style-type: none"> <li>6. Processing status</li> <li>7. Single-receiver ambiguity-fixing</li> <li>8. Model updates and reprocessing</li> <li>9. SLR validation</li> <li>10. S-3 cross-over analysis</li> <li>11. S-3 alternative combined orbit</li> <li>12. S-1 new GPS ARPs + other updates</li> <li>13. Review and status of recommendations</li> </ol>	<p>Attendees</p> <ul style="list-style-type: none"> <li>+ <a href="mailto:gmespod@gmv.com">gmespod@gmv.com</a></li> <li>+ <a href="mailto:remko.scharroo@eumetsat.int">remko.scharroo@eumetsat.int</a></li> <li>+ <a href="mailto:rene.zandbergen@esa.int">rene.zandbergen@esa.int</a></li> <li>+ <a href="mailto:adrian.jaeggi@aiub.unibe.ch">adrian.jaeggi@aiub.unibe.ch</a></li> <li>+ <a href="mailto:urs.hugentobler@bv.tum.de">urs.hugentobler@bv.tum.de</a></li> <li>+ <a href="mailto:oliver.montenbruck@dlr.de">oliver.montenbruck@dlr.de</a></li> <li>+ <a href="mailto:frank.g.lemoine@nasa.gov">frank.g.lemoine@nasa.gov</a></li> <li>+ <a href="mailto:hcapdeville@cls.fr">hcapdeville@cls.fr</a></li> <li>+ <a href="mailto:pierre.potin@esa.int">pierre.potin@esa.int</a></li> <li>+ <a href="mailto:ferran.gascon@esa.int">ferran.gascon@esa.int</a></li> <li>+ <a href="mailto:Susanne.mecklenburg@esa.int">Susanne.mecklenburg@esa.int</a></li> <li>+ <a href="mailto:anja.stromme@esa.int">anja.stromme@esa.int</a></li> <li>+ <a href="mailto:hilary.wilson@eumetsat.int">hilary.wilson@eumetsat.int</a></li> <li>+ <a href="mailto:nuno.miranda@esa.int">nuno.miranda@esa.int</a></li> <li>+ <a href="mailto:philippe.goryl@esa.int">philippe.goryl@esa.int</a></li> <li>+ <a href="mailto:betlem.rosich@esa.int">betlem.rosich@esa.int</a></li> <li>+ <a href="mailto:Olivier.colin@esa.int">Olivier.colin@esa.int</a></li> <li>+ <a href="mailto:franck.desbouillons@esa.int">franck.desbouillons@esa.int</a></li> <li>+ <a href="mailto:alessandra.boungiorno@esa.int">alessandra.boungiorno@esa.int</a></li> <li>+ <a href="mailto:jordi.farres@esa.int">jordi.farres@esa.int</a></li> <li>+ <a href="mailto:patrick.grimont@esa.int">patrick.grimont@esa.int</a></li> <li>+ <a href="mailto:mike.krassenburg@esa.int">mike.krassenburg@esa.int</a></li> </ul>

**Agreements, declarations, actions**

**Copernicus POD QWG#8 summary**

**General:**

- Very good performance of all orbit products from all satellites.
- Several background model updates are planned within the Copernicus POD Service. Results are presented. A final validation by the CPOD QWG will be done in an offline process.
- GPS carrier phase ambiguity fixing is planned to be implemented for the orbit determination processing as well. Further validation is needed to find the best suitable bias product.

**Sentinel-3:**

- Sentinel-3A & -3B CPOD Service operations are running nominally
- Planned background model updates will bring the CPOD orbit modelling closer to the CNES POE-F standards.

**Sentinel-1:**

- Sentinel-1A & -1B CPOD Service operations are running nominally
- In future the CPOD QWG solutions delivered for the CPOD Regular Service Review (RSR) comparisons will be based on the new GPS ARP+PCO/PCV configuration. It is demonstrated that the new configuration is clearly preferable to the currently used configuration for the operational CPOD Service solutions.
- If the configuration is not changed for the operational S1 CPOD Service solutions (operationally used in the S1 PDGS), the S1 orbit accuracy requirements will no longer be fulfilled (see Recommendation #26)

### **Sentinel-2:**

- Sentinel-2A & -2B CPOD Service operations are running nominally
- Recommendation #21 from CPOD QWG#7 is reinforced => parallel running of main and redundant receiver not only for few hours but for a full day (0-24 h).

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### **Details:**

#### **Status of Copernicus Sentinel missions (PF)**

(details see Annex02a+02b attached)

S-1

BD: SAR observation capacity is double than originally designed

S-2

BD: All observations are in spec, sometimes at the edge of the specs. It is tried to get all better within specs.

BD: Several strategies are developed/looked at for flying the C-units in addition to A- and B-units

#### **Status Copernicus POD Service (JF)**

(details see Annex03 attached)

Ocean and atmosphere part of the GFZ AOD L1B products are used

#### **S-1 RSR#14**

S-1A: AIUB, TUM, TUD have delivered ambiguity-fixed orbits, all other groups have delivered ambiguity-float orbits

S-1B: Only ambiguity-float orbits are delivered, because of problems in ambiguity-fixing caused by the usage of the wrong GPS ARP (antenna reference point)

#### **S-3**

Different SLR station list is used from different CPOD QWG members. Current SLR station list (nine stations, resulting from analysis based on Ref.QWG005-POS-AI-006) used for the validation of CPOD QWG orbit solutions has to be reviewed again to follow up developments in the SLR tracking performance (e.g., new stations tracking S-3, improvement of station performances, etc.)

**AI on POSITIM** to review the SLR station list for CPOD QWG S-3 orbit validation again **Ref. QWG008-POS-AI-008**

#### **Status S-3 processing at CNES (JM)**

(details see Annex04 attached)

SLR performance is slightly better for S-3B than for S-3A

#### **POD groups and other contributions**

#### **ESOC - Presentation of POD system for Copernicus satellites (MO)**

(details see Annex05a attached)

Overall discussion on S-1:

Which orbits should be provided for the RSR?

**Overall agreement that the groups should submit those orbits, which they think are the best for the specific satellite (and not those orbits which fit best to the majority of the other solutions).**

(see also Recommendation#26)

#### **GFZ - Status S-3 processing (RK)**

(details see Annex05b attached)

S-3A & S-3B: currently 4 cm along-track bias of DORIS-only and SLR-only orbit w.r.t. combined QWG orbit, cause is to be investigated

**Single-receiver ambiguity fixing (comparing different bias products)**

**CPOD (EC)**

(details see Annex06a attached)

**AIUB (DA)**

(details see Annex06b attached)

**TUM (BD)**

(details see Annex06c attached)

**Model updates (e.g., gravity field, ocean tide models) and reprocessing**

**CPOD/PTIM (EC/HP)**

(details see Annex07 attached)

**SLR validation**

**DLR (SH)**

(details see Annex08a attached)

Suggestion to put SLR residuals in an azimuth-elevation diagram before and after SLR station range bias corrections to analyse if the range bias corrections are really station biases or not.

**CNES (FM)**

(details see Annex08b attached)

CNES noticed similar geographically correlated differences in latitude between CNES and some of the other QWG orbit solutions. Differences are identical for S-3A and S-3B.

**AI on ALL** to investigate similar geographically correlated S-3 orbit differences of several groups w.r.t. CNES orbits, e.g., comparing background models and processing settings **Ref. QWG008-ALL-AI-005**

**TUD - S-3 cross-over analysis (PV)**

(details see Annex09 attached)

**AIUB - S-3 alternative combined orbit (CK)**

(details see Annex10 attached)

**AI on AIUB** to provide combined orbit solution for last RSR#14 together with weights **Ref. QWG008-AIUB-AI-001**

**AI on GMV** to analyse the differences between the two combined orbit solutions **Ref. QWG008-GMV-AI-024**

**AI on ALL** to analyse the relative orbit accuracy between S-3A and S-3B during the tandem phase **Ref. QWG008-ALL-AI-006**

**Discussion (S-3 or general)**

Planned updates in Copernicus POD processing chains

- Ambiguity-fixing
- Model updates

⇒ Planned updates will be properly documented and then distributed to the CPOD QWG for approval

⇒ Ambiguity-fixing: it would be nice to have other bias products available

**AI on AIUB** to provide a longer time series of the phase bias product **Ref. QWG008-AIUB-AI-002**

**AI on ESOC** to provide access to one week (4-10 November 2018) of ESOC bias products for single-receiver ambiguity fixing, if possible **Ref. QWG008-ESOC-AI-001**

S-3 timespan alignment of CNES and CPOD orbit solutions

- ⇒ E-mail from PDGS to CPOD Service, if desired

#### **Format of quaternion files**

Processed attitude files may contain two different information. The nominal attitude is simulated for the satellite and then the measured attitude is put on top of this (interpolated to full seconds). That means that possible data gaps are available from the simulation of the nominal attitude.

- ⇒ Agreement to use these processed attitude files for dissemination on the Copernicus Data Hub

Availability of information about changes in CPOD Service processing in orbit products

- ⇒ Sentinels POD Product Handbook
- ⇒ Table with current processing settings for Sentinels online
- ⇒ Table with CNES and CPOD settings for Sentinel-3 on Sentinels online

**AI on GMV** to prepare table with main models and settings for S-1 and S-2 orbits for Sentinels online **Ref. QWG008-GMV-AI-025**

**AI on GMV/CNES** to provide a table with main models and settings for S-3 orbits for Sentinels online **Ref. QWG008-GMV/CNES-AI-026**

#### **S-1 new GPS ARPs + other updates**

##### **Status of investigations at CPOD Service**

- **CPOD - Proposal for different S-1 orbit validation in RSRs (JF)**  
(details see Annex11a attached)
- **CPOD/PTIM – Offline reprocessing & sensitivity of offset estimation to modelling issues (HP)**  
(details see Annex11b attached)

##### **AIUB Comparison of S-1 empirical accelerations old ↔ new ARP+PCO (DA)**

(details see Annex11c attached)

##### **TUD S-1 new GPS ARP + PCO update (WS)**

(details see Annex11d attached)

##### **TUM S-1 new GPS ARP + PCO update (BD)**

(details see Annex11e attached)

**AI on GMV** to prepare a technical note summarizing all elements needed for POD of a low Earth orbiting satellite. After review and endorsement by the CPOD QWG members the TN will be forwarded to Sentinel mission projects and ESA to ensure availability of necessary information for C-/D-units and other applicable missions. **Ref.**

**QWG008-GMV-AI-027**

##### **Review of recommendations from previous Copernicus POD QWG meetings:**

(details see Annex12 attached)

##### **Copernicus POD QWG#1**

**Recommendation#1 - Open**

**Recommendation#2 - Open**

**Recommendation#3 – Open**

**Recommendation#4 - Closed**

**Copernicus POD QWG#2**

**Recommendation#5 - Open**

**Recommendation#6 – Closed**

**Recommendation #7 -Open**

**Copernicus POD QWG#3**

**Recommendation #8 - Obsolete - renewed in Recommendation #27**

**Recommendation #9 – Closed**

**Recommendation #10 – Closed**

**Recommendation #11 – Open**

**Recommendation #12 – Closed**

**Recommendation #13 – Closed**

**Recommendation #14 – Open**

**Recommendation #15 - Closed**

**Copernicus POD QWG#5**

**Recommendation #16 - Closed**

**Recommendation #17 - Closed**

**Recommendation #18 - Closed**

**Recommendation #19 - Open**

**Recommendation #20 - Closed**

**Copernicus POD QWG#7**

**Recommendation #21 - Open - Reinforcement**

**Recommendation #22 - Open - Reinforcement**

**Recommendation #23 - Closed**

**Recommendation #24 - Obsolete – replaced by recommendations #26+#27.**

**Recommendation #25 - Open**

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**List of action items**

**QWG008-POS-AI-008 (30/09/2019):** PosiTim to review the SLR station list for CPOD QWG S-3 orbit validation again

**QWG008-ALL-AI-005 (30/06/2020):** ALL to investigate similar geographically correlated S-3 orbit differences of several groups w.r.t. CNES orbits, e.g., comparing background models and processing settings

**QWG008-AIUB-AI-001 (30/09/2019):** AIUB to provide combined orbit solution for last RSR#14 together with weights

**QWG008-GMV-AI-024 (30/10/2019):** GMV to analyse the differences between the two combined orbit solutions

**QWG008-ALL-AI-006 (30/06/2020):** ALL to analyse the relative orbit accuracy between S-3A and S-3B during the tandem phase

**QWG008-AIUB-AI-002 (30/09/2019):** AIUB to provide a longer time series of the phase bias product (RSR#13 time period)

**QWG008-ESOC-AI-001 (30/09/2019):** ESOC to provide access to one week (4-10 November 2018) of ESOC bias products for single-receiver ambiguity fixing, if possible (RSR#13 time period)

**QWG008-GMV-AI-025 (30/09/2019):** GMV to prepare table with main models and settings for S-1 and S-2 orbits for Sentinels online

**QWG008-GMV/CNES-AI-026 (30/09/2019):** GMV/CNES to provide a table with main models and settings for S-3 orbits for Sentinels online

**QWG008-GMV-AI-027 (31/12/2019):** GMV to prepare a technical note summarizing all elements needed for POD of a low Earth orbiting satellite. TN to be forwarded to Sentinel mission projects and ESA to ensure availability of necessary information for C-/D-units and other applicable missions.

**QWG008-GMV/CNES-AI-028 (31/12/2019):** GMV/CNES to prepare a plan for the PODRIX test measurements

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#### **List of recommendations**

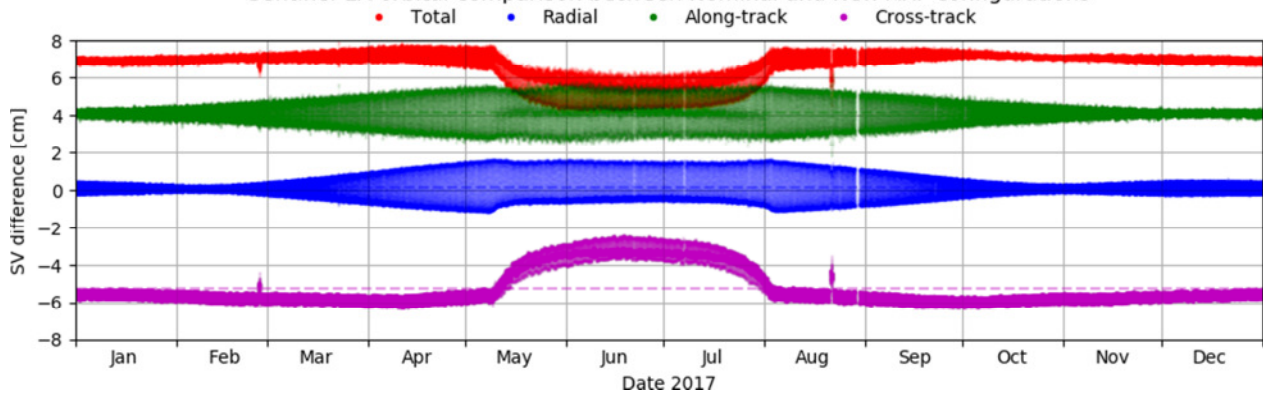
##### **Recommendation #26 (Open):**

The CPOD QWG strongly recommends to change the S-1 processing configuration (coordinates of the GPS ARPs (Antenna Reference Point) and the corresponding antenna phase center offsets (PCO) and variations (PCV)), which is wrongly used since the beginning of the missions. Using the current GPS ARP+PCO/PCV values the S-1 precise orbits are not fulfilling the orbit accuracy requirements as clearly shown from analysis beyond the RSR reports (memo **GMV-GMESPOD-MEM-0033** attached as Annex13). It is also shown that the consistency between the individual CPOD QWG orbit solutions get better with the new GPS ARP+PCO/PCV values. Although the GPS ARP coordinate change is a constant bias, the result on the precise orbit has periodic (orbital) and seasonal effects (see figures below). These variations have up to 3 centimetres on the cross-track component.

##### **Recommendation #27 (Open):**

If recommendation #26 is endorsed by ESA, the CPOD QWG recommends to generate reprocessed orbits of S-1 A&B, from the beginning of each mission, using the new processing configuration (corrected GPS ARP+PCO/PCV values), for the benefit of SAR community.

Sentinel-1A orbital comparison between Nominal and New ARP configurations



Sentinel-1B orbital comparison between Nominal and New ARP configurations

