First Meeting of the IERS Second Earth Orientation Parameter Prediction Comparison Campaign (2nd EOP PCC) Working Group

Chairs of the WG on the 2nd EOP PCC:
Jolanta Nastula – Chair
Henryk Dobslaw – Co-chair

EOP PCC Office at CBK PAN (Warsaw):
Jolanta Nastula
Justyna Śliwińska
Małgorzata Wińska
Tomasz Kur
Aleksander Partyka
Danuta Śleszyńska
Konrad Kowalski

6 May 2021, online meeting
Meeting Agenda

1. Welcome and Scope of the Meeting – J. Nastula
2. Outline of the EOP PCC and the IERS Working Group – J. Śliwińska
3. Technical Preparations for the EOP PCC at CBK – T. Kur, K. Kowalski, A. Partyka
5. Proposed Schedule of the EOP PCC – H. Dobslaw
6. Questions, Discussion & Feedback – all
Outline of the EOP PCC and the IERS Working Group
Introduction

- **Earth orientation parameters (EOP)** comprising of nutation offsets, pole coordinates, and length-of-day variations (or UT1–UTC) represent a critically needed link between the terrestrial and the celestial reference frame.
- Such transformation is needed for many advanced geodetic and astronomical tasks such as navigation of deep-space satellite missions, the pointing of astronomical instruments, or precise positioning on Earth.
- In many real-time applications, accurate predictions of the EOP are needed (due to the delay caused by computation procedures, the EOP estimates cannot be published in real time).
- Therefore, various agencies and institutions worldwide maintain capacities to rapidly process space geodetic observations to obtain estimates for the EOPs with short latencies as a basis for the subsequent prediction.
- Between 2005 and 2008, the **first EOP Prediction Comparison Campaign** (EOP PCC; Kalarus et al., 2010) provided a comprehensive assessment of the capabilities of different EOP prediction methods in an operational setting.

Information about First EOP Prediction Comparison Campaign (1\textsuperscript{st} EOP PCC)

• Between 2006 and 2008 – the operational part of the EOP PCC lasted 29 months.
• Prepared by Vienna University of Technology with close cooperation of Space Research Centre of Polish Academy of Sciences after discussing the idea within the IERS Directing Board.
• The campaign supported predictions of all EOP: pole coordinates \((x_p, y_p)\), universal time (UT1 – UTC), length of day (LOD), precession nutation \((dX, dY\) or \(d\psi, d\epsilon)\).
• The predictions were divided into three categories: ultra short-term (<10 days), short-term (<30 days), and medium-term (500 days).
• Each participant could apply more than one prediction technique.
• All predictions had to be submitted using proper filename and format.
• The most important rule of the campaign was that all the predictions had to be submitted every week on Thursday at noon (UTC) before any new EOP observations were available.
• 13 participants (11 active participants) took part in the campaign, 20 prediction techniques were evaluated, and almost 6,500 submissions were sent to the office.

Second EOP Prediction Comparison Campaign (2\textsuperscript{nd} EOP PCC)

• Since the end of the 1\textsuperscript{st} EOP PCC, much progress has been made in terms of improved geodetic data processing, reduced VLBI latency, and routine availability of model-based forecasts of effective angular momentum functions for atmosphere, oceans, and the terrestrial hydrosphere.

• In light of those developments, a re-assessment of the various EOP prediction capabilities will be pursued in the frame of the 2\textsuperscript{nd} EOP Prediction Comparison Campaign (2\textsuperscript{nd} EOP PCC).

• Starting in 2021, the 2\textsuperscript{nd} EOP PCC is being performed under the auspices of the IERS. The dedicated IERS Working Group on 2\textsuperscript{nd} EOP PCC has been established.

• The campaign will to some extent repeat the efforts made during the 1\textsuperscript{st} EOP PCC, considering similar evaluation procedures and parameters. However, we expect more participants and more prediction methods, which would improve the results of the current campaign.
Second EOP Prediction Comparison Campaign (2\textsuperscript{nd} EOP PCC)

- The 2\textsuperscript{nd} EOP PCC is open to all. Predictions of each EOP ($x_p, y_p$ pole coordinates, UT1–UTC universal time, LOD length of day, $dX$, $dY$ or $d\psi$, $d\epsilon$ precession–nutation residuals) are welcome. New types of prediction methods might enter at any time during the course of the campaign.

- The 2\textsuperscript{nd} EOP PCC is expected to officially start in \textbf{summer 2021} and run until 2023. We can consider extending the duration of the campaign, because it was stated in the conclusions of the 1\textsuperscript{st} EOP PCC that to objectively evaluate EOP prediction methods, more predictions should be used.

- The campaign will be supervised and led by the office maintained by the Space Research Centre of the Polish Academy of Sciences (CBK PAN) in Warsaw in cooperation with GeoForschungsZentrum (GFZ) in Potsdam.
IERS Working Group on the 2\textsuperscript{nd} EOP PCC

Officially established by IERS on March 24, 2021 (IERS Message No. 425)

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IERS Message No. 425  March 24, 2021
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Call for Participation: 2nd EOP Prediction Comparison Campaign

Dear Colleagues,

We would like to draw your attention to a new Working Group devoted to the prediction of Earth Orientation Parameters (EOP) which has been recently established by IERS:

https://www.iers.org/WS2022PC2

Following the highly successful first EOP prediction comparison campaign (Kalmarus et al., 2010), this new Working Group will collect valid predictions of EOP for up to 365 days into the future in a coordinated setting. All predictions need to be submitted to the office of the campaign before a specified deadline for evaluation against (subsequently available) geodetic estimates. Participation in the campaign is open to all interested scientists and institutions from all countries.

The campaign is expected to start in summer 2022, but new prediction methods might enter the campaign also at a later stage. We kindly invite scientists interested in shaping the campaign to become members of the working group by contacting Jolanta Haslata until March 31st, 2021. Another call for participation in the campaign by means of either contributing predictions or evaluating submissions will be issued in early summer 2021 again via an IERS Message.

Kind regards,

Jolanta Haslata (WG Chair)
Henryk Dobrzew (WG Co-Chair)


https://datacenter.iers.org/data/2/message_425.txt
The IERS Working Group on the 2nd EOP PCC is designed to:

• Collect and compare operationally processed EOP predictions from different agencies and institutions over a representative period of time,
• Evaluate the accuracy of final estimates of EOP,
• Identify both accurate and robust prediction methodologies,
• Assess the inherent uncertainties in present-day EOP predictions.

Chairs

• Jolanta Nastula
• Henryk Dobslaw (co-chair)

Members

• Robert Heinkelmann (IERS Analysis Coordinator, ex officio)
• Daniela Thaller (Director of IERS Central Bureau, ex officio)
• Christian Bizouard (Observatoire de Paris)
• Mathis Blossfeld (DGFI)
• Sigrid Boehm (TU Vienna)
• Robert Dill (GFZ)
• Jose Manuel Ferrandiz (University of Alicante)
• Richard Gross (JPL)
• Maciej Kalarus (University of Berne)
• Wieslaw Kosek (Military University of Technology)
• Dennis McCarthy (USNO)
• Sadegh Modiri (BKG)
• Erricos Pavlis (University of Maryland)
• David Salstein (AER)
• Erik Schoenemann (ESA)
• Harald Schuh (GFZ)
• Justyna Sliwinska (CBK)
• Nick Stamatakos (USNO)
• Benedikt Soja (ETH)
• Malgorzata Winska (Warsaw University of Technology)
• Leonid Zotov (Sternberg Astronomical Institute)

Website of the WG: https://www.iers.org/WGEOPPCC2
Office of the 2nd EOP PCC at CBK PAN

The EOP PCC Office at CBK will be responsible for data collecting, routine visualization and final evaluation of all submitted predictions.

Members of the Office:
- Jolanta Nastula (CBK, Scientific Advisor)
- Justyna Śliwińska (CBK, Coordinator)
- Małgorzata Wińska (Warsaw University of Technology, Main Scientific Evaluator)
- Tomasz Kur (CBK, Scientific Member of the Office)
- Aleksander Partyka (CBK, Scientific Member of the Office)
- Konrad Kowalski (CBK, IT Support)
- Danuta Śleszyńska (CBK, Administrative Support)

Contact
Centrum Badań Kosmicznych PAN (CBK PAN)
Bartycka 18a, 00-716 Warsaw
Office email: eoppcc@cbk.waw.pl

Webpage of the 2nd EOP PCC
http://eoppcc.cbk.waw.pl/ (note that the webpage of 2nd EOP PCC is under construction and not all information may be available now)
Technical Preparations for the EOP PCC:

Participant registration
Participant registration

- EOP PCC is open to all. Those interested should register to obtain numerical three-digit **Candidate Identifier (ID)**, which will be used in the data submission process.
- Any new candidate is welcomed at any time. We accept and encourage collaborative efforts across different institutes.
- Collaborative efforts across different institutes will receive only a single ID.
- An individual candidate with more than one prediction method should register separately to obtain several IDs for those methods.
- Only those IDs will be used to reference individual candidate solutions.
- A single ID allows to submit predictions for all parameters predicted with the assigned method.
Participant registration

Registration requirements (obligatory):
• Name of the prediction group,
• Prediction group members with affiliations,
• Corresponding person,
• Contact email.

The Office also ask all candidates to send a description of the prediction algorithm which will include the following information (one single page only):
• computation method,
• the information what EOP input(s) data is used to compute the predictions,
• programming language or other tools used.
Participant registration

http://eoppcc.cbk.waw.pl/participant-registration/
Participant registration – Example

**Participant registration**

Name of prediction group

Prediction group members with affiliations

First Name of Corresponding Person

Last Name of Corresponding Person

Email address of Corresponding Person

Short description of computation method, input data and programming language used to compute the predictions

Message
Participant registration – Example

Participant registration

Name of prediction group * Centrum Badań Kosmicznych

Prediction group members with affiliations *
Jolanta Nastula (CBK)
Justyna Śliwińska (CBK)
Małgorzata Wińska (Warsaw University of Technology)
Tomasz Kur (CBK)
Aleksander Partyka (CBK)
Danuta Śleszyńska (CBK)

First Name of Corresponding Person * Aleksander
Last Name of Corresponding Person * Partyka

Email address of Corresponding Person * apartyka@cbk.waw.pl
Participant registration – Example

Short description of computation method, input data and programming language used to compute the predictions *

Computation method
Input data
Programming language

Message
Message to the office

Register
Technical Preparations for the EOP PCC:

Format definition of an individual prediction
As all data will be analysed automatically, the Office imposes strict naming and file structure conventions.

The Office will try to individually solve all possible issues with prediction files concerning structure.
Format definition of an individual prediction

The office allows two conventions for submitted files – Candidates should choose the most convenient method for their predictions.

**Case 1:**

- All parameters \((x_p, y_p, \text{UT1-UTC}, \text{LOD}, d\psi, d\varepsilon, dX, dY)\) reside in a single file.
- Not predicted parameters must be filled up with NaN, nan, NA or -999999.
- Replacing missing parameters with zeros is not recommended.
- Using the parameter order given by the Office is required:

<table>
<thead>
<tr>
<th>Column 1</th>
<th>Column 2</th>
<th>Column 3</th>
<th>Column 4</th>
<th>Column 5</th>
<th>Column 6</th>
<th>Column 7</th>
<th>Column 8</th>
<th>Column 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>MJD</td>
<td>(x_p)</td>
<td>(y_p)</td>
<td>\text{UT1-UTC}</td>
<td>LOD</td>
<td>(d\psi)</td>
<td>(d\varepsilon)</td>
<td>(dX)</td>
<td>(dY)</td>
</tr>
</tbody>
</table>
Case 2:

• One file per predicted parameter distinguished by assigned suffix in the file name.

• Only files for predicted parameters will be submitted.

Parameter suffixes:

- p – $x_p$, $y_p$;
- u – UT1-UTC;
- l – LOD;
- e – $d\psi$, $d\epsilon$;
- n – $dX$, $dY$. 

Format definition of an individual prediction
General (for both Cases):

- it is recommended to saving files as text files (*.txt);
- whitespace as a delimiter between each parameter is recommended;
- files should contain prediction data only (i.e., without any additional text e.g., header);
- Candidate can choose either the only one or even all types of parameters;
- daily sampling is required, all values to be given for 0h UTC and each file should start with values for day zero 0h UTC;
- only files sent on time will be analysed;
- maximum forecast horizon is 365 days, shorter forecasts are possible;
- recalculation of missing parameters: UT1-UTC <-> LOD and \{dψ, dε\} <-> \{dX, dY\} will be performed for analysis purposes;
- Candidates can change cases for data submissions during the campaign.
Format definition of an individual prediction

Recommended parameter numeric formats: based on Bulletin A and Bulletin B with increased precision (plus two digits)

<table>
<thead>
<tr>
<th>MJD</th>
<th>$x_p$</th>
<th>$y_p$</th>
<th>UT1-UTC</th>
<th>LOD</th>
<th>$d\psi$</th>
<th>$d\varepsilon$</th>
<th>$dX$</th>
<th>$dY$</th>
</tr>
</thead>
<tbody>
<tr>
<td>5d</td>
<td>.8f</td>
<td>.8f</td>
<td>.9f</td>
<td>.6f</td>
<td>.5f</td>
<td>.5f</td>
<td>.5f</td>
<td>.5f</td>
</tr>
</tbody>
</table>
File naming convention

File names should be created according the following scheme:

1) All predicted parameters in one file
   eoppcc_<ID>_<MJD day zero>.txt  eoppcc_111_59298.txt

2) Predicted parameters in separated files
   eoppcc_<ID>_<MJD day zero>_<parameter>.txt  eoppcc_111_59298_p.txt

where:
ID - Candidate Identifier assigned during registration
MJD day zero - submission day
parameter suffixes:
   p – x_p, y_p;
   u – UT1-UTC;
   l – LOD;
   e – dψ, dε;
   n – dX, dY.
### Case 1

**ID = 111**  
**MJD = 59298**

Example for $x_p$, $y_p$, UT1-UTC, LOD, $d\psi$, $d\epsilon$, $dX$, $dY$

**Filename:** eoppcc_111_59298.txt

<table>
<thead>
<tr>
<th>MJD</th>
<th>$x_p$</th>
<th>$y_p$</th>
<th>$d\psi$</th>
<th>$d\epsilon$</th>
<th>$dX$</th>
<th>$dY$</th>
<th>UT1-UTC</th>
<th>LOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>59298</td>
<td>0.07276100</td>
<td>0.40785000</td>
<td>-0.170526400</td>
<td>-0.060000</td>
<td>-106.26700</td>
<td>-8.91700</td>
<td>0.00020</td>
<td>-0.00000</td>
</tr>
<tr>
<td>59299</td>
<td>0.07377600</td>
<td>0.40898600</td>
<td>-0.170588600</td>
<td>0.198500</td>
<td>-106.18000</td>
<td>-9.15700</td>
<td>0.00023</td>
<td>0.00002</td>
</tr>
<tr>
<td>59300</td>
<td>0.07499800</td>
<td>0.40960900</td>
<td>-0.170920800</td>
<td>0.449400</td>
<td>-105.83600</td>
<td>-9.22300</td>
<td>0.00021</td>
<td>0.00004</td>
</tr>
<tr>
<td>59301</td>
<td>0.07657300</td>
<td>0.40985100</td>
<td>-0.171478800</td>
<td>0.674700</td>
<td>-105.37100</td>
<td>-9.00800</td>
<td>0.00019</td>
<td>0.00006</td>
</tr>
<tr>
<td>59302</td>
<td>0.07818600</td>
<td>0.41013700</td>
<td>-0.172244000</td>
<td>0.821500</td>
<td>-105.26200</td>
<td>-8.71700</td>
<td>0.00016</td>
<td>0.00007</td>
</tr>
<tr>
<td>59303</td>
<td>0.07955500</td>
<td>0.41051700</td>
<td>-0.173053500</td>
<td>0.763400</td>
<td>-105.70900</td>
<td>-8.65000</td>
<td>0.00016</td>
<td>0.00005</td>
</tr>
<tr>
<td>59304</td>
<td>0.08066800</td>
<td>0.41106700</td>
<td>-0.173733200</td>
<td>0.592400</td>
<td>-106.34900</td>
<td>-8.84300</td>
<td>0.00017</td>
<td>0.00001</td>
</tr>
</tbody>
</table>

Example for $x_p$, $y_p$, UT1-UTC, LOD, $d\psi$, $d\epsilon$, $dX$, $dY$ with unpredicted UT1-UTC

**Filename:** eoppcc_111_59298.txt

<table>
<thead>
<tr>
<th>MJD</th>
<th>$x_p$</th>
<th>$y_p$</th>
<th>$d\psi$</th>
<th>$d\epsilon$</th>
<th>$dX$</th>
<th>$dY$</th>
<th>UT1-UTC</th>
<th>LOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>59298</td>
<td>NaN</td>
<td>-0.060000</td>
<td>-106.26700</td>
<td>-8.91700</td>
<td>0.00020</td>
<td>-0.00000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>59299</td>
<td>NaN</td>
<td>0.198500</td>
<td>-106.18000</td>
<td>-9.15700</td>
<td>0.00023</td>
<td>0.00002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>59300</td>
<td>NaN</td>
<td>0.449400</td>
<td>-105.83600</td>
<td>-9.22300</td>
<td>0.00021</td>
<td>0.00004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>59301</td>
<td>NaN</td>
<td>0.674700</td>
<td>-105.37100</td>
<td>-9.00800</td>
<td>0.00019</td>
<td>0.00006</td>
<td></td>
<td></td>
</tr>
<tr>
<td>59302</td>
<td>NaN</td>
<td>0.821500</td>
<td>-105.26200</td>
<td>-8.71700</td>
<td>0.00016</td>
<td>0.00007</td>
<td></td>
<td></td>
</tr>
<tr>
<td>59303</td>
<td>NaN</td>
<td>0.763400</td>
<td>-105.70900</td>
<td>-8.65000</td>
<td>0.00016</td>
<td>0.00005</td>
<td></td>
<td></td>
</tr>
<tr>
<td>59304</td>
<td>NaN</td>
<td>0.592400</td>
<td>-106.34900</td>
<td>-8.84300</td>
<td>0.00017</td>
<td>0.00001</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Case 2

ID = 111  
MJD = 59298

Filename: eoppcc_111_59298_p.txt

Example for $x_p$, $y_p$ only

<table>
<thead>
<tr>
<th>MJD</th>
<th>$x_p$</th>
<th>$y_p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>59298</td>
<td>0.07300000</td>
<td>0.40800000</td>
</tr>
<tr>
<td>59299</td>
<td>0.07390000</td>
<td>0.40930000</td>
</tr>
<tr>
<td>59300</td>
<td>0.07480000</td>
<td>0.41060000</td>
</tr>
<tr>
<td>59301</td>
<td>0.07560000</td>
<td>0.41180000</td>
</tr>
<tr>
<td>59302</td>
<td>0.07640000</td>
<td>0.41290000</td>
</tr>
<tr>
<td>59303</td>
<td>0.07730000</td>
<td>0.41400000</td>
</tr>
<tr>
<td>59304</td>
<td>0.07820000</td>
<td>0.41510000</td>
</tr>
</tbody>
</table>
Technical Preparations for the EOP PCC:

Data Submission
Data submission

General information

- **File upload frequency:** Predictions should be sent **weekly**.
- **Due date:** *Submission should be made always on Wednesday – submission deadline is 20h UTC (sharp)*
- **File format:** @see: file format definition

Technical information

- After registration, participant will receive **login details** (individual login and password)
  - Passwordless login using SSH Keys (optional)
- Secure upload using **SFTP** (SSH File Transfer Protocol)
  - CLI tools: scp, sftp, lftp, curl, etc.; GUI tools: FileZilla, WinSCP etc.
- SFTP server located in CBK PAN data center

More information

- EOP PCC website: http://eoppcc.cbk.waw.pl/data-submission/
First Ideas for the Scientific Assessment of EOP Predictions
Conclusions from the 1st EOP Prediction Comparison Campaign (1st EOP PCC)

- The most accurate prediction techniques for $x_p$, $y_p$ pole coordinates: LS extrapolation of the harmonic model + AR prediction (M. Kalarus), Spectral analysis + LS extrapolation (S. Kumakshev), Neural networks (L. Zotov).

- The most accurate prediction techniques for UT1–UTC and LOD: Kalman filter (AAM forecast: NCEP) (R. Gross), Wavelet decomposition + autocovariance prediction (W. Kosek), Adaptive transformation from AAM to LODR (D. Gambis).

- The advantages of using a combined solution were clearly indicated.

- The accuracy of the predictions benefited from using atmospheric forecasts data as an input.

- The best prediction technique was different for different categories (parameter to be predicted and prediction length), and there was not one particular prediction technique superior to the others for all EOP and all prediction intervals.

- It was underlined that insufficient number of submissions resulting from short length of the campaign made it impossible to draw final conclusions.

- It was recommended that any continuation of the campaign or of a similar should be performed. Different scenarios could be considered in order to increase the number of collected submissions.

First Ideas for the Scientific Assessment of EOP Predictions

Comparison and assessment of EOP predictions will be performed in two steps:

1. **Routine visualization of all (anonymized) submissions** – available shortly after the submission deadline as a first feedback to all candidates. This will include number of submissions per submission cycle and statistics like ensemble mean, standard deviation as a measure of ensemble spread, skewness, excess kurtosis and quantiles as a measure of asymmetry etc. The results will be available at the campaign’s webpage.

2. **Evaluation based on comparison with reference data** – further validation metrics should closely follow Kalarus et al. (2009)
   - **Preliminary evaluation** – routine comparison against C04 as soon as it is available; statistics should be calculated always for all past submissions. A threshold computed from the median absolute prediction error MDAE defined for the \( i \)-th day in the future will be set up and some of the time series that do not meet the criteria will be rejected from future analysis. The number of not qualified predictions will be monitored.
   - **Final evaluation** – at the end of the campaign
Reference data

- In 1\textsuperscript{st} EOP PCC, the official statistics were originally referred to the IERS EOP 97 C04 series, and later to the IERS EOP 05 C04 series.
- The results of 2\textsuperscript{nd} EOP PCC will be probably referred to the IERS EOP 14 C04.
- Additional analyses may include comparison with IGS combined polar motion solution, ITRF2020 EOP solution, COMB2020, IERS Rapid data, ESA/DGFI final EOP solution, etc.
Length of predictions

- In 1st EOP PCC, the predictions were divided into three categories:
  - **ultra short-term** (predictions to 10 days into the future),
  - **short-term** (30 days),
  - **medium-term** (500 days).

- Participants had to follow this rule and submit the predictions of a certain length.

- For the 2nd EOP PCC, we suggest daily sampling of each prediction with maximum forecast horizon of 365 days. Shorter forecasts are possible (no required prediction length specified).
Final evaluation

- consider latest C04 series, and possibly IGS combined polar motion solution, ITRF2020 EOP solution, COMB2020, etc.
- pair-wise comparison of all available final series
- calculation combined series of EOP predictions computed as a weighted mean of all final series
- quantification of the current accuracy level of final EOP series
- re-evaluation of all past submissions against the mean final series
- compare results to the preliminary evaluation: any major changes?
Proposed Schedule of the 2\textsuperscript{nd} EOP PCC

\textbf{Q1 2021}: open call for participation in Working Group via IERS message – IERS Message No. 425: Call for Participation: 2nd EOP Prediction Comparison Campaign (24 March 2021)

\textbf{Q2 2021}: definition of the validation protocol

\textbf{Q2 2021}: website of EOP PCC online

- draft a technical document summarizing all the rules and requirements discussed today
- open the server for ID applications
- open the server for preliminary submissions of predictions for testing purposes
- define an official start date and announce an open call for participation in Campaign via IERS message

\textbf{Q2 2021}: open call for participation in Campaign via IERS message

\textbf{Q3 2021}: first weekly submission of EOP predictions

\textbf{Q2 2022}: presentation of preliminary results at EGU GA

\textbf{Q4 2022}: last weekly submission of EOP predictions

\textbf{Q2 - Q4 2023}: presentation of final results