3.5.2 Rapid Service/Prediction Centre

Processing Techniques

The algorithm used by the IERS Rapid Service/Prediction Centre for the determination of the quick-look Earth orientation parameters (EOP) is based on a weighted cubic spline with adjustable smoothing fit to contributed observational data (McCarthy & Luzum, 1991a). Contributed data are corrected for possible systematic differences. Biases and rates are determined with respect to the C04 system of the IERS Earth Orientation Centre (EOC). Statistical weighting used in the spline is proportional to the inverse square of the estimated accuracy of the individual techniques. Minimal smoothing is applied, consistent with the estimated accuracy of the observational data.

Weights in the algorithm may be either a priori values estimated by the standard deviation of the residual of the techniques or values based on the internal precision reported by contributors. Estimated accuracies of data contributed to the IERS Rapid Service/Prediction Centre are given in Table 1. These estimates are based on a random sampling of the statistical reports that were generated weekly as part of the Bulletin A Rapid Service EOP solution for 2002.

Table 1. Estimated accuracies of the techniques in 2002. Units are milliseconds of arc for x, y, $\delta\psi$, and $\delta\varepsilon$ and milliseconds of time for UT1-UTC and LOD.

Contributor	Estimated Accuracy					
	X	Y	UT1	LOD	$\delta\psi$	$\delta\varepsilon$
CSR 3-day SLR	0.3	0.5	0.11*			
DUT 3-day SLR	0.3	0.3				
IAA 1-day SLR	0.3	0.3				
MCC 1-day SLR	0.2	0.2				
GSFC daily VLBI			0.020			
SpbU daily VLBI			0.021			
GSFC weekly VLBI	0.1	0.1	0.008		0.4	0.1
IAA weekly VLBI	0.1	0.1	0.005		0.4	0.1
IGS Final	0.02	0.05				
IGS Rapid	0.03	0.06		0.02*		
USNO GPS UT*			0.018*			
EMR GPS UT*			0.04*			
USNO AAM UT			0.030			

**All satellite techniques provide information on the rate of change of Universal Time contaminated by effects due to unmodelled orbit node motion. VLBI-based results have been used to correct for LOD biases and to minimize drifts in UT estimates.*

Operationally, the weighted spline uses as input the epoch of observation, the observed value, and the weight of each individual data point. The software computes the spline coefficients for every data point which are then used to interpolate the Earth orientation time series so that x, y, UT1-UTC, $\delta\psi$, and $\delta\varepsilon$ values are computed at the epoch of zero hours UTC for each day. The only data points that are excluded from this process are points whose errors, as reported by the contributors, are greater than three times their average reported precision or those points that have a residual that is more that four times the associated a priori error estimate. Since all of the observations are reported with the effects of sub-daily variations removed, no processing is done to account for these effects (see IERS Gazette No. 13, 30 January 1997).

Table 2. Mean and standard deviation of the differences between the Rapid Service/Prediction Centre solutions and IERS Bulletin B and C04 EOP solutions for 2002. Polar motion X and Y values are in milliseconds of arc and UT1-UTC values are in units of milliseconds of time.

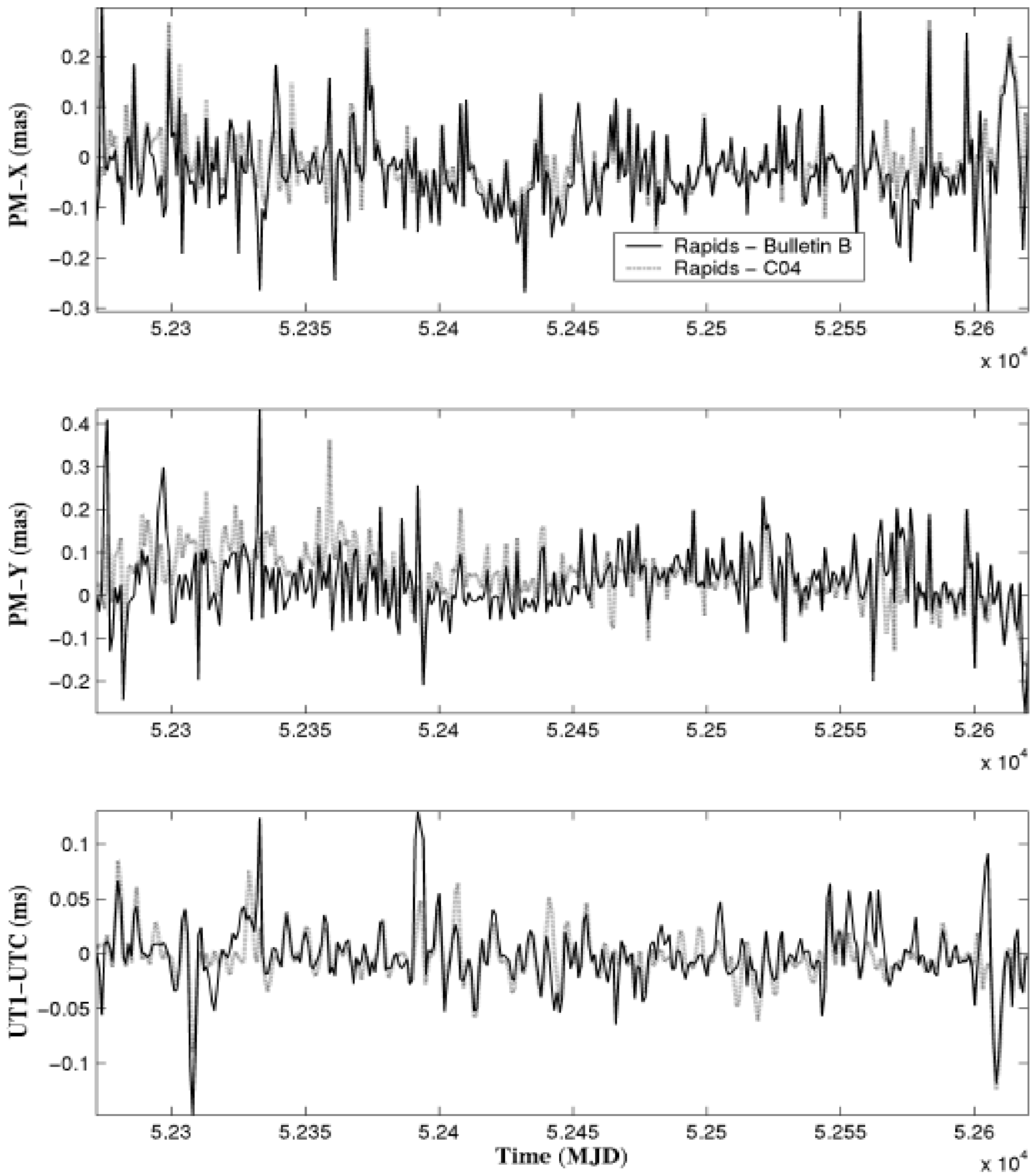
	Bulletin A – Bulletin B		Bulletin A – C04	
	Mean	Std. Deviation	Mean	Std. Deviation
Bulletin A Rapid Solution (finals.data)				
X	0.03	0.09	–0.01	0.07
Y	0.03	0.08	0.05	0.07
UT1-UTC	0.001	0.030	–0.004	0.023
Bulletin A Daily Solution (finals.daily)				
X	0.01	0.15	0.02	0.15
Y	–0.04	0.14	–0.03	0.13
UT1-UTC	0.011	0.060	0.015	0.056

The uncertainties in the daily values listed in Bulletin A are derived from the quality of the spline fit in the neighbourhood of the day in question. Table 2 shows the accuracies of two different Rapid Service/Prediction Centre products compared to the Bulletin B and C04 series maintained by the IERS EOC at the Paris Observatory. The agreement between the Bulletin A solutions and the IERS EOC solutions is quite good. In addition the EOP accuracies for the Bulletin A rapid solution and daily solution are similar at the time of solution epoch.

Prediction Techniques

Polar motion predictions are based on the extrapolation of an annual and semiannual ellipse and a Chandler circle fit to the previous 400 days of observed values of x and y (McCarthy and Luzum, 1991b; Johnson, 2002). The differences between the last observed pole position and rate and those of the curve are computed. These differences are then used to adjust the extrapolated curve by an amount that decreases with the length of the forecast. In February 1998, the near-term polar motion predictions (less than about 30 days) were improved significantly by modifying the transition proc-

Figure 1: Differences between Bulletin A Rapid Solutions and the Earth Orientation Parameters available in Bulletin B and C04 for 2002.



ess from the last observed polar motion result to the long-term predictions. Continuity in the first derivatives was enforced placing great weight on the observed polar motion rate reported by the IGS in their Rapid series. The improvement was most pronounced for the shortest prediction intervals. The procedure for UT1-UTC involves a simple technique of differencing (McCarthy and Luzum, 1991b). All known effects such as leap seconds, solid Earth zonal tides, and seasonal effects are first removed from the observed values of UT1-UTC. Then, to determine a prediction of UT1-UTC n days into the future, $(UT1\text{-}TAI)_n$, the smoothed time value from n days in the past, $\langle(UT1R\text{-}TAI)_{-n}\rangle$ is subtracted from the most recent value, $(UT1R\text{-}TAI)_o$.

$$(UT1\text{-}TAI)_n = 2(UT1R\text{-}TAI)_o - \langle(UT1R\text{-}TAI)_{-n}\rangle.$$

The amount of smoothing used in this procedure depends on the length of the forecast. Short-term predictions with small values of n make use of less smoothing than long-term predictions. Once this value is obtained, it is possible to account for known effects in order to obtain the prediction of UT1-UTC. This process is repeated for each day's prediction.

The very near-term UT1-UTC prediction is strongly influenced by the observed daily Universal Time estimates derived at USNO from the motions of the GPS orbit planes reported by the IGS Rapid service. The IGS estimates for LOD are combined with the GPS-based UT estimates to constrain the UT1 rate of change for the most recent observational day. For the 5 days after the latest observed day, AAM-based predictions of LOD excitation are combined smoothly with the longer-term UT1 predictions described above.

Errors of the estimates are derived from analyses of the past differences between observations and the published predictions. Formulas published in Bulletin A are used to extend the tabular data. The prediction of $\delta\psi$ and $\delta\varepsilon$ is based on the IERS Conventions (McCarthy, 1996). Table 3 shows the standard deviation of the differences between the daily solution and C04 solution, respectively, for 2002. Recent prediction performance in UT1-UTC has been improved by 42% at 10 days into the future by the addition of a UT1-like data product derived from NCEP AAM (UTAAM) to the combination and prediction routine (Johnson et al., 2003). This estimate of improvement was determined by examining one year's worth of daily solutions that used UTAAM in the combination and prediction.

Table 3. Standard Deviation of the differences between the Daily solutions and the C04 EOP solutions for 2002.

Days in Future	X mas	Y mas	UT1-UTC ms	$\delta\psi$ mas	$\delta\varepsilon$ mas
1	.47	.37	.118	.39	.17
5	2.15	1.51	.445	.40	.18
10	3.69	2.57	1.09	.41	.18
20	6.41	4.46	3.59	.42	.19
40	10.2	8.23	7.00	.46	.21
90	15.1	18.5	13.8		

** $\delta\psi$ and $\delta\varepsilon$ not predicted to 90 days into future in daily solutions.*

The predictions of δψ and δε are based solely on VLBI data. If no new data are available, a new prediction of these nutation angles cannot be determined. Therefore, the length of the prediction into the future for δψ and δε can and does vary in the daily solution files.

Predictions, of UT1-TAI up to 2010 January 1, are given in Table 4 below. They are derived using a prediction algorithm similar to that employed in the Bulletin A predictions of UT1-UTC. Up to twenty years of past observations of UT1-TAI are used. Estimates of the expected one-sigma error for each of the predicted values are also given. These are based on analyses of the past performance of the model with respect to the observations.

Table 4. Predicted values of UT1-TAI, 2003–2012. Note that TT-UT1 can be obtained from this table using the expression TT-UT1=32.186s – (UT1-TAI).

DATE	UT1-TAI (s)	Uncertainty (s)
2003 Jan 1	–32.27	.02
2003 Apr 1	–32.33	.02
2003 Jul 1	–32.68	.03
2003 Oct 1	–32.89	.04
2004 Jan 1	–33.10	.06
2004 Apr 1	–33.31	.1
2004 Jul 1	–33.6	.2
2004 Oct 1	–33.8	.2
2005 Jan 1	–34.1	.3
2005 Apr 1	–34.3	.4
2005 Jul 1	–34.5	.4
2005 Oct 1	–34.7	.5
2006 Jan 1	–34.9	.6
2006 Apr 1	–35.2	.8
2006 Jul 1	–35.4	.9
2006 Oct 1	–36.	1.
2007 Jan 1	–36.	1.
2007 Apr 1	–36.	1.
2007 Jul 1	–36.	1.
2007 Oct 1	–36	2.
2008 Jan 1	–36.	2.
2008 Apr 1	–36.	2.
2008 Jul 1	–36.	2.
2008 Oct 1	–37.	2.
2009 Jan 1	–37.	2.
2009 Apr 1	–37.	2.
2009 Jul 1	–37.	3.
2009 Oct 1	–37.	3.
2010 Jan 1	–37.	3.
2010 Apr 1	–37.	3.
2010 Jul 1	–37.	3.
2010 Oct 1	–38.	3.
2011 Jan 1	–38.	3.
2011 Apr 1	–38.	4.
2011 Jul 1	–38.	4.
2011 Oct 1	–38.	4.
2012 Jan 1	–38.	4.

Please contact the IERS Rapid Service/Prediction Centre for details on how to obtain these data. Further information on recent improvements to IERS Bulletin A and the significance for predictions of GPS orbits for real-time users is provided in the paper by Luzum et al. (2001).

Centre Activities in 2002

During 2002 a few changes occurred which affect the performance of IERS Bulletin A. In January software formats were modified to handle the new IVS VLBI data formats. In February the software was modified to allow the editing of all data techniques used in polar motion and UT1 combination solutions. In addition data editing was introduced into the nutation software.

Due to the improved accuracy of the Bulletin A daily solutions, the weekly nature of VLBI 24-hour sessions, and personnel limitation, the frequency of the Bulletin A rapid solution was reduced from twice weekly to weekly on 1 July 2002.

In September a study to evaluate the potential improvements by introducing USNO and IVS Combination 24-hour VLBI products into the Bulletin A rapid service/prediction EOP series was initiated. By November the results clearly indicated that the robustness of the Bulletin A could be improved by the addition of these two VLBI series, especially for the nutation angles. It was decided that the USNO and IVS Combination 24-hour VLBI products would be introduced into the operational Bulletin A solution in early January 2003.

On 9 November 2002 the software script that produces the finals.daily data file failed to produce a data file over the correct period. The software produced the file as if the solution epoch was 52586 (8 November 2002). This problem continued until 13 November 2002. The results of this error caused the solution published in the finals.daily to be given ±90 days with respect to 52586 and not with the appropriate epoch of the solution even though the values stored in the files appear to be correct. This problem was corrected by the 14 November 2002 solution.

In late 2002 the Centre prepared for the implementation of the IAU 2000 resolutions by creating a dX and dY series with respect to the IAU 2000A Precession/Nutation Theory. The complete replacement of the IAU 1980 Theory of Nutation and the IERS Precession/Nutation Theory should be completed by mid- to late-2003.

The Centre is currently investigating improvement of the current methods employed to estimate the biases between the different Analysis Centre datasets and C04.

Availability of Rapid Service

The data available from the IERS Rapid Service/ Prediction Centre consist mainly of the data used in the IERS Bulletin A. This includes: x, y, UT1-UTC, $\delta\psi$, $\delta\varepsilon$ from IAA VLBI; x, y, UT1-UTC, $\delta\psi$ from GSFC VLBI; UT1-UTC from Saint Petersburg University 1-day

Intensives; UT1-UTC from GSFC 1-day Intensives; x, y, UT1-UTC from GSFC 1-day Intensives; x, y, UT1-UTC from CSR LAGEOS 3-day SLR; x, y from Delft University of Technology 3-day SLR; x, y from Institute of Applied Astronomy 1-day SLR; x, y from the Russian Mission Control Centre 1-day SLR; x, y, LOD from the International GPS Service; UT from USNO GPS; UT from NRCanada (EMR) GPS; x, y, UT1-UTC, $\delta\psi$, $\delta\varepsilon$ from the IERS Rapid Service/Prediction Centre; x, y, UT1-UTC, $\delta\psi$, $\delta\varepsilon$ from the IERS Earth Orientation Centre; and predictions of x, y, UT1-UTC from the IERS Rapid Service/ Prediction Centre.

In addition to this published information, other data sets are available. This includes: UT0-UTC from University of Texas as Austin LLR, UT0-UTC from JPL LLR; UT0-UTC from CERGA LLR; UT0-UTC from JPL VLBI; latitude and UT0-UTC from Washington PZTs 1,3,7; latitude and UT0-UTC from Richmond PZTs 2,6; x and y from CSR LAGEOS 5-day SLR; x and y from Delft 5-day SLR; x, y, UT1-UTC, $\delta\psi$, and $\delta\varepsilon$ from IRIS VLBI.

The data described above are available from the Centre in a number of forms. You may request a weekly machine-readable version of the IERS Bulletin A containing the current ninety day’s worth of predictions via electronic mail from

<ser7@maia.usno.navy.mil> or <http://maia.usno.navy.mil/>.

Internet users can also direct an anonymous FTP to

<maia.usno.navy.mil>

and change to the ser7 directory where the IERS Bulletin A and more complete databases can be accessed including the daily Bulletin solutions.

World Wide Web access is available at

<http://maia.usno.navy.mil/>.

Centre Staff

For most of 2002, the Rapid Service/Prediction staff consisted of the following members.

Jim R. Ray	director and program manager
Thomas Johnson	research, software maintenance and support
Merri Sue Carter	assists in daily operations and support
Jerry Josties	assists in operations and support

Jim Ray resigned from USNO in May 2002 and Jerry Josties retired in October 2002, after 42 years of service to USNO. Thomas Johnson managed the program for the remainder of 2002. William Wooden is the new director of the Centre as of February 2003.

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