Recent developments in time references

Włodzimierz Lewandowski and Elisa Felicitas Arias

ICG-7 Beijing, China, 4-9 November 2012

Outline

- Rapid UTC Pilot Experiment
  - Motivation
  - Impact on UTC(k) and on GNSS times
  - Status report
  - Next actions
- Redefinition of UTC without leap seconds
  - Chain of responsibilities
  - Status of discussion at ITU-R
  - Impact on GNSS
  - Future steps, involvement of international organizations

On the frequency of publication of UTC

- 10-40 days delay as publication of *BIPM Circular T* is not adequate for some applications
  - Short term assessment of UTC(k) steering to UTC, impacting contributing laboratories, and in particular
    - GNSS times steering to UTC(k)

      UTC(USNO) → GPS
      UTC(SU) → GLONASS
      $UTC(k)_{Eur}$ → GALILEO
      UTC(NIM) → BeiDou
      UTC(k)India → IRNSS
  - Better determination of GNSS times offsets, essential for interoperability and interchageability of navigation systems
- Discussions at the ICG (2010, 2011);
- Discussions with experts in commissions for developing strategies for GNSS times;
- Need of a « rapid » product, to give access on a shorter delay to an approximation to UTC, before final validation by *Circular T*
  - IERS, IGS publish their products with different latency (ultra-rapid, rapid, final)

Implementation of UTCr

- UTC contributing laboratories have been invited to participate on a voluntary basis to a pilot experiment (daily submission of daily data); positive responses of labs with adequate equipment;
- Pilot experiment started on January 2012,
- Report to the Consultative Committee for Time and Frequency in September 2012;
- Pilot experiment will continue until final validation (few months)
- Routine production of UTCr should start in 2013;
- UTC as calculated and published today will not be affected, however, it will benefit from UTCr
  - Shorter latency of publication (anticipated data checking and pre-processing)
  - Better quality of data from contributing laboratories (expected)

Publication

Every Wednesday before 18:00 UTC on

ftp://tai.bipm.org/UTCr/Results/

UTCr_1211
2012 MARCH 21, 13h UTC

The results in this page are established by the BIPM Time Department in the frame of the pilot experiment on a rapid UTC, UTCr. The computed values [UTCr-UTC(k)] are reported.

Date 2012 0h UTC	MAR 12	MAR 13	MAR 14	MAR 15	MAR 16	MAR 17	MAR 18
MJD	55998	55999	56000	56001	56002	56003	56004
Laboratory k	[UTCr-UTC(k)]/ns						
AOS (Borowiec)	-2.6	-2.4	-1.9	-1.3	-1.9	-1.9	-1.2
BEV (Wien)	11.9	11.3	10.3	6.5	0.4	-2.3	-5.7
CAO (Cagliari)	-6291.7	-6290.8	-6293.1	-6291.4	-6298.8	-6308.3	-6300.0
CH (Bern)	-12.5	-12.3	-12.0	-10.9	-9.8	-9.2	-9.3
CNM (Queretaro)	-13.8	-15.0	-15.5	-14.9	-17.3	-18.4	-17.1
CNMP (Panama)	75.8	81.4	85.5	83.1	83.8	83.0	88.0
DTAG (Frankfurt/M)	6.8	5.1	5.8	5.7	6.8	6.4	7.7
IFAG (Wettzell)	-620.2	-619.1	-623.8	-627.3	-627.8	-626.7	-627.4
IGNA (Buenos Aires)	6691.8	6700.6	6711.9	6724.6	6737.0	6747.7	6762.6
INTI (Buenos Aires)	-26.4	-32.2	-32.6	-32.7	-32.5	-31.6	-36.7
IPQ (Caparica)	-23.1	-29.1	-27.5	-24.7	-22.6	-16.5	-12.5
IT (Torino)	1.2	2.3	2.6	3.0	3.4	3.8	4.0
KRIS (Daejeon)	-8.3	-8.7	-9.4	-	-	-	-
LT (Vilnius)	42.4	39.1	32.9	35.0	30.1	37.5	43.8
MSL (Lower Hutt)	67.0	61.2	55.3	-	-	-	-
NAO (Mizusawa)	54.8	49.9	52.4	54.7	50.1	49.0	50.8
NICT (Tokyo)	2.5	2.7	2.6	3.1	3.4	3.2	3.2
NIM (Beijing)	-7.1	-7.5	-8.3	-8.9	-9.8	-9.8	-10.7
NIMT (Pathumthani)	987.6	1008.5	1026.4	1042.7	1058.3	1074.2	1090.9
NIS (Cairo)	-782.1	-784.0	-783.8	-786.8	-794.0	-797.0	-799.5
NIST (Boulder)	-4.1	-5.0	-4.2	-3.9	-6.6	-6.3	-5.2
NMIJ (Tsukuba)	-8.7	-8.4	-8.5	-8.2	-7.7	-8.0	-8.2
NMLS (Sepang)	-664.4	-665.1	-667.1	-667.0	-670.4	-672.4	-674.5
NRC (Ottawa)	-18.1	-14.2	-15.1	-13.9	-13.8	-14.0	-13.6
NTSC (Lintong)	0.8	2.2	2.1	5.0	4.3	4.5	3.8
ONRJ (Rio de Janeiro)	-12.3	-9.7	-6.9	-7.5	-7.8	-4.7	-1.9
OP (Paris)	-24.5	-22.8	-23.7	-21.8	-21.4	-21.8	-24.5
ORB (Bruxelles)	-0.4	-0.1	0.5	0.0	0.4	-0.5	-1.0
PL (Warszawa)	15.8	16.5	18.1	16.1	15.0	12.4	12.8
PTB (Braunschweig)	-3.2	-3.4	-3.6	-3.5	-4.0	-4.0	-4.6
ROA (San Fernando)	-2.8	-2.2	-2.7	-3.1	-3.5	-3.8	-4.4
SCL (Hong Kong)	13.8	11.5	5.2	5.5	2.8	-5.8	-2.0
SG (Singapore)	9.6	9.3	7.5	7.8	7.8	7.4	6.6
SP (Boras)	-15.7	-15.6	-15.5	-15.6	-15.5	-15.6	-16.0
SU (Moskva)	1.4	1.2	2.0	2.2	0.6	0.3	0.9
TL (Chung-Li)	6.4	6.5	5.5	4.9	4.2	2.7	1.3
UME (Gebze-Kocaeli)	103.3	100.2	104.3	109.5	107.7	105.3	107.1
USNO (Washington DC)	-0.7	-1.1	-1.2	-1.3	-1.5	-1.5	-1.5
VSL (Delft)	10.0	8.1	3.6	3.2	4.4	4.5	4.6

These results should not be used as a prediction of UTC.
UTC remains available from the monthly Circular T at
(http://www.bipm.org/jsp/en/TimeFtp.jsp?TypePub=publication).

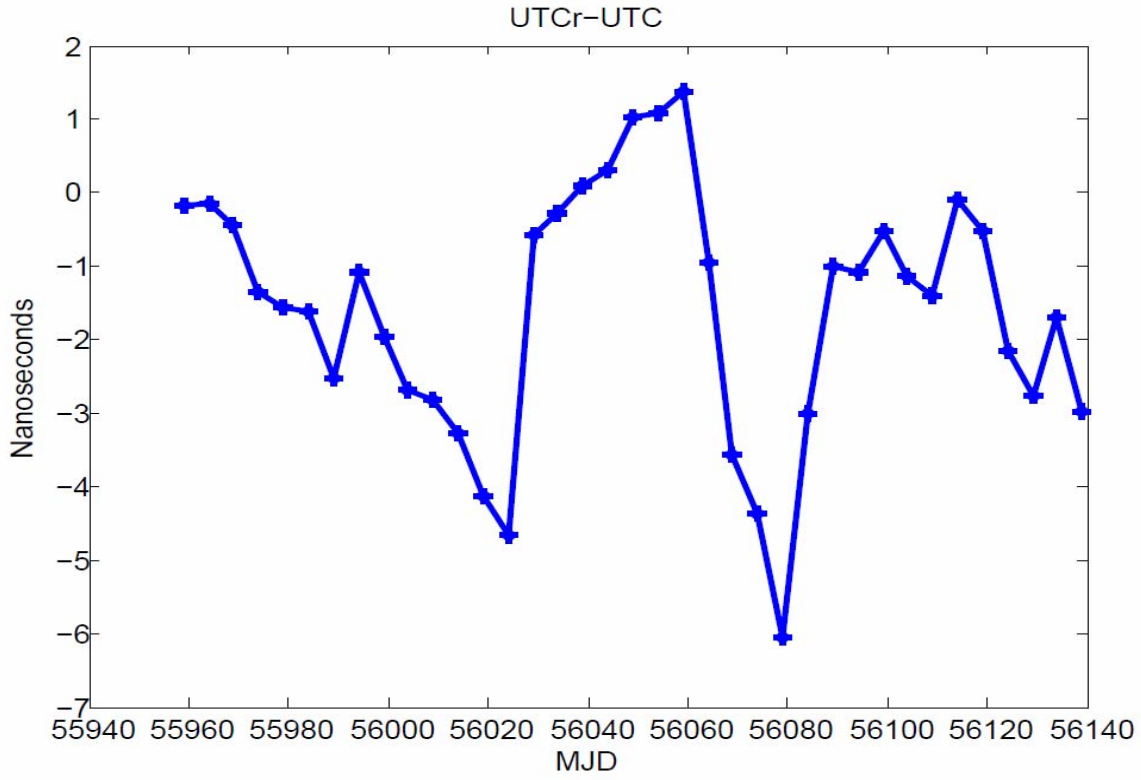
Comparisons between UTCr and UTC (1): Results

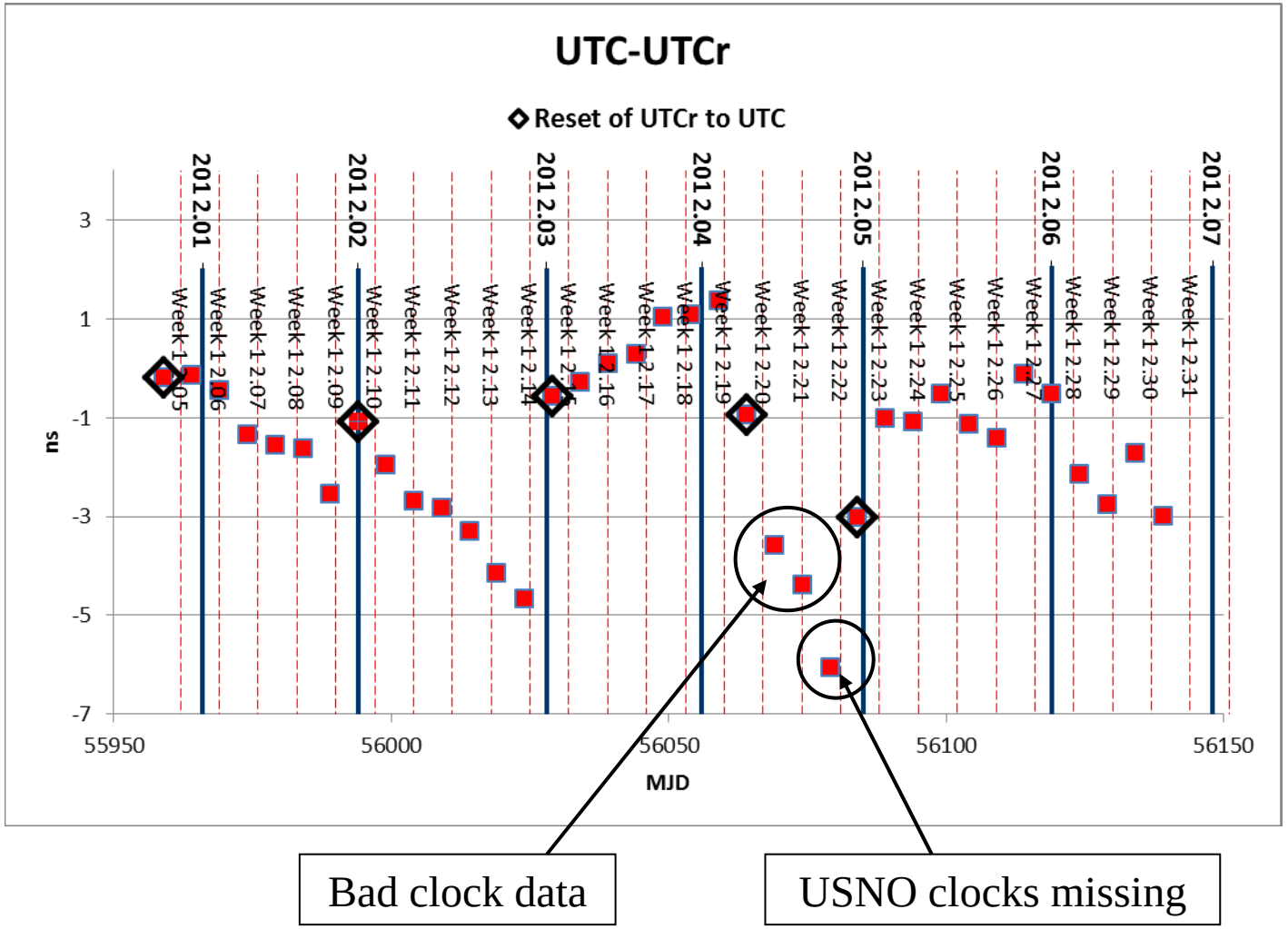
Based on first six months (February to July 2012)

Some drift expected due to the linear prediction in UTCr

Initial steering procedure (reset + rate correction) stopped in April

A number of features need to be studied in detail





Several events affected UTCr . Also the reset to UTC was not systematically done in time

=> some a posteriori recomputations of UTCr to test different configurations

Conclusions

UTCr started as a pilot experiment in January 2012

“regular production” since week 1208, with disclaimer

6-month analysis suggests

- some changes in the operational algorithm
- to keep the disclaimer

UTC kept unchanged so far. Will benefit from UTCr due to better anticipation and easier detection of problems (clocks and links).

UTC- ....

2011	GPS time +15 s /ns	**UTC(USNO) by GPS** /ns	GLONASS time /ns	**UTC(SU) by GLONASS** /ns
APR 1	-3.5	-3.4	-153.8	-307.8
APR 2	-3.0	-3.8	-156.1	-312.8
APR 3	-2.3	-2.2	-154.8	-313.4
APR 4	-4.3	-5.0	-152.0	-311.9
APR 5	-2.6	-3.8	-152.4	-313.5
APR 6	1.1	0.8	-153.9	-316.4
APR 7	0.3	-0.7	-155.2	-319.4
APR 8	-2.2	-3.5	-156.0	-322.0
APR 9	-3.3	-3.4	-154.7	-322.5
APR 10	-8.0	-8.5	-153.2	-322.7
APR 11	-10.2	-10.4	-151.6	-323.1
APR 12	-7.9	-5.9	-146.9	-320.5
APR 13	-3.7	-2.2	-146.5	-321.3
APR 14	-3.0	-2.0	-147.6	-323.8
APR 15	-2.4	-2.0	-148.4	-325.7
Stand. dev.	**1.5**	**1.6**	**6.8**	**6.8**
Uncert. uB	**10.0**	**10.0**	**500.0**	**500.0**

Practical information

- If you wish to participate see the information in
  ftp://tai.bipm.org/UTCr/Documents/

- Publication of [UTCr-UTC(k)] every Wednesday on
  ftp://tai.bipm.org/UTCr/Results/

Future of UTC - Responsibilities on timescales

General Conference on Weights and Measures (CGPM)

- Defines of the second (units in general)
- Adopts International Atomic Time (TAI)
- Endorses UTC

International Telecommunication Union (ITU)

- Fixes de rules for t&f dissemination by signals
- Rec ITU-R TF-460.6 (describes the process for synchronizing UTC to UT1 better than 1s)

International Bureau of Weights and Measures (BIPM)

- Calculates UTC based on data provided by ~ 70 institutes world-wide spread, coordinates activities for accomplishing this mandate

International Earth Rotation and Reference Systems Service (IERS)

- Monitors the rotation of the Earth, fixes and announces the application of leap seconds

National institutes (69) maintain local approximations to UTC, UTC(k)

Possible redefinition of UTC without leap seconds

~ 2000	Discussion started at the ITU-R, SG7 Science Services, WP7A Time signals and frequency standard emissions
2000-2010	WP7A studied the issue, considered different options, organized an open meeting (Torino, 2003), and worked on a proposal for an amended recommendation
2010	The Draft Recommendation ITU-R TF.460-6 (new proposed version) was submitted by WP7A to SG7; discussion came to a « dead-end » with a 10-year opposition from one administration, plus 2 more administrations joining this position
2011	SG7 sent the Draft Recommendation to the Radiocommunication Assembly 2012 (January) for « final decision »
2012	RA 2012 put back the recommendation to SG7-WP7A for a final decision at WRC 2015; WRC 2012 Resolution 653 on the feasibility of a continuous UTC involves the BIPM, CCTF, CGPM, IAU, IUGG, URSI, ICAO, IMO, WMO, ISO.

The Secretary-General

REÇU
Le 25 JUIN 2012

Geneva, 18 June 2012

Prof. Michael Kühne
Director of BIPM
The General Conference on Weights and Measures (CGPM)
Bureau International des Poids et Mesures (BIPM)
Pavillon de Breteuil
92312 SEVRES Cedex
France

Dear Sir,

The World Radiocommunication Conference, Geneva, 2012 (WRC-12), adopted or revised, several Resolutions considered to be of interest to the General Conference on Weights and Measures and has instructed me to bring these Resolutions to the General Conference's attention.

In pursuance of the above instruction, I have the honor to forward herewith, for information and appropriate action, copies of the said Resolutions in the six official languages of the ITU.

It would be greatly appreciated if you would keep me informed of the General Conference's action on any of these matters, so that I may advise the ITU administrations accordingly.

Yours faithfully,

Dr Hamadoun I. Touré

Annexes: Resolution 653 (WRC-12)
Resolution 807 (WRC-12)
Resolution 808 (WRC-12)

International Telecommunication Union • Place des Nations • CH-1211 Geneva 20 • Switzerland
Tel: +41 22 730 5111 • Fax: +41 22 733 7256 • E-mail: itumail@itu.int • www.itu.int •

Resoltion 653 (WRC-12)
Future of the Coordinated Universal Time time-scale

.....

resolves to invite WRC-15

to consider the feasabilty of achieving a continuous reference time-scale, whether by the modification of UTC or some other method, and take appropriate action, taking into acount ITU-R studies,

.....

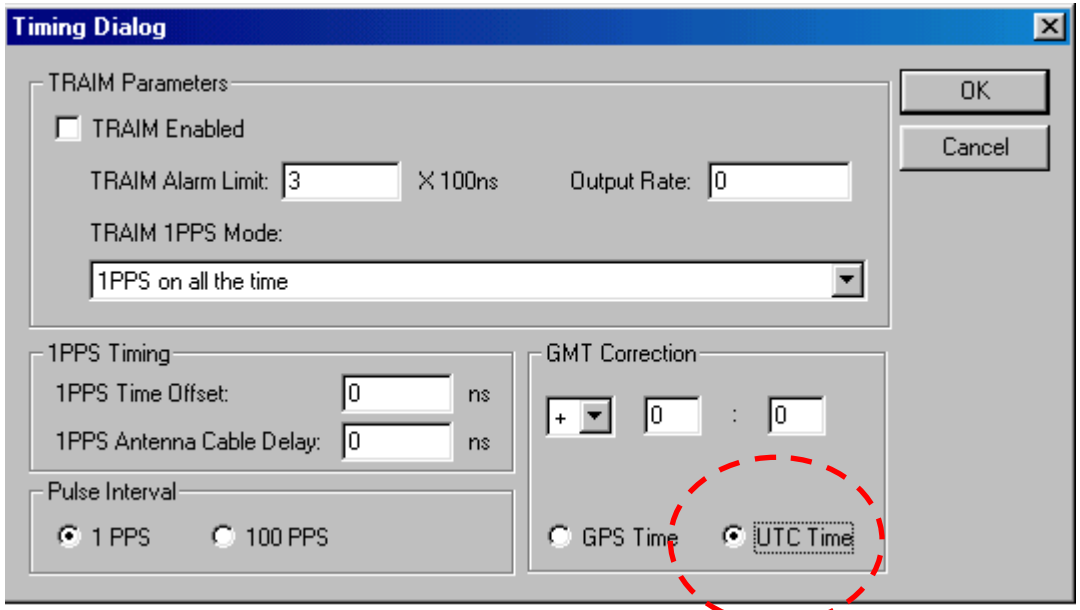
Is a stepped UTC adapted for modern applications?

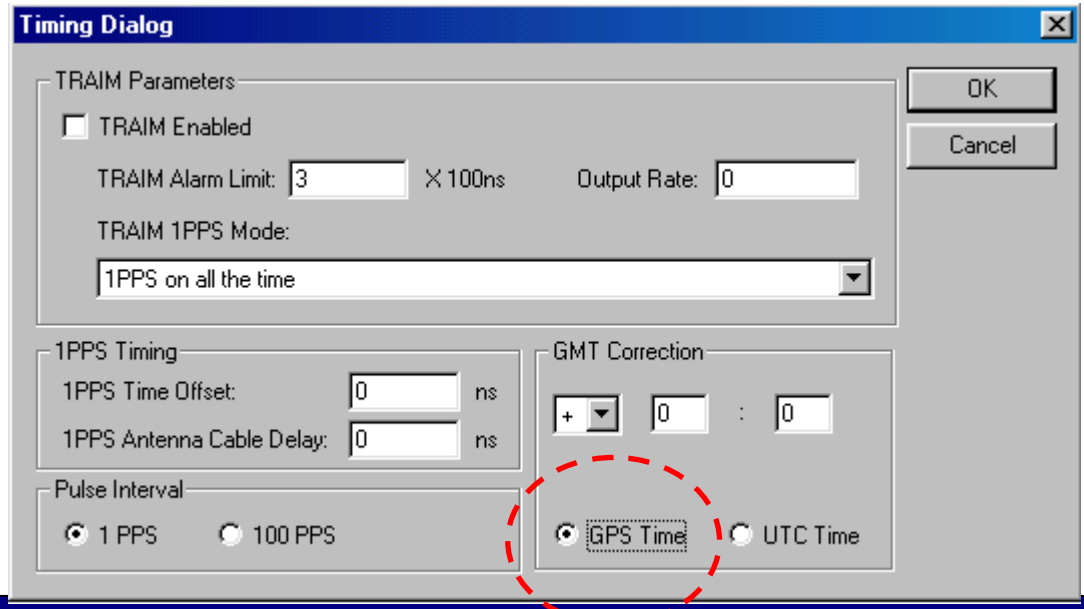
- The leap-second event (artificial injection of a second in a device not adapted for a second named « 60 ») provokes system interruptions, affecting:
- Synchronization of networks
  - Communications
  - NTP (network time protocole)
  - Computers
- Satellite synchronization
  - GNSS times
- Space operations
  - Vehicles launching
- Air traffic control, airport operations
- Time dissemination in general

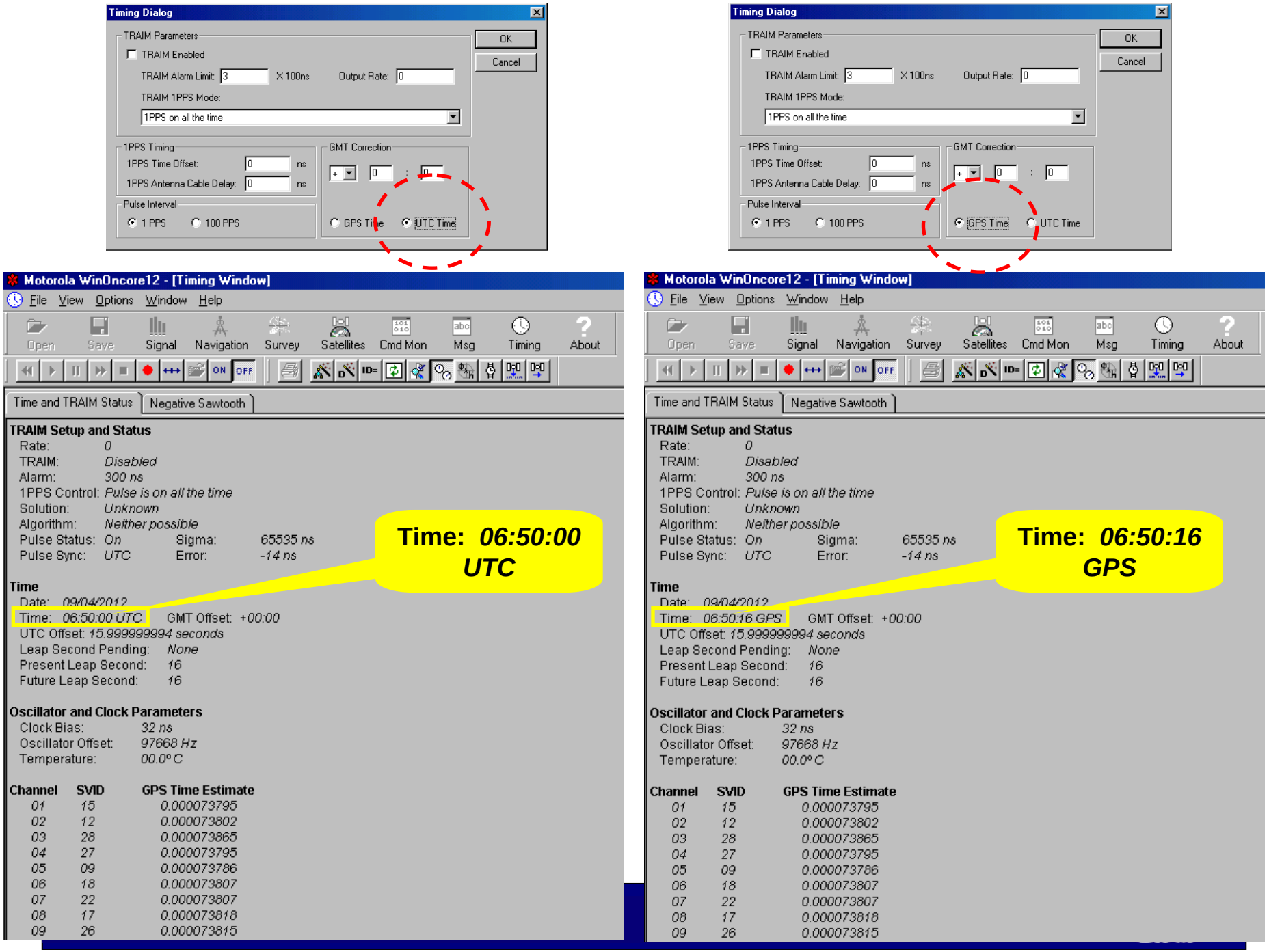
Typical problems and ambigüities arising from the LS

Timescales differing by seconds
http://leapsecond.com/java/gpsclock.htm

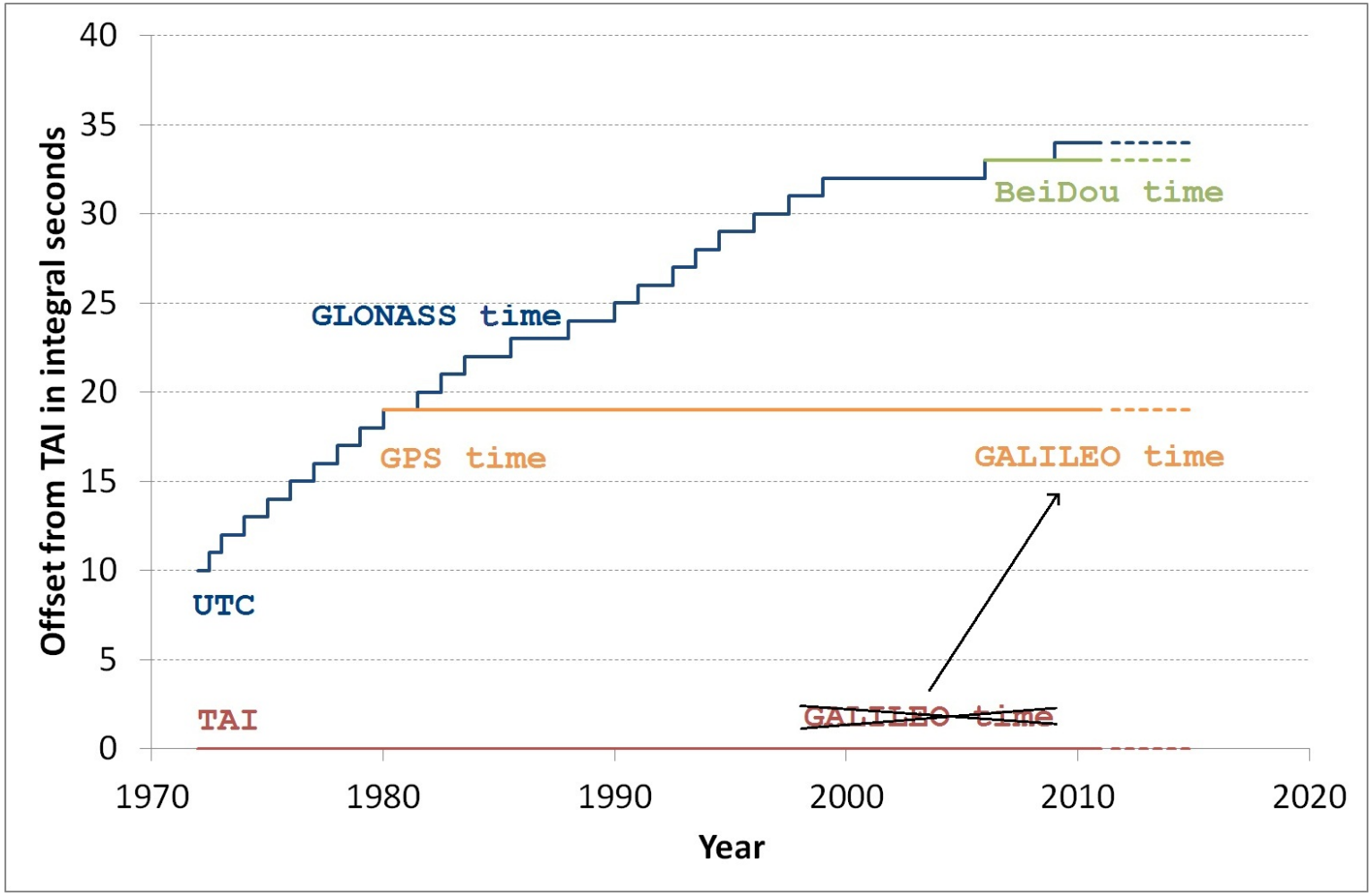
- Change of day problem
  - Some systems have time tagging on different timescales for different services;
  - At the leap second occurrence the change of day is not simultaneous for the timescales;
  - Happens in some GNSS, when the GNSS time and UTC are used.
- Change of week problem
  - Analogous to the change of day;
  - Dating in weeks is typical of GNSS
- MJD counting
  - Measure of time intervals by the number of days of 86400 s elapsed between the extremes of the interval


Timing Dialog
TRAIM Parameters
TRAIM Enabled
TRAIM Alarm Limit: 3
X 100ns
Output Rate: 0
TRAIM 1PPS Mode:
1PPS on all the time
OK
Cancel
1PPS Timing
1PPS Time Offset: 0 ns
1PPS Antenna Cable Delay: 0 ns
GMT Correction
+ 0 : 0
Pulse Interval
1 PPS
100 PPS
GPS Time
UTC Time


Timing Dialog
TRAIM Parameters
TRAIM Enabled
TRAIM Alarm Limit: 3
X 100ns
Output Rate: 0
TRAIM 1PPS Mode:
1PPS on all the time
OK
Cancel
1PPS Timing
1PPS Time Offset: 0 ns
1PPS Antenna Cable Delay: 0 ns
GMT Correction
+ 0 : 0
Pulse Interval
1 PPS
100 PPS
GPS Time
UTC Time


Timing Dialog
TRAIM Parameters
TRAIM Enabled
TRAIM Alarm Limit: 3 X100ns
Output Rate: 0
TRAIM 1PPS Mode:
1PPS on all the time
OK
Cancel
1PPS Timing
1PPS Time Offset: 0 ns
1PPS Antenna Cable Delay: 0 ns
GMT Correction
+ 0 : 0
Pulse Interval
1 PPS
100 PPS
GPS Time
UTC Time
Motorola WinOncore12 - [Timing Window]
File View Options Window Help
Open Save Signal Navigation Survey Satellites Cmd Mon Msg Timing About
Time and TRAIM Status
Negative Sawtooth
TRAIM Setup and Status
Rate: 0
TRAIM: Disabled
Alarm: 300 ns
1PPS Control: Pulse is on all the time
Solution: Unknown
Algorithm: Neither possible
Pulse Status: On
Sigma: 65535 ns
Pulse Sync: UTC
Error: -14 ns
Time
Date: 09/04/2012
Time: 06:50:00 UTC
GMT Offset: +00:00
UTC Offset: 15.999999994 seconds
Leap Second Pending: None
Present Leap Second: 16
Future Leap Second: 16
Oscillator and Clock Parameters
Clock Bias: 32 ns
Oscillator Offset: 97668 Hz
Temperature: 00.0° C
Channel SVID GPS Time Estimate
01 15 0.000073795
02 12 0.000073802
03 28 0.000073865
04 27 0.000073795
05 09 0.000073786
06 18 0.000073807
07 22 0.000073807
08 17 0.000073818
09 26 0.000073815
Time: 06:50:00 UTC
Time: 06:50:16 GPS

Relationship between TAI, UTC and the GNSS times



Possible redefinition of UTC without leap seconds

*** Access to UT1 is required for many applications**

Questions for analysis:

- Is the UTC system with leap seconds **still necessary**?
- For which users UTC is **the only way** to approximate UT1?
- Which are the drawbacks of using the **IERS predictions of UT1-UTC** for accessing to UT1?
- [Decorrelation with the solar regime in human activities? (**does correlation really exist**?)]
- **Is the ITU the place for making recommendations on the definition of timescales?**
  - Authority for fixing rules and procedures for time and frequency signals emmission
  - The international metrology coordination system would be more appropriate