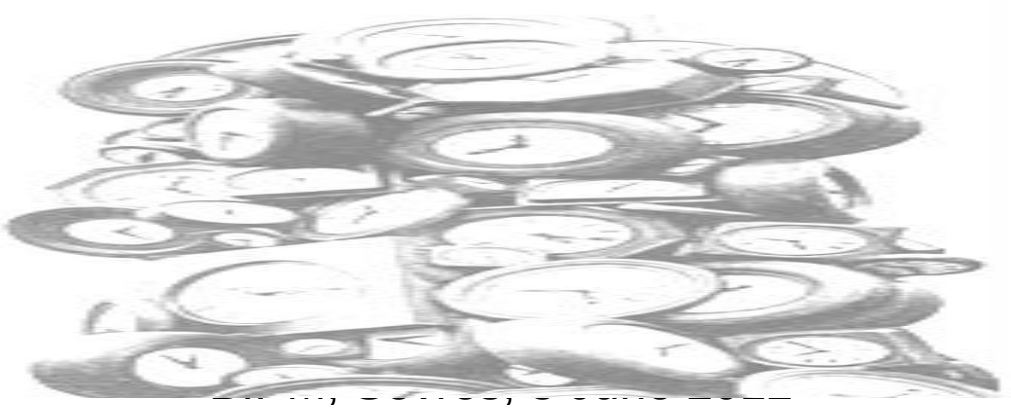
Report on the activities of the BIPM Time Department to the 19th Meeting of the CCTF

(formerly Time, Frequency and Gravimetry Department)

Elisa Felicitas Arias



Programme of work 2009-2012

- Establishment of TAI/UTC
- Time and frequency transfer studies
  - For improvement of TAI/UTC
  - For application in optical standards
- GNSS equipment calibration
  - GPS, GLONASS differential calibration for TAI/UTC
  - GNSS absolute calibration (research and development)
- Improvement of TAI accuracy
- Gravimetry (end of activity)
  - ICAG 2009
  - g for watt balance
- Coordination and international liaison
  - CCs, WGs, KCs
  - International organisations
- Services to other BIPM departments
  - Frequency reference

Staff of Time Department (2009-2012)

E. Felicitas Arias	director
Zhiheng Jiang	t.transfer, softw., gravimetry
Wlodzdimierz Lewandowski	t.transfer, int. liaison
Gianna Panfilo	algorithms, primary frequency standards
Gérard Petit	t.transfer, frequency standards
Lennart Robertsson	freq. standards, gravimetry, BIPM projects
Aurélie Armegnies	assistant, calculation, software
Hawaï Konaté	technical support
Laurent Tisserand	technical support
Amandine Proïa, PhD (11/2008-11/2011)	charact. absolute delays in GNSS, cooperation BIPM/CNES/OP
Leonid Vitushkin (retired on 30/11/2009)	gravimetry

Staff (permanent) in 2012: director, 5 physicists, 1 assistant, 2 technicians

Expenditure 2009-2012 — Total Time Department 240 K€

YEAR	TOTAL	MAJOR ITEMS	COST
2009	53	Cs Tube	38
		IT-PCs, servers, licences	10
2010	38	Frequency distribution	16
		IT, lab minor equipment	8
2011	43	Frequency distribution	6
		H-maser moving H source replacement	10
		IT-PCs, servers, licences	14
2012	40 60 (carry forward)	Septentrio receiver	16
		TTS-4 receiver	28
		IT-PCs, servers, licences	6

+ 48 k€ (2 GNSS receivers)

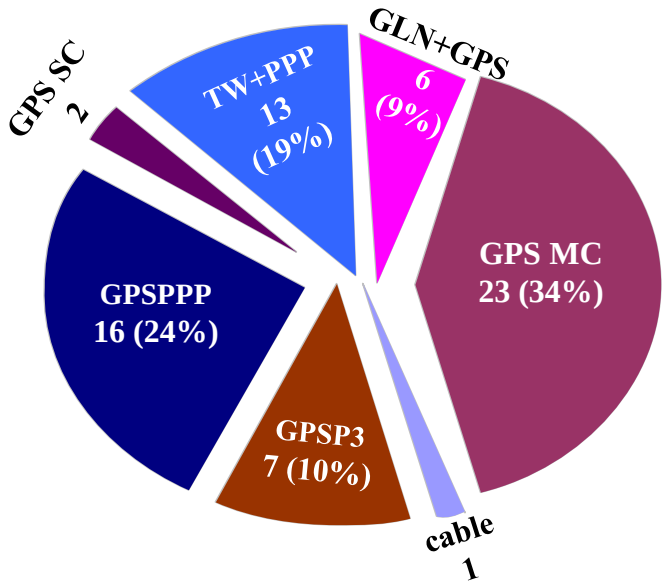
Major achievements 2009-2012

- Time transfer improvement and innovation
- New model for the clock frequency prediction
  - Stopping the drift of EAL
- Pilot experiment on a rapid UTC
- Contribution to the discussion of the future of UTC
- Conclusion of ICAG2009 and transfer to other laboratories

Time transfer - 1

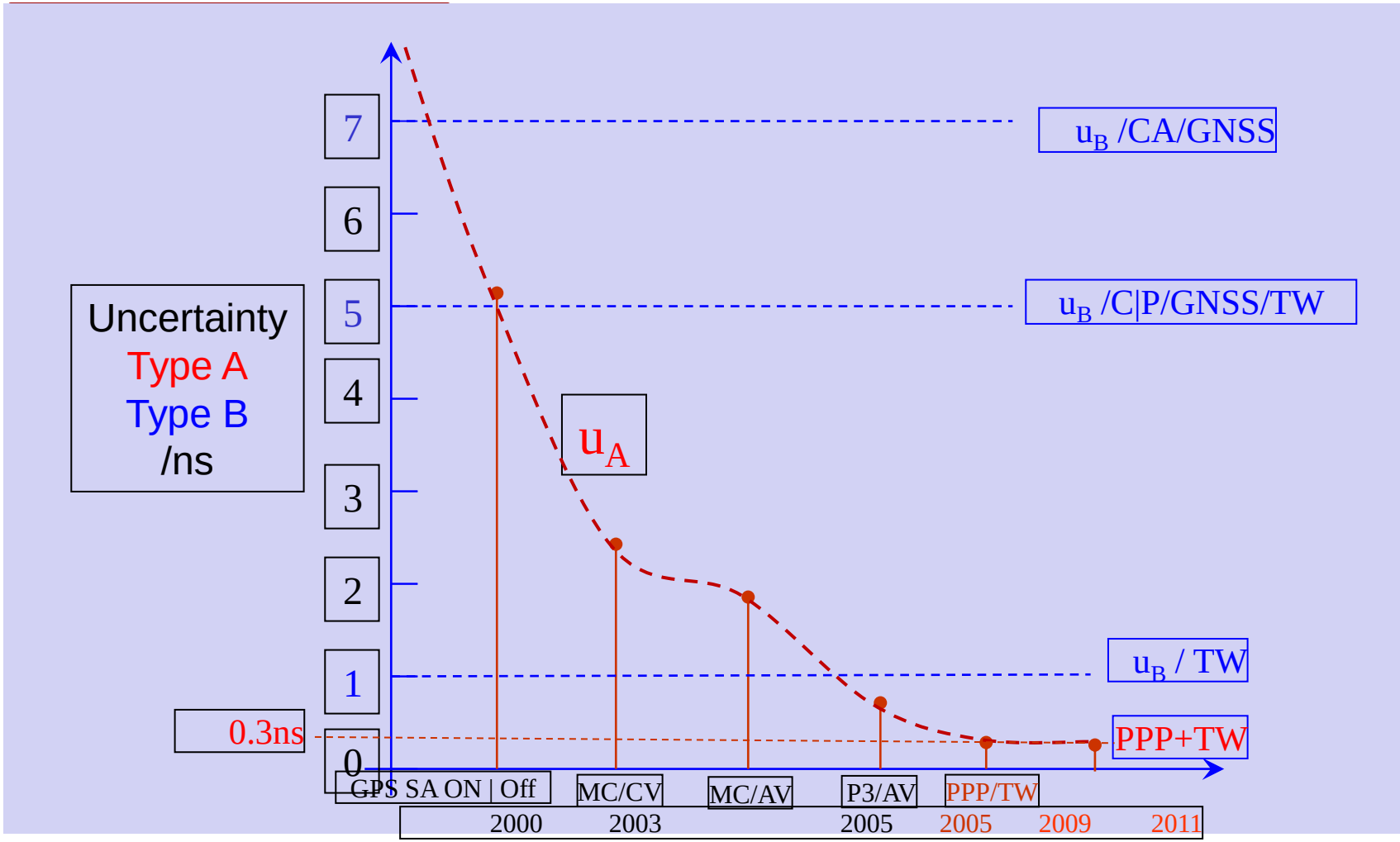
Time links combination
- GPS + GLN
- TW + PPP

Studies on
- Improving GLONASS
  - P3
  - biases



69 UTC labs

Time transfer - 2



Time and frequency transfer
Characterization of GNSS equipment delays

Differential calibration using traveling receivers:

- Ashtech Z12T
- Dicom GTR50
- TTS-3/4

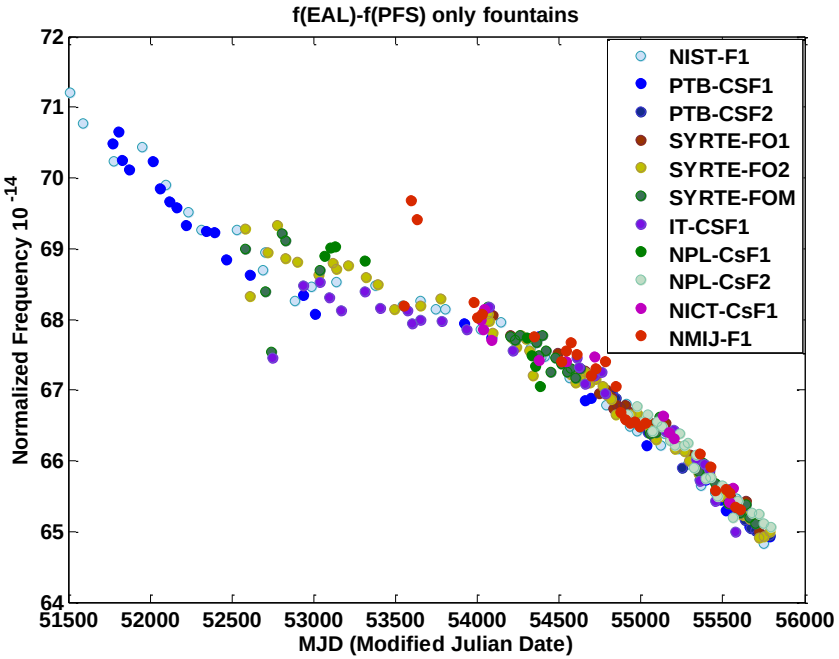
Differential calibration results

- all successful results are on a web page

PhD thesis on GPS absolute calibration (BIPM/CNES/OP)

- absolute calibration
- global analysis of all results
- successfully concluded October 2011

Improvements on the time scale algorithm
Clock frequency prediction



Drift of EAL wrt TAI
-1.3×10^{-17}/day
Difficult to correct with steering (until 07/2011)

[1] G. Panfilo and E.F. Arias. "Studies and possible improvements on EAL algorithm". *UFFC*, Vol. 57, No.1, January 2010, pp. 154-160.

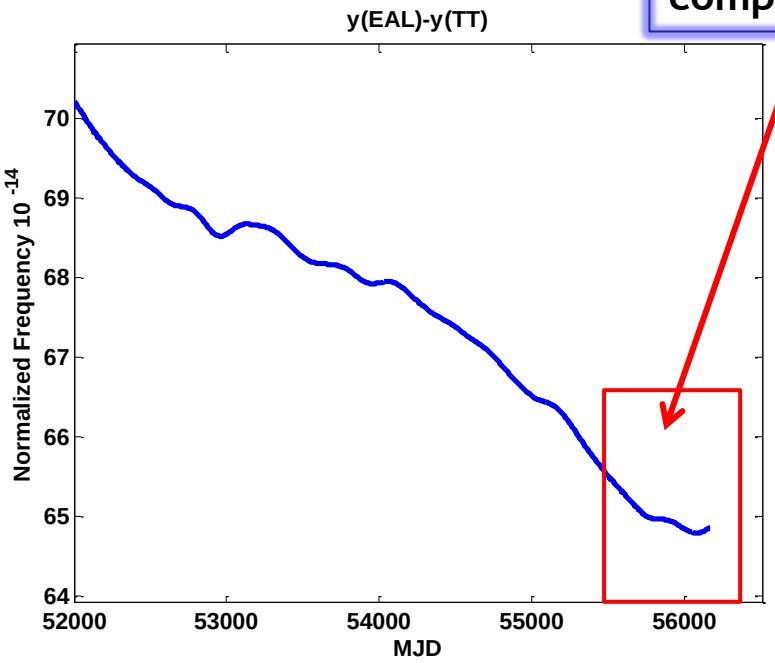
[2] G. Panfilo, A. Harmegnies, L. Tisserand. "A new prediction algorithm for the generation of International Atomic Time". *Metrologia*, 2012, 49, n°1, 49-56.

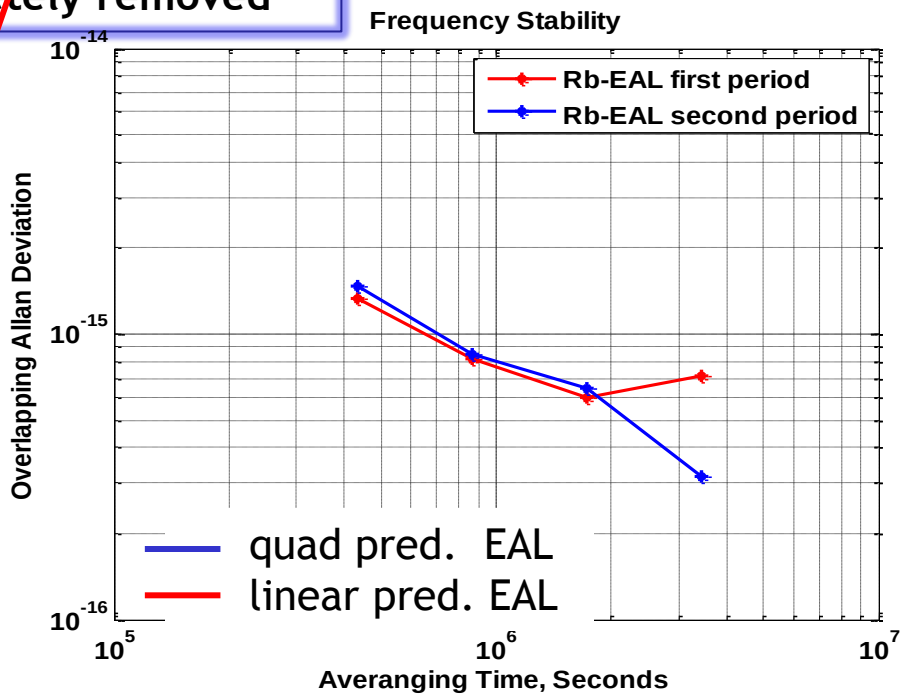
[3] G. Panfilo, A. Harmegnies, L. Tisserand. *Report to CCTF*. A new prediction algorithm for EAL.

[4] G. Panfilo, Invited lecture at EFTF 2012 (Göteborg, Sweden)

From August 2011 a quadratic prediction model for the clock frfequency is officially used to calculate UTC; the frequency drift is considered in the model for all kind of clocks.

The frequency drift affecting EAL is almost completely removed





Frequency of EAL wrt Terrestrial Time TT(BIPM)

Long term stability of EAL vs. USNO Rb fountain
MJD 55634-55984

On the frequency of publication of UTC

- 10-40 days delay 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(NTSC) →
      UTC(k)India → IRNSS
  - Better determination of GNSS times offsets, essential for interoperability and interchageability of navigation systems
- Discussions at the International Committee for GNSS (2010), 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, with the target of producing a report for the CCTF by September 2012; CCTF SPWG supports;
- Final decision on the routine production of UTCr will be taken on the last third of 2012;
- 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).

BIPM TIME DEPARTMENT DATABASE

Introduction

In response to an identified demand and **to centralize all information on time scales**, the BIPM Time Department is developping a web-based database to collect and share information with the time community.

1.1 Objectives

The purpose of this site is to connect to a database that contains **all the information necessary to the maintenance of UTC**. We propose to Time Laboratories a portal for user-friendly navigation that is at once a site of information and communication support to facilitate access to information related to contributing laboratories including their equipment (originally GNSS receivers, calibration dates, etc). This site will allow **to download documents and images**.

1.2 The target

This project address the members of **Time Department**, the **Time laboratories**, the **RMOs** and in general those with related activities in the field of t&f.

While the creation of the database has been the responsibility of one staff member (H. Konaté), its testing and evolution need the input from the Time Department and time laboratories through consultation, advice and contributions.

Contents of the database (expansion expected)

Laboratories [Identification, localisation, date of entry/departure, master clock, atomic time, primary or secondary frequency standard, RMO, Circular T, UTCr, contacts]

GNSS [Identification, description, serial number, cable type, calibration date, maker, status(official, additional,breakdown,stopped)]

User will be allowed to:

- Consult data, news and information provided by Time Department;
- Search by laboratory, by receiver and others;
- Explore the site;
- Download documents;
- Send feedback

Timetable for action

- Structure of the database (done)
- Partial data included (done)
- Testing and evaluation
- Validation
- Data completion
- Access to users (end 2012)
- Continuous updating

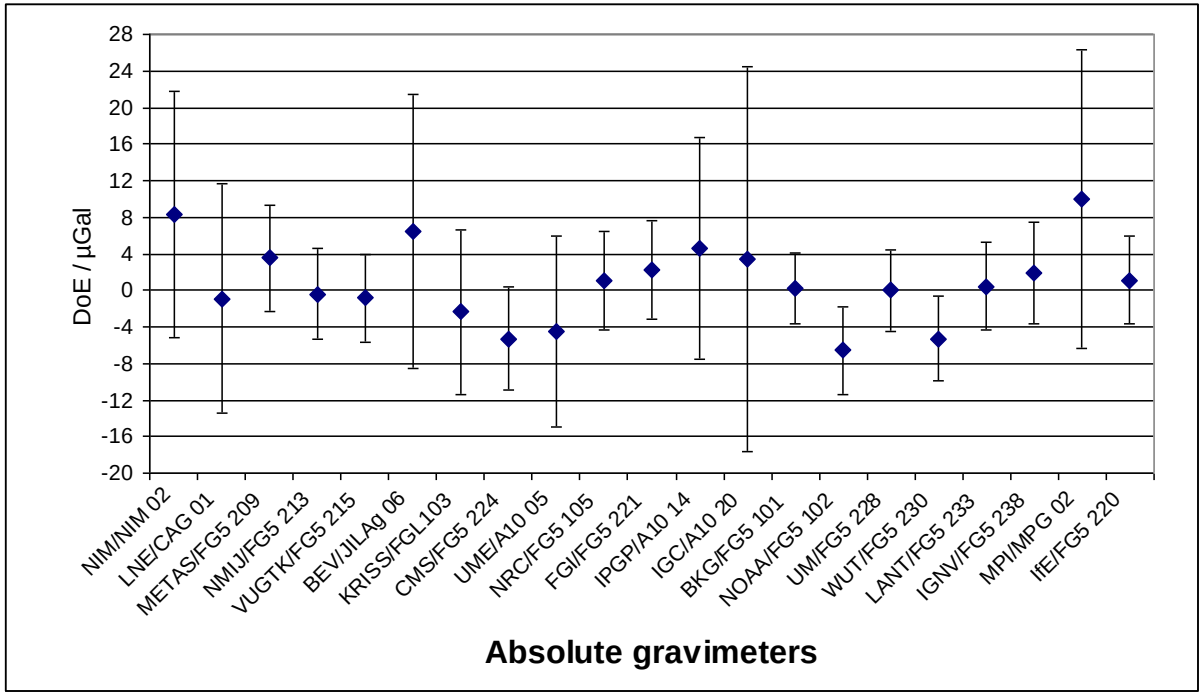
Future of UTC (leap second discussion)

- ITU-R
  - Active work at WP7A
  - BIPM representation at Radiocommunication Assembly 2012
  - Radiocommunication Bureau Seminar for RCC countries and Baltic States
  - ITU Seminar for Americas Region (20-21 Sept 2012)
- Dissemination of information
  - *Metrologia Special Issue* “Modern Time Scales”, August 2011
    14 articles; F. Arias, W. Lewandowski (eds.)
  - Royal Society Discussion Meeting, January 2012, London area
    Invited participants only; T. Quinn, F. Arias (organizers)
- Situation at present
  - RA2012 postponed the decision until WRC2015 (continuous scale), input from BIPM, CCTF, CIPM, CGPM, IAU, IAG, URSI

Gravimetry

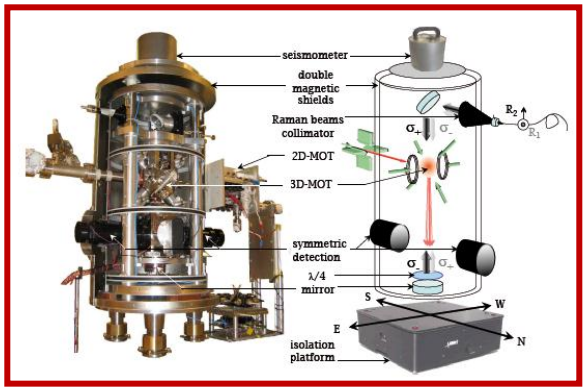
CCM.G-K1 : International Comparison of Absolute Gravimeters

Consultative Committee on Mass and Related Quantities (CCM)
Working Group on Gravimetry (WGG)
IAG Sub-Commission 2.1 “Gravimetry and Gravity networks”
Study Group 2.1.1 on Comparison of Absolute Gravimeters (SGCAG)



Gravimetry
Results of ICAG-2009

- ICAG 2009 closes a ~30 year series of comparisons at the BIPM
- For the first time it had the form of a KC + PS
- Long list of publications
  - Final report
  - Supporting relative campaign
  - Leveling at the BIPM
  - Self-attraction-effect and correction
  - Scientific results of ICAG2009
  - Gravimetry at the BIPM for the watt balance
- ICAG2013 in Luxemburg, METAS will pilot
- Proposals for future ICAGs come from
  - NIM (China)
  - VNIIM (Russian Federation)
  - LNE (France)



Programme of work 2013-2015

- Continues with the activities in 2009-2012 *
- Assuring the frequency accuracy and stability of UTC
  - Multi-GNNS-system time links
  - Novel methods of time comparison
  - GNNS equipment delays, support from RMOs, NMIs
  - Revised clock weghting in EAL
- Traceability and access to UTC
  - CCTF.UTC-K (values of [UTC-UTC(k)] monthly, BIPM Circular T)
  - Rapid UTC (values of [UTCr-UTC(k)] weekly
- Highly accurate t&f transfer
  - Optical clock comparison
  - Use of SRS for the accuracy of TAI

Programme of work 2013-2015 (cont.)

- Coordination activities
  - ITU-R, also IAU, URSI and IUGG
    - Discussion of leap second since 2000
    - Preparation for WRC2015, continuous timescale
    - Strategy for changing the responsibility for the definition of UTC from ITU to international metrology coordination
  - ICG
    - Coordination between GNSS service providers and time users
    - Standards for GNSS references
    - Promoting actions for enhancing the interoperability and interchangeability of systems, leap second is included

Expenditure / Staff 2013-2015

YEAR	TOTAL	MAJOR ITEMS	COST
2013	82 (45)	GNSS receivers (2)	30
2014	119 (82)	New Cs standard	70
2015	80 (43)	GNSS receiver (1)	35

Staff (DD included)

- 2013: 9; 1 post-doc co-financed with CNES (GNSS)
- 2014: 8 (1retirement); 1 post-doc co-financed with CNES (GNSS)
- 2015: 8; 1 post-doc co-financed (accurate t&f transfer)