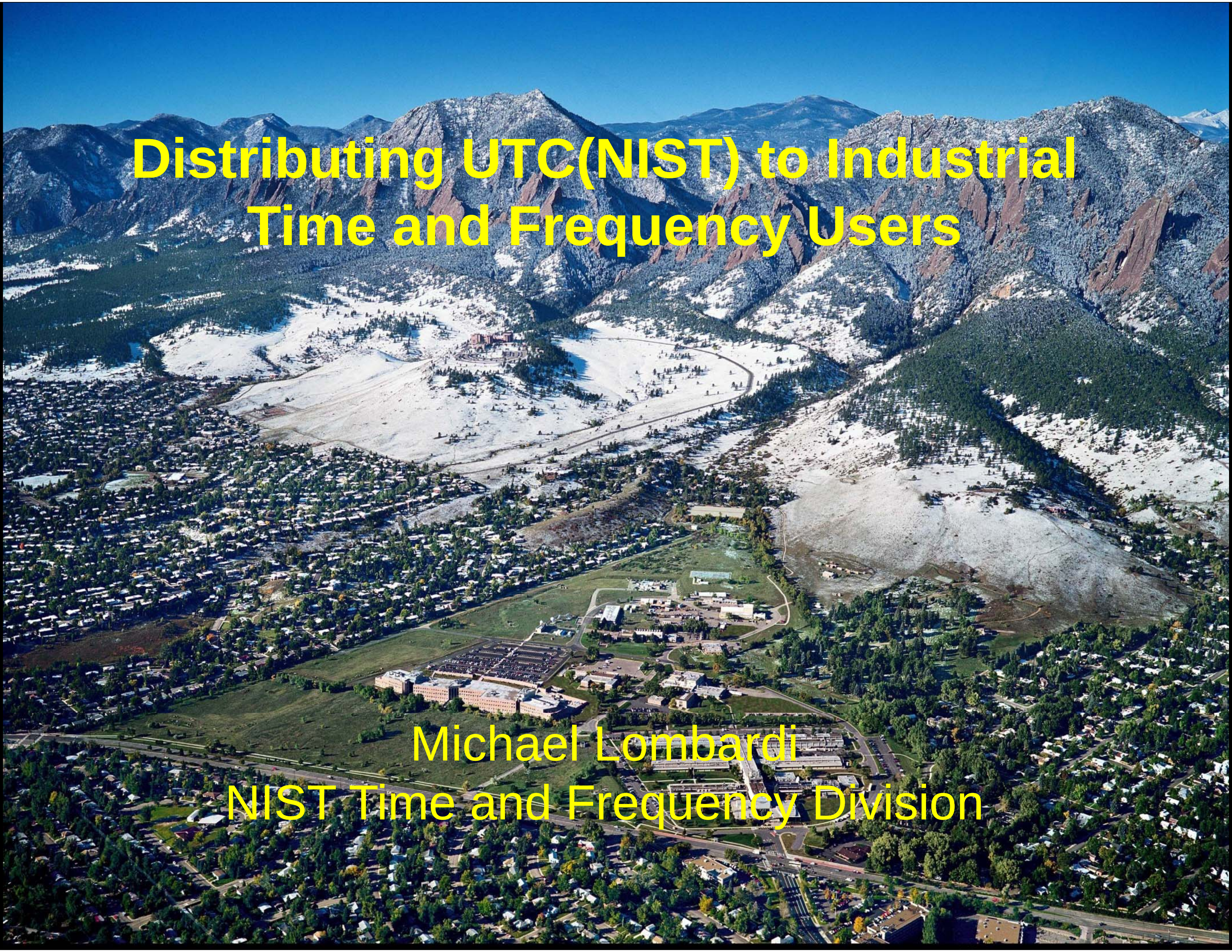
Distributing UTC(NIST) to Industrial Time and Frequency Users



Michael Lombardi
NIST Time and Frequency Division

Outline

Introduction

The Generation of UTC(NIST)

International Comparisons

Remote Calibration Services

Radio Broadcasts

Computer Time Signals

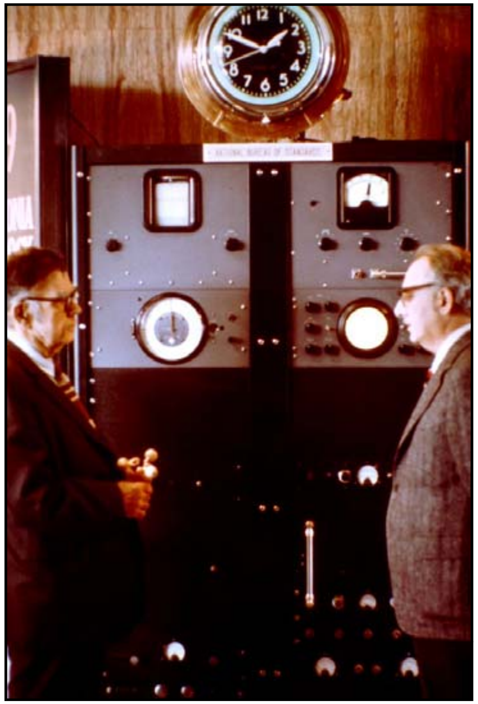
Introduction

NIST maintains a Coordinated Universal Time scale, called UTC(NIST), that it distributes to industrial time users through a wide range of activities.

These activities include remote calibrations at state-of-the-art accuracy levels and free broadcast services that synchronize many millions of clocks every day.

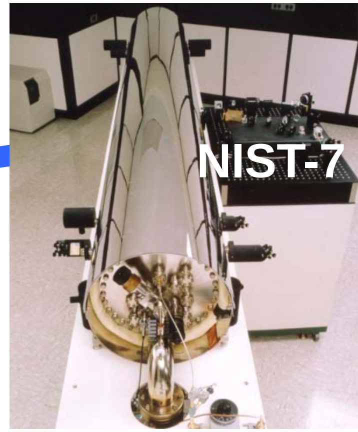
NIST’s involvement with atomic timekeeping spans more than 60 years

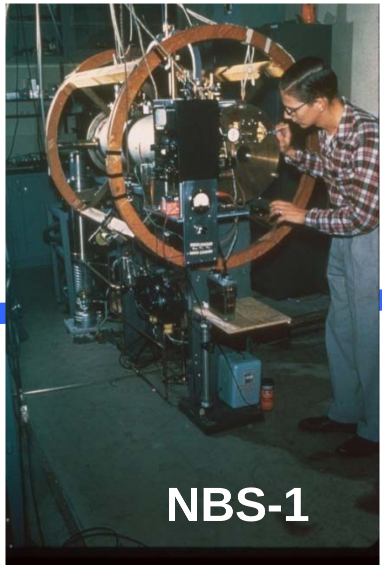
The world’s first atomic clock was built at NIST (NBS) in 1949



- Based on the ammonia molecule, it was unveiled in January 1949.
- Well publicized, but it never worked well enough to be used as a standard or reference. Its best reported uncertainty was about 2×10^{-8}, which was not accurate enough to replace the quartz oscillators then used as the national frequency standard. But it provided a glimpse of what the future would bring ……

Seven Cesium Beam Primary Frequency Standards were built at NBS/NIST





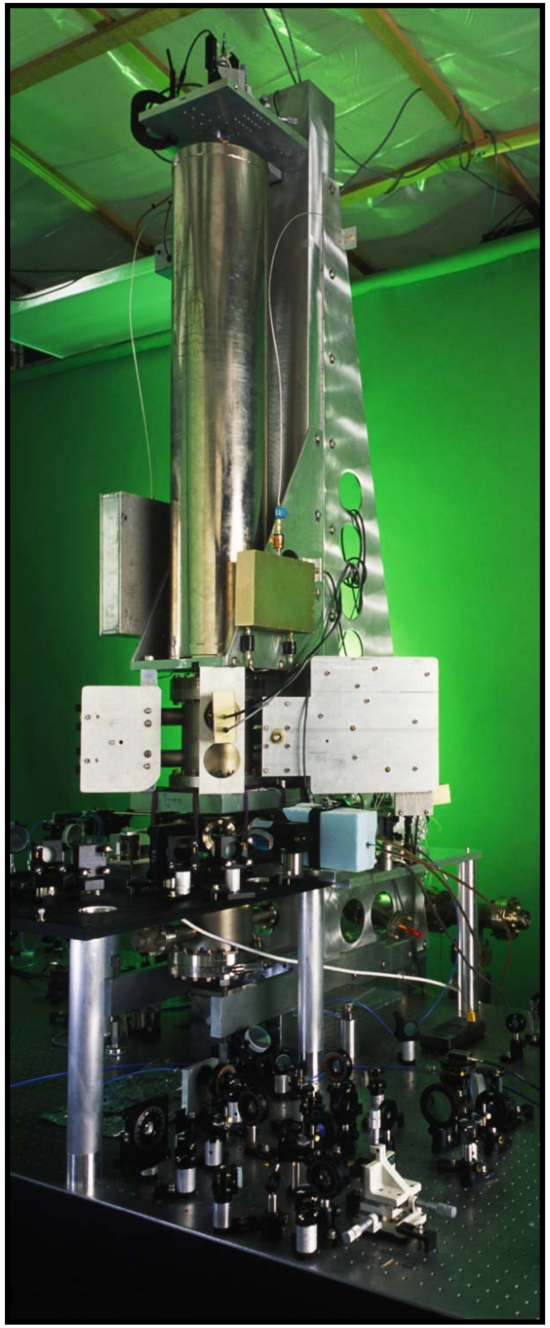
Cesium Primary Frequency Standards Designed at NBS/NIST

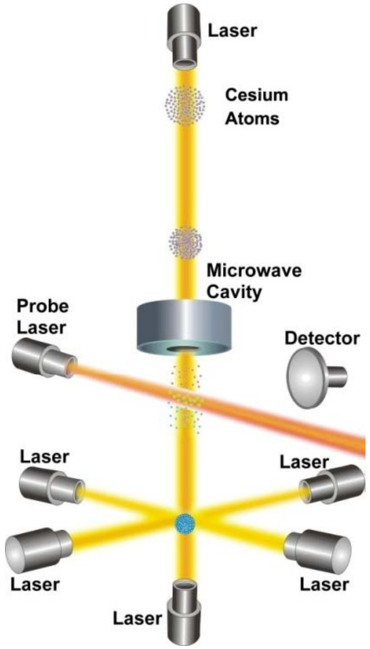
Cesium Frequency Standard	Lifetime as Experimental or Operational Device	Years of Operation as NPFS	Linewidth	Length of Ramsey Cavity	Best Published Accuracy
NBS–1	1952–1962	1959–1960	300 Hz	55 cm	1×10^{-11} [44]
NBS–2	1959–1965	1960–1963	110 Hz	164 cm	8×10^{-12} [44]
NBS–3	1959–1970	1963–1970	48 Hz	366 cm	5×10^{-13} [45]
NBS–4	1965–1990s	NA *	130 Hz	52.4 cm	3×10^{-13} [46]
NBS–5	1966–1974	1972–1974	45 Hz	374 cm	2×10^{-13} [46]
NBS–6	1974–1993	1975–1993	26 Hz	374 cm	8×10^{-14} [48]
NIST–7	1988–2001	1993–1998	62 Hz	155 cm	5×10^{-15} [51]

Table 1. Summary of NIST cesium beam primary frequency standards, including the best published accuracy number.

* NA indicates that NBS-4 was used in conjunction with NBS-5 and NBS-6, but was never officially designated as a standalone NPFS.

NIST-F1 Atomic Fountain Clock





NIST-F1 laser-cooled fountain standard "atomic clock"

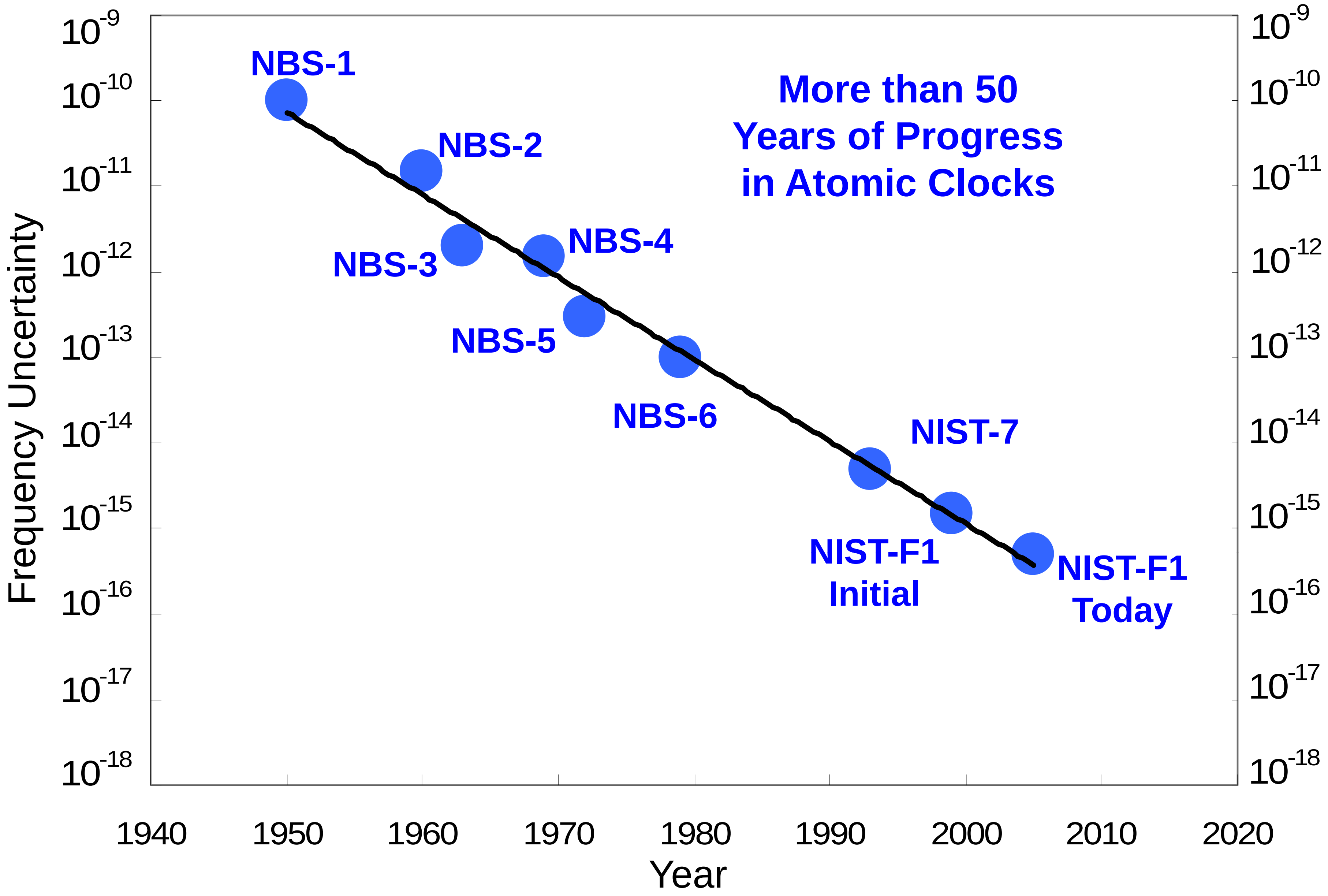
A cesium fountain frequency standard. The SI second is defined as the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the ^{133}Cs atom.

Current accuracy (uncertainty):

- 3×10^{-16}
- 26 trillionths of a second per day.
- 1 second in 105 million years.

Equivalent to measuring distance from earth to sun (1.5 x 10^{11} m or 93 million miles) to uncertainty of about 45 μm (less than thickness of human hair).

Improvements in Primary Frequency Standards at NBS/NIST



UTC(NIST) Time Scale

The NIST Time Scale consists of an ensemble of commercial clocks, currently six hydrogen masers and four cesium beam standards.

The weighted average of these clocks generates a continuous, real-time signal from a high resolution frequency synthesizer that is locked to a hydrogen maser. Both 5 MHz (frequency) and 1 pps (time) signals are generated.

The clock ensemble is periodically calibrated using the NIST-F1 primary standard.

UTC(NIST) is a real-time realization of Coordinated Universal Time (UTC). The true UTC is a post processed time scale that is not available in real time. The BIPM's *Circular-T* document shows the difference between UTC(NIST) and UTC at five-day intervals.

BIPM Circular T (www.bipm.org)

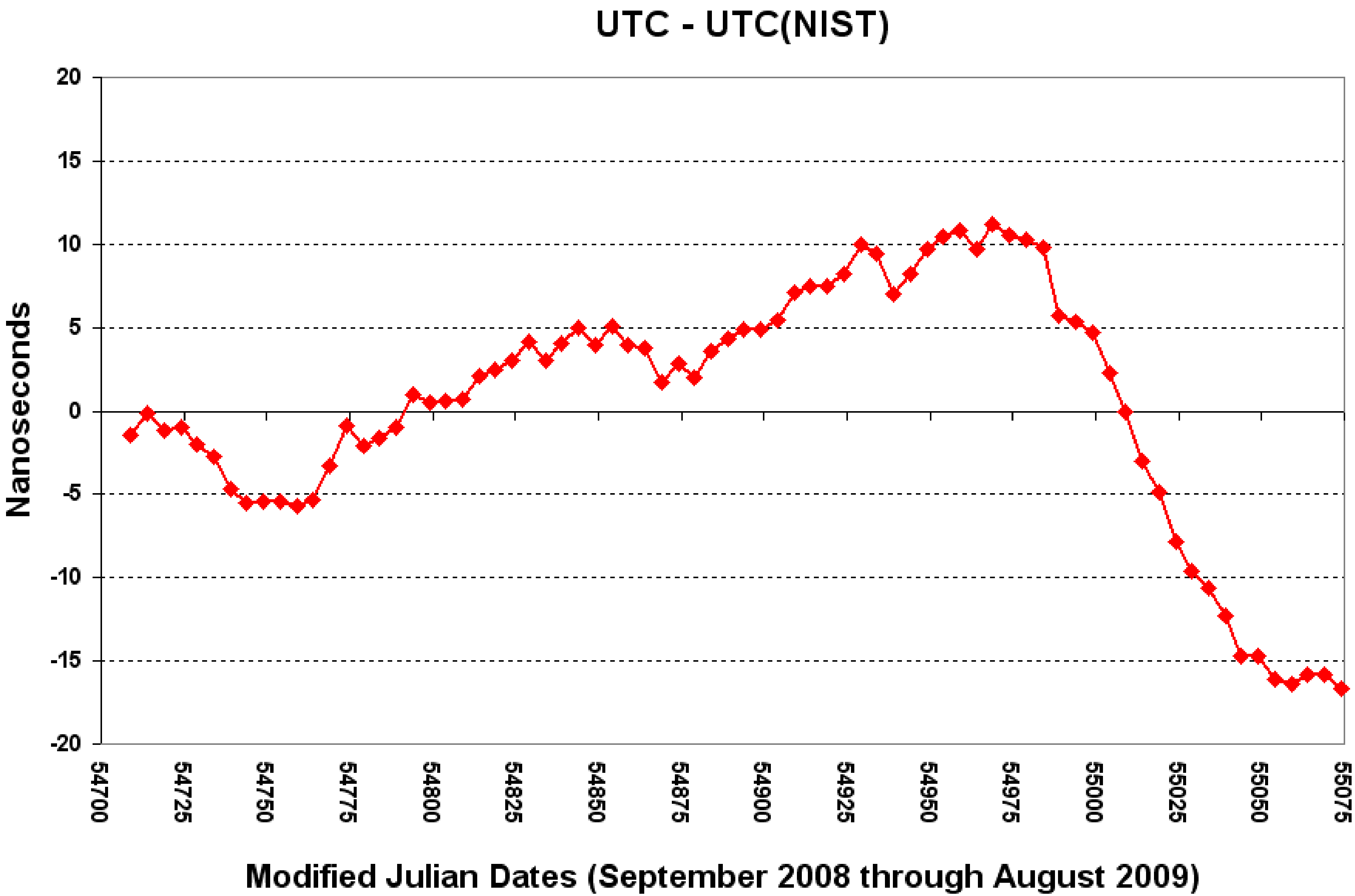
CIRCULAR T 241 ISSN 1143-1393
2008 FEBRUARY 13, 17h UTC

BUREAU INTERNATIONAL DES POIDS ET MESURES
ORGANISATION INTERGOUVERNEMENTALE DE LA CONVENTION DU METRE
PAVILLON DE BRETEUIL F-92312 SEVRES CEDEX TEL. +33 1 45 07 70 70 FAX. +33 1 45 34 20 21 tai@bipm.org

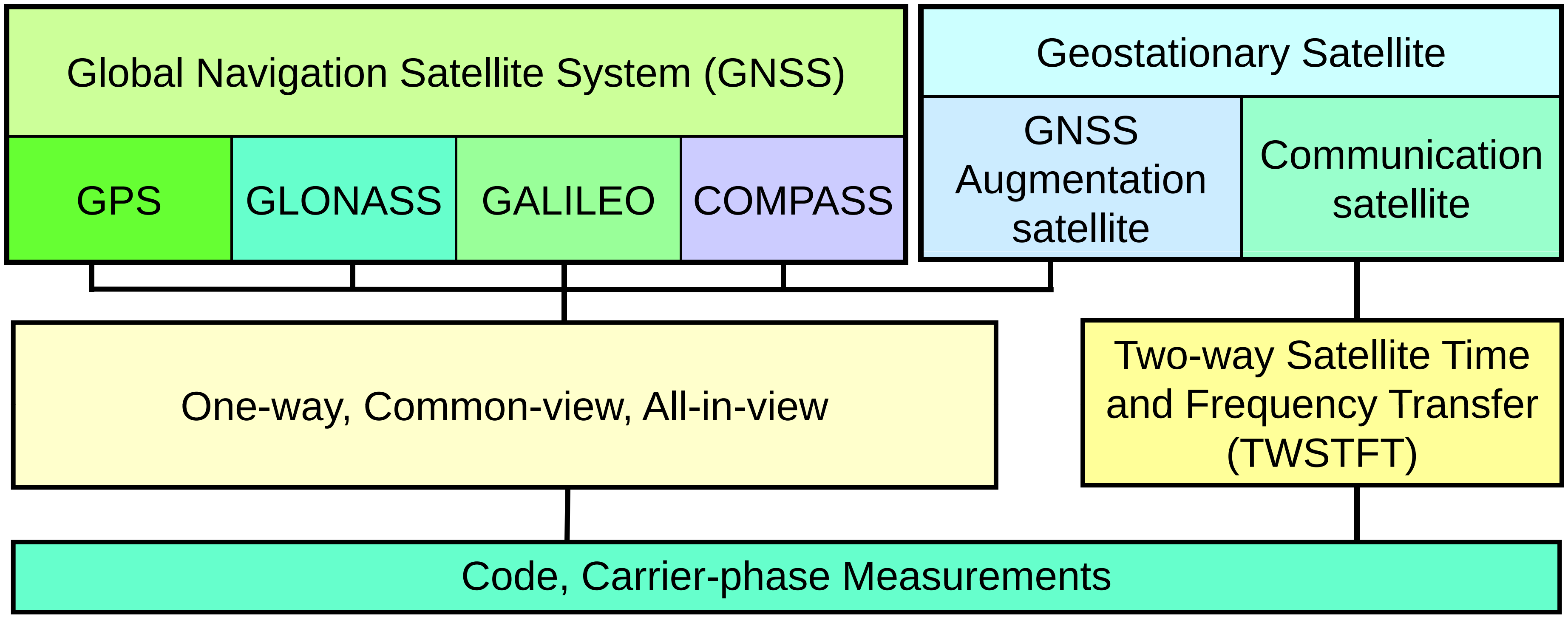
1 - Coordinated Universal Time UTC and its local realizations UTC(k). Computed values of [UTC-UTC(k)] and uncertainties valid for the period of this Circular. From 2006 January 1, 0h UTC, TAI-UTC = 33 s.

Date 2007/08 0h UTC	DEC 30	JAN 4	JAN 9	JAN 14	JAN 19	JAN 24	JAN 29	Uncertainty/ns			Notes
MJD	54464	54469	54474	54479	54484	54489	54494	uA	uB	u	
Laboratory k				[UTC-UTC(k)]/ns							
AOS (Borowiec)	-8.7	-4.8	-14.9	7.3	-9.3	0.4	1.5	1.5	5.1	5.4	(1)
APL (Laurel)	-28.0	-18.2	-0.9	-3.6	4.0	7.0	6.9	1.5	5.1	5.3	
AUS (Sydney)	129.0	124.8	126.1	129.9	130.4	121.9	106.9	1.5	5.1	5.3	
BEV (Wien)	-19.3	-23.5	-25.8	-32.6	-46.0	-61.4	-60.7	1.5	5.1	5.3	
BIM (Sofiya)	-6008.1	-6014.7	-6014.8	-6005.6	-6004.5	-6007.4	-6011.1	2.0	7.1	7.4	
BIRM (Beijing)	-4357.6	-	-	-	-	-	-	-	-	-	
BY (Minsk)	233.9	226.5	222.3	212.7	205.5	216.8	213.9	7.0	20.0	21.2	
CAO (Cagliari)	-1471.5	-1484.9	-1490.8	-1499.8	-1533.3	-1552.2	-1552.9	1.5	7.1	7.2	
CH (Bern)	-18.7	-27.2	-17.2	-9.3	-0.2	1.6	-1.6	0.5	1.5	1.6	
CNM (Queretaro)	23.9	16.0	3.1	-9.4	-19.9	-22.8	-32.4	5.0	5.1	7.1	
CNMP (Panama)	73.7	79.2	90.7	100.5	94.6	88.2	85.0	3.0	5.1	6.0	
DLR (Oberpfaffenhofen)	-56.4	-57.0	-51.2	-52.6	-59.8	-49.1	-43.1	0.7	5.1	5.2	
DTAG (Frankfurt/M)	213.5	200.2	194.6	198.4	196.6	212.2	213.5	4.0	10.0	10.8	
EIM (Thessaloniki)	-	-	-8.7	-5.7	-5.2	-1.5	2.5	3.0	20.0	20.3	
HKO (Hong Kong)	91.2	88.0	79.7	76.0	71.4	77.8	76.4	2.5	5.1	5.7	
IFAG (Wettzell)	-453.3	-439.4	-435.9	-432.1	-421.6	-411.5	-412.6	0.7	5.1	5.1	
IGMA (Buenos Aires)	-	-	-	-	-	-	-	-	-	-	
INPL (Jerusalem)	-	-	-	-	-	-	-	-	-	-	
IT (Torino)	-3.0	-4.8	-4.0	-4.5	-2.4	-0.8	-0.4	0.5	1.5	1.6	
JATC (Lintong)	-8.2	-5.2	-7.2	-8.0	-9.9	-7.8	-6.2	1.4	4.9	5.1	
JV (Kjeller)	5135.3	5251.3	5392.5	5524.1	5670.1	5787.1	5893.8	5.0	20.0	20.6	
KRIS (Daejeon)	-12.7	-8.5	-6.3	-5.7	-11.7	-2.9	-14.8	0.7	5.1	5.1	
LDS (Leeds)	4314.8	-	-	-	-	-	-	-	-	-	
LT (Vilnius)	230.7	222.5	239.3	229.7	223.8	224.4	229.8	1.5	5.1	5.3	
LV (Riga)	466.0	521.8	581.7	643.5	707.6	766.5	827.9	2.0	7.1	7.4	
MIKE (Espoo)	-106.9	-121.0	-112.6	-108.7	-114.2	-104.4	-120.3	4.9	19.8	20.4	
MKEH (Budapest)	-	-	-240.2	-427.6	-603.3	-782.2	-982.5	2.5	20.0	20.2	
MSL (Lower Hutt)	-250.0	-269.5	-283.7	-260.9	-213.6	-164.9	-124.0	1.0	20.0	20.0	
NAO (Mizusawa)	-67.2	-62.7	-51.9	-38.5	-24.5	-2.5	10.2	3.0	19.9	20.1	
NICT (Tokyo)	-28.4	-27.4	-26.1	-27.0	-26.6	-27.4	-29.3	0.5	4.5	4.6	

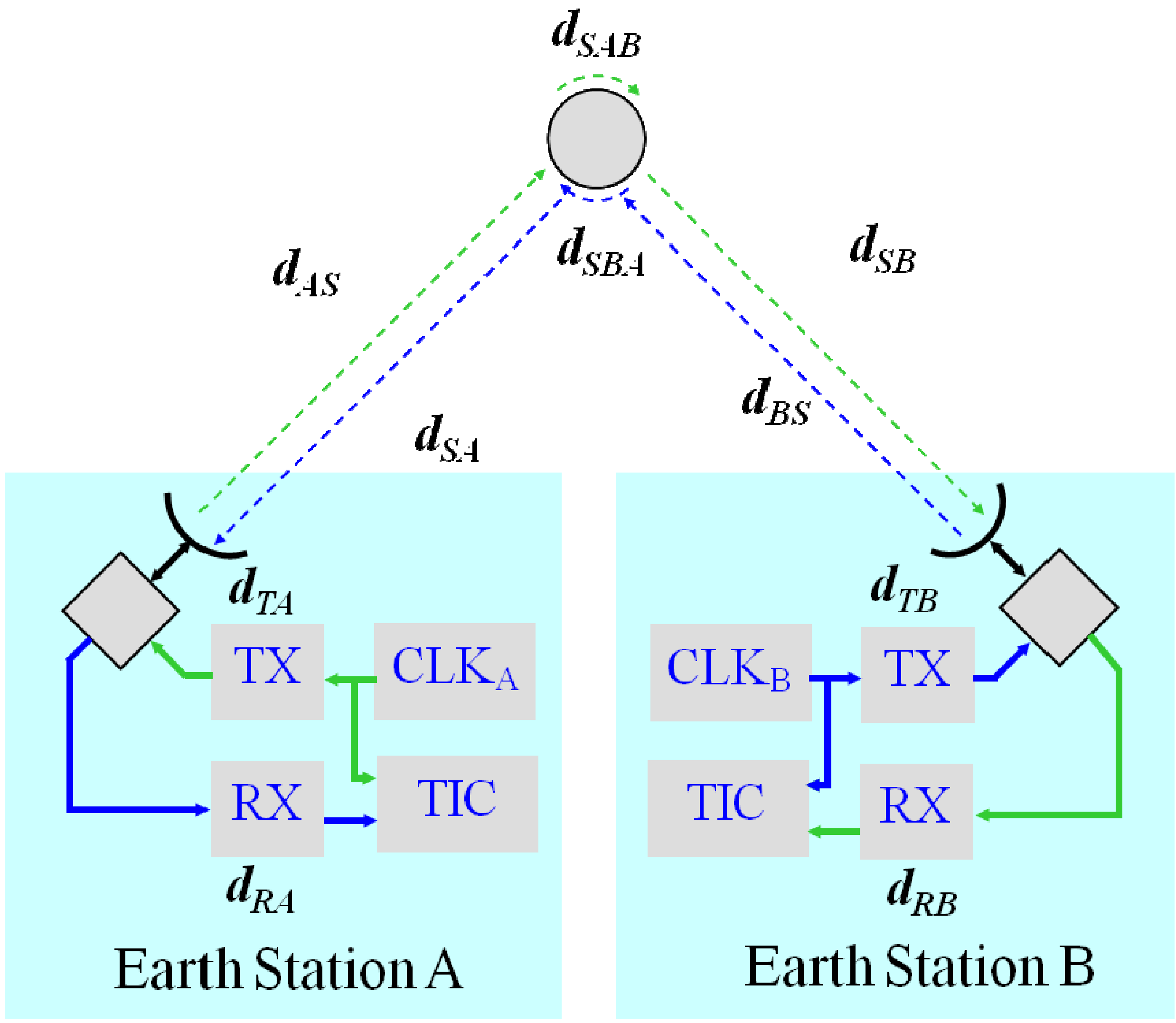
Date 2007/08 0h UTC	DEC 30	JAN 4	JAN 9	JAN 14	JAN 19	JAN 24	JAN 29	Uncertainty/ns			Notes
MJD	54464	54469	54474	54479	54484	54489	54494	uA	uB	u	
Laboratory k				[UTC-UTC(k)]/ns							
NIM (Beijing)	[illegible]	-52.2	-49.7	-52.3	-55.0	[illegible]	[illegible]	[illegible]	19.7	19.8	
NIM[illegible] ([illegible]arest)	-1111.3	-1112.9	-1113.0	-1119.6	-1148.2	-1156.0	-1134.6	2.0	20.0	[illegible]	
NIMT (Bangkok)	-628.5	-657.0	-679.3	-706.8	-720.5	-757.5	-780.3	1.0	20.0	20.1	
NIS (Cairo)	28.2	19.8	14.5	13.9	17.5	26.6	33.0	2.5	7.1	7.5	
NIST (Boulder)	0.9	1.3	0.6	-0.9	-1.9	-1.2	-2.3	0.5	4.9	4.9	
NMIJ (Tsukuba)	20.6	22.9	21.6	18.4	16.7	15.6	13.3	0.7	5.1	5.1	
NML[illegible] ([illegible]ang)	-241.1	-238.4	-224.8	-227.0	-221.6	-214.4	-215.4	2.0	20.0	[illegible]	
NPL (Teddington)	[illegible]	8.2	-39.2	13.1	15.1	[illegible]	[illegible]	[illegible]	5.1	5.4	(2)
NPLI (New-Delhi)	6.4	-4.0	-1.5	6.1	9.1	14.8	14.7	2.5	7.1	7.5	
NRC (Ottawa)	-69.4	-70.7	-70.9	-67.7	-64.1	-54.9	-59.5	3.0	5.1	5.9	
NRL (Washington DC)	-	72.9	84.0	94.5	106.2	119.0	129.8	0.7	5.1	5.2	(3)
NTSC (Lintong)	23.4	17.5	20.3	13.5	7.5	9.0	12.4	1.4	4.8	5.0	


UTC - UTC(NIST)
Nanoseconds
20
15
10
5
0
-5
-10
-15
-20
54700
54725
54750
54775
54800
54825
54850
54875
54900
54925
54950
54975
55000
55025
55050
55075
Modified Julian Dates (September 2008 through August 2009)

UTC(NIST) is compared internationally using many methods of satellite-based time and frequency transfer



Two-Way Satellite Time and Frequency Transfer



- The primary technique used by NIST to contribute to UTC.
- NIST is involved in regular comparison with 12 European NMIs.
- NIST earth station uses a 3.7 m dish, and K_U band radio equipment.

Common-View GPS Measurements

Common-view GPS is the easiest, most practical, and cost effective way to compare two clocks at remote locations.

The common-view method involves a GPS satellite (S), and two receiving sites (A and B). Each site has a GPS receiver, a local time standard, and a time interval counter.

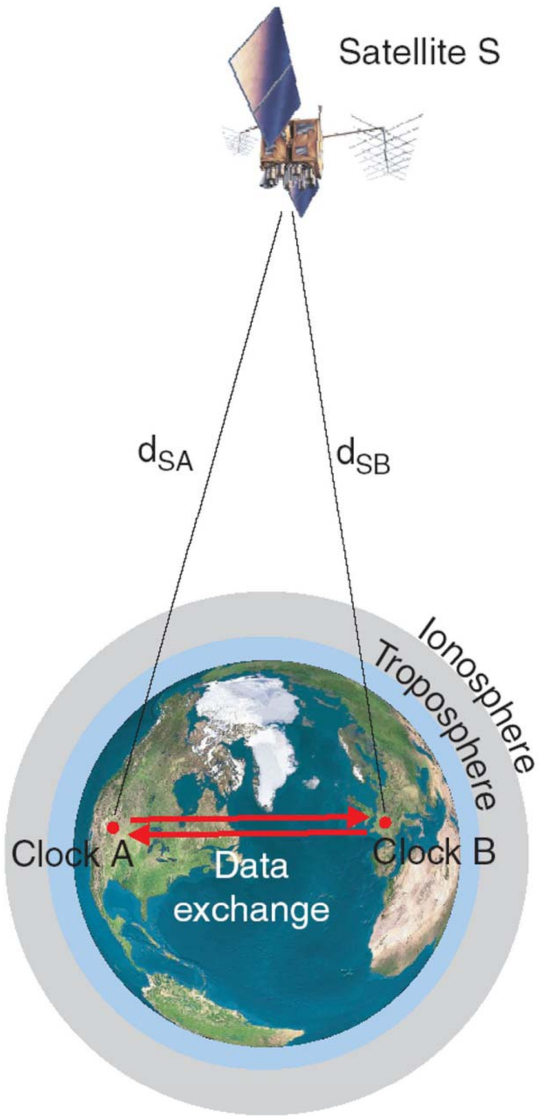
Measurements are made at sites A and B that compare the received GPS signal to the local time standard.

Two data sets are recorded (one at each site):

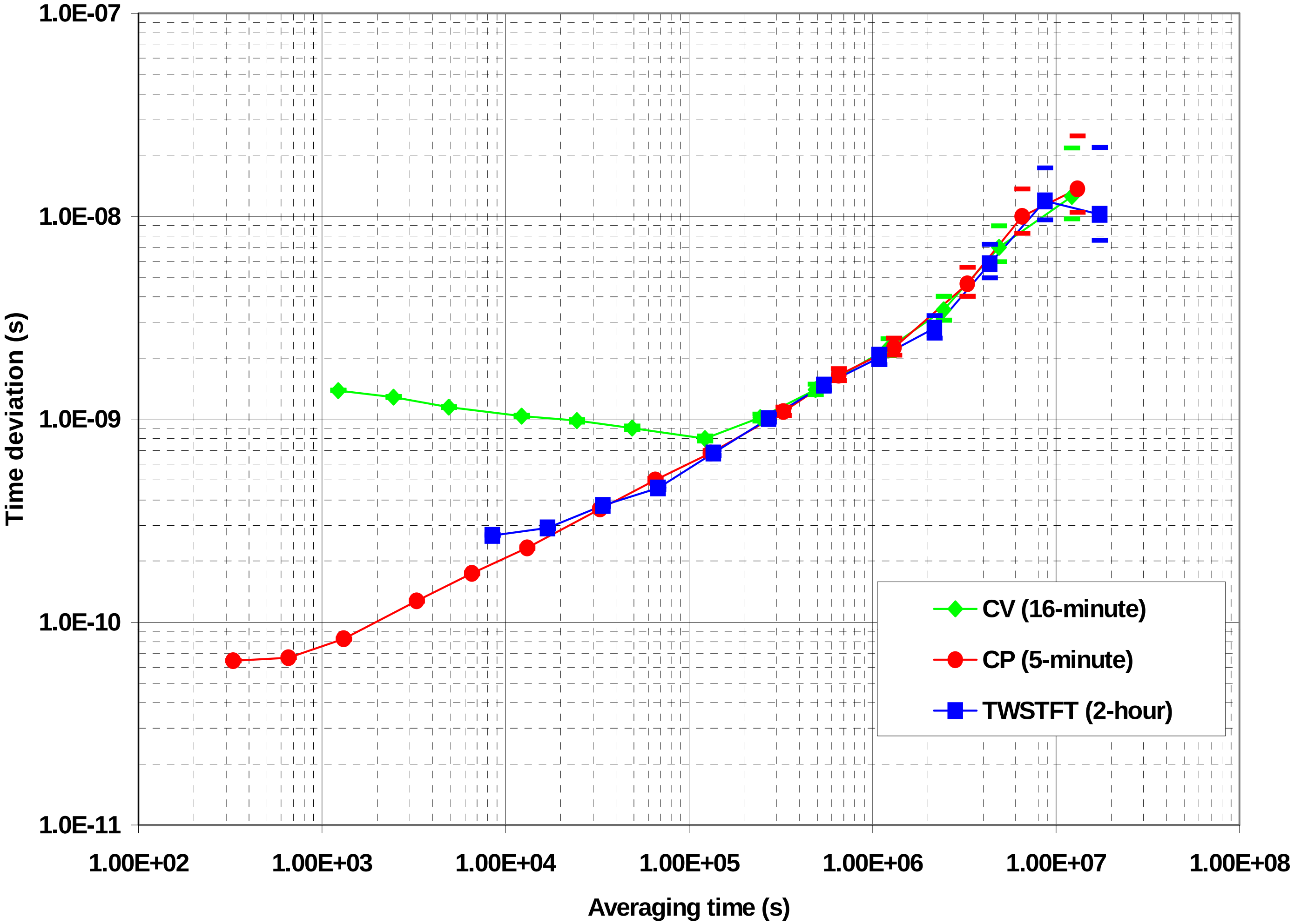
- Clock A - S
- Clock B - S

The two data sets are then exchanged and subtracted from each other to find the difference between Clocks A and B. Delays that are common to both paths (d_{SA} and d_{SB}) cancel, but delays that are not common to both paths contribute uncertainty to the measurement. The equation for the measurement is:

$$(\text{Clock A} - S) - (\text{Clock B} - S) = (\text{Clock A} - \text{Clock B}) + (d_{SA} - d_{SB})$$



Comparison of GPS and TWSTFT Time Transfer



UTC(NIST)-UTC(PTB)

- Baseline: 7530km
- 854 days (MJD 53519 – 54372)
- CV: code-based multi-channel common-view with IGS ionospheric delay correction
- CP: carrier phase all-in-view from IGS clock products
- TWSTFT: Ku-band
- TDEV (at 1 day)
  - CV: 900ps
  - CP: 500ps
  - TWSTFT: 500ps

The SIM Network

- SIM is the Interamerican Metrology System, the RMO for North, Central, and South America. The SIM Network is an excellent example of how NMIs can establish traceability through international comparisons, even if they are not involved in the BIPM key comparisons.
- Fourteen NMIs (light colored clocks on the map) now participate. Two more NMIs (dark colored clocks) are expected to join the network in 2010. All of these labs continuously compare their time and frequency standards, 24 hours per day, 7 days per week.

SIM Results are available on-line at: tf.nist.gov/sim

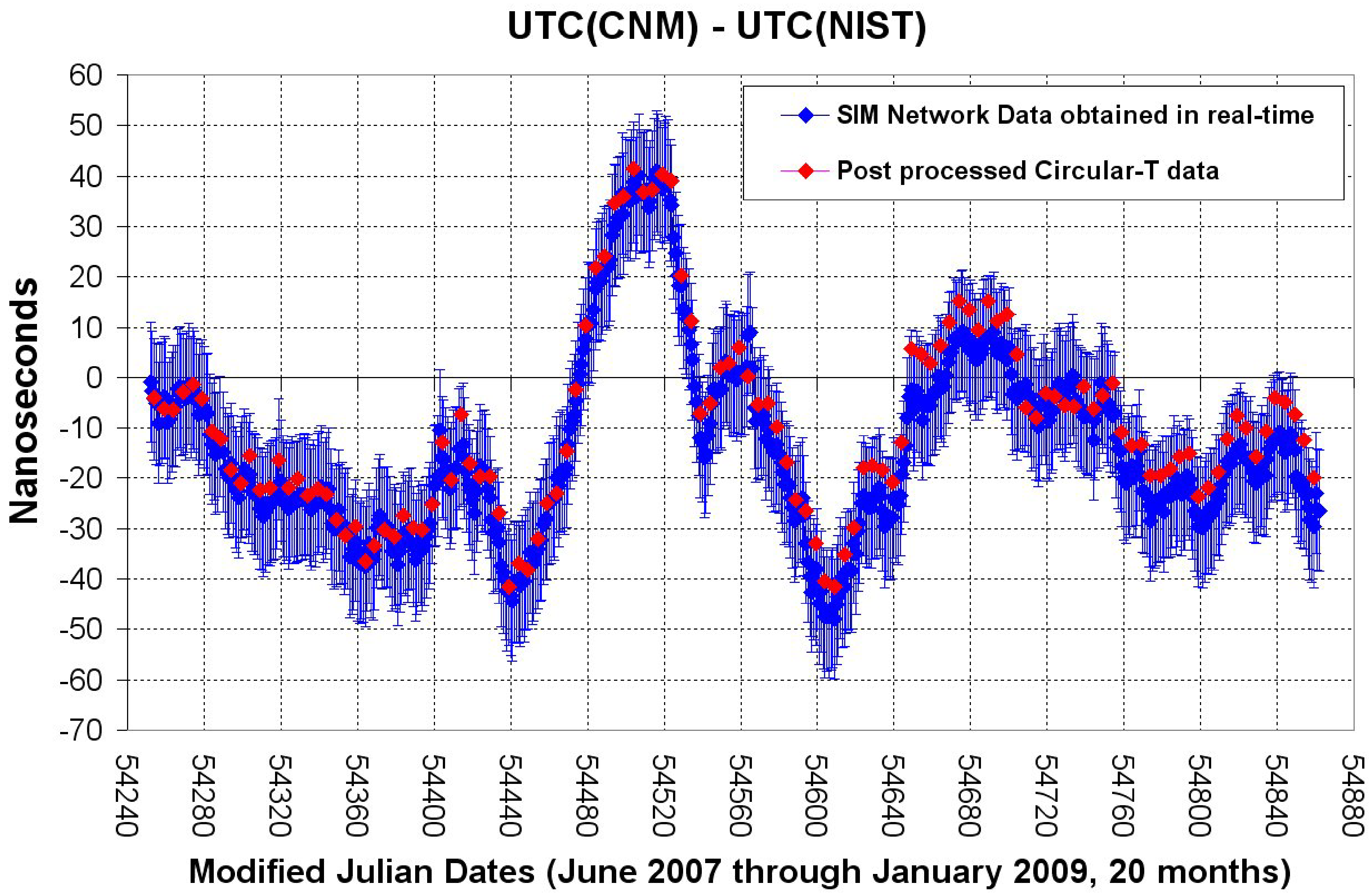
SIM Time Network

(real-time measurement results for the 10-minute period ending on 09-29-2009 at 2250 UTC)

	United States SIMT(NIST)	Mexico SIMT(CNM)	Canada SIMT(NRC)	Panama SIMT(CNMP)	Brazil SIMT(ONRJ)	Costa Rica SIMT(ICE)	Colombia SIMT(SIC)	Argentina SIMT(INTI)	Guatemala SIMT(LNM)	Jamaica SIMT(BSJ)	Uruguay SIMT(UTE)	Paraguay SIMT(INTN)	Peru SIMT(INDP)	Trinidad SIMT(TTBS)
United States SIMT(NIST)		10.6	80.5	5.3	1.6	234.6	-8.6			20.5			451190513.0	
Mexico SIMT(CNM)	-10.6		71.6	-11.6	-17.0	221.4	-17.6	-12.2		9.3	-14.9		451190509.1	
Canada SIMT(NRC)	-80.5	-71.6		-85.8	-80.5	149.9	-88.8			-59.7			451190432.7	
Panama SIMT(CNMP)	-5.3	11.6	85.8		-1.0	231.2	-3.5	1.0		15.6	-1.3		451190524.7	
Brazil SIMT(ONRJ)	-1.6	17.0	80.5	1.0		235.4	-2.2	1.0		17.0	-3.0		451190528.5	
Costa Rica SIMT(ICE)	-234.6	-221.4	-149.9	-231.2	-235.4		-238.6	-233.5		-216.1	-235.8		451190289.7	
Colombia SIMT(SIC)	8.6	17.6	88.8	3.5	2.2	238.6		2.0		25.6	-1.8		451190528.3	
Argentina SIMT(INTI)		12.2		-1.0	-1.0	233.5	-2.0			10.7	-3.6		451190525.9	
Guatemala SIMT(LNM)														
Jamaica SIMT(BSJ)	-20.5	-9.3	59.7	-15.6	-17.0	216.1	-25.6	-10.7			-12.1		451190499.6	
Uruguay SIMT(UTE)		14.9		1.3	3.0	235.8	1.8	3.6		12.1			451190527.6	
Paraguay SIMT(INTN)														
Peru SIMT(INDP)	-451190513.0	-451190509.1	-451190432.7	-451190524.7	-451190528.5	-451190289.7	-451190528.3	-451190525.9		-451190499.6	-451190527.6			
Trinidad SIMT(TTBS)														
Last Update (HHMM)	2250	2250	2250	2250	2250	2250	2250	2250		2250	2250		2250	

This table was created at 09-29-2009 (MJD 55103) 22:58:39 UTC and will refresh every five minutes. Values are in units of nanoseconds.

Click on a time scale or country name to view a **one-way** GPS graph for the current day (GPS-NMI). Click on a number to view a **common-view** graph between two laboratories for the current day.



UTC(CNM) - UTC(NIST)
Nanoseconds
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
SIM Network Data obtained in real-time
Post processed Circular-T data
54240
54280
54320
54360
54400
54440
54480
54520
54560
54600
54640
54680
54720
54760
54800
54840
54880
Modified Julian Dates (June 2007 through January 2009, 20 months)

NIST Time Scale and Distribution

4 Cesium Beam standards

6 Hydrogen Masers

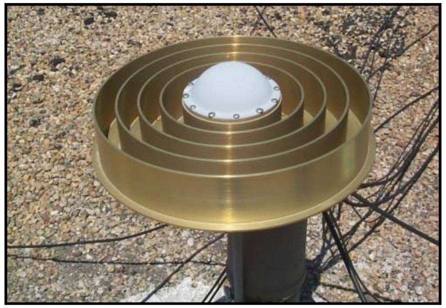
Calibrated by NIST-F1 primary frequency standard

UTC(NIST)

Measurement System

Two-way satellite time & frequency transfer

GPS



International coordination of time and frequency: UTC, TAI, etc.

Remote Calibration Services

Remote calibration services satisfy the most demanding industrial timing customers, including timing laboratories, research laboratories, and the telecommunications industry.

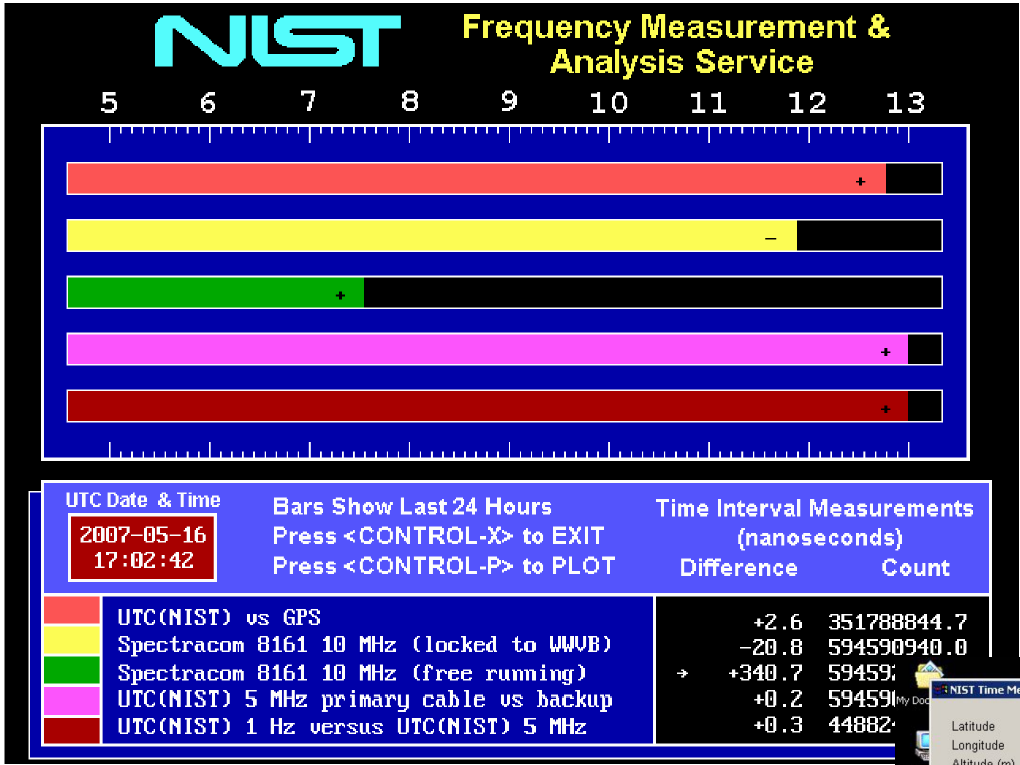
Time Measurement and Analysis Service

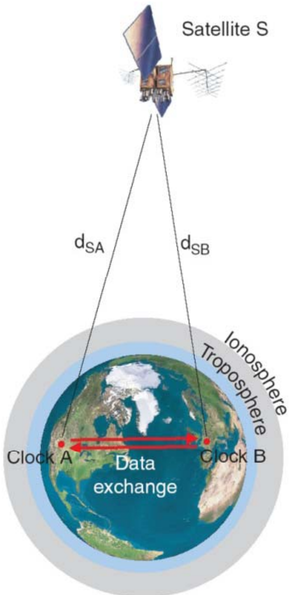
Time Measurement and Analysis Service (TMAS)

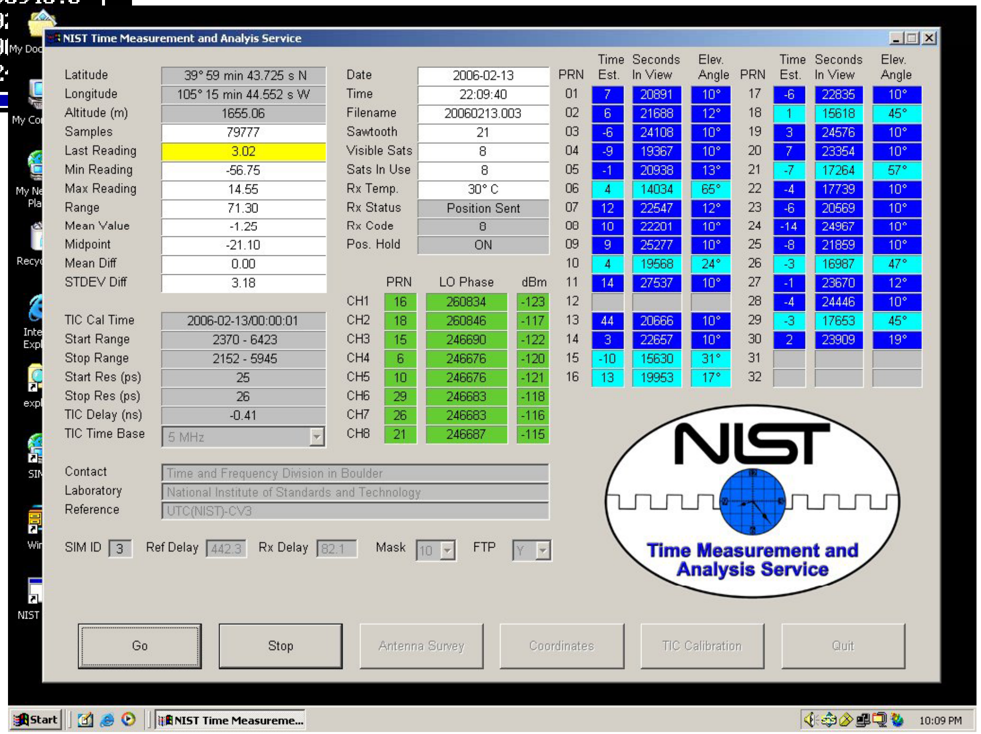
- Direct comparison to to UTC(NIST) via Common-View GPS. Based on technology of SIM Time Network.
- < 15 ns uncertainty (*k* = 2).
- Real-time measurement results available via Internet.

Frequency Measurement and Analysis Service

- Full measurement system with continuous remote monitoring by NIST through telephone lines.
- Frequency uncertainty w/respect to UTC(NIST) is ~2 x 10^{-13} after 1 day of averaging.


NIST
Frequency Measurement &
Analysis Service
5 6 7 8 9 10 11 12 13
UTC Date & Time
2007-05-16
17:02:42
Bars Show Last 24 Hours
Press <CONTROL-X> to EXIT
Press <CONTROL-P> to PLOT
Time Interval Measurements
(nanoseconds)
Difference
Count
UTC(NIST) vs GPS
Spectracom 8161 10 MHz (locked to WWVB)
Spectracom 8161 10 MHz (free running)
UTC(NIST) 5 MHz primary cable vs backup
UTC(NIST) 1 Hz versus UTC(NIST) 5 MHz
+2.6 351788844.7
-20.8 594590940.0
+340.7
+0.2
+0.3

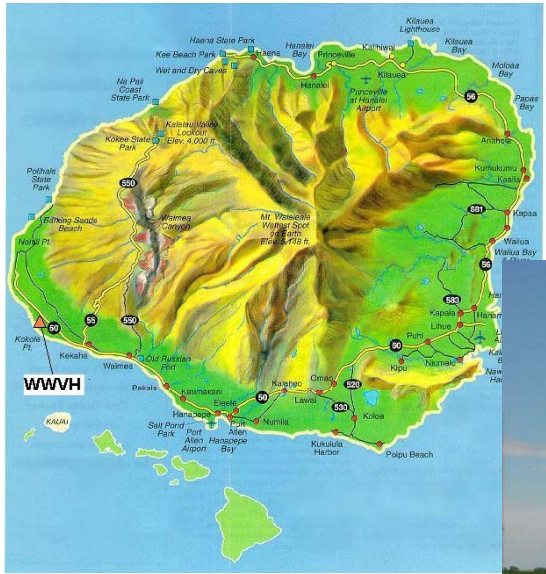

Satellite S
d_{SA}
d_{SB}
Ionosphere
Troposphere
Clock A
Clock B
Data
exchange

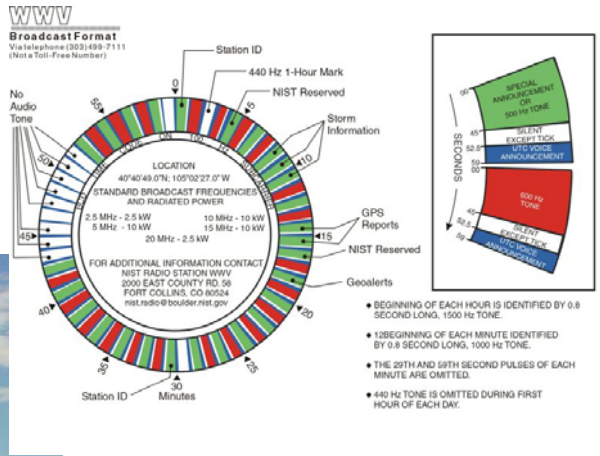

NIST Time Measurement and Analyis Service
Latitude 39° 59 min 43.725 s N
Longitude 105° 15 min 44.552 s W
Altitude (m) 1655.06
Samples 79777
Last Reading 3.02
Min Reading -56.75
Max Reading 14.55
Range 71.30
Mean Value -1.25
Midpoint -21.10
Mean Diff 0.00
STDEV Diff 3.18
TIC Cal Time 2006-02-13/00:00:01
Start Range 2370 - 6423
Stop Range 2152 - 5945
Start Res (ps) 25
Stop Res (ps) 26
TIC Delay (ns) -0.41
TIC Time Base 5 MHz
Date 2006-02-13
Time 22:09:40
Filename 20060213.003
Sawtooth 21
Visible Sats 8
Sats In Use 8
Rx Temp. 30° C
Rx Status Position Sent
Rx Code 0
Pos. Hold ON
PRN
LO Phase
dBm
Time Est.
Seconds In View
Elev. Angle
Contact Time and Frequency Division in Boulder
Laboratory National Institute of Standards and Technology
Reference UTC(NIST)-CV3
SIM ID 3
Ref Delay 442.3
Rx Delay 82.1
Mask 10
FTP Y
NIST
Time Measurement and Analysis Service
Go
Stop
Antenna Survey
Coordinates
TIC Calibration
Quit
Start
NIST Time Measureme...
10:09 PM

FMAS/TMAS Comparison

Feature	FMAS	TMAS
Number of Channels	5	1
Frequency Inputs	1 Hz to 120 MHz	1 Hz only
Time Uncertainty w/respect to UTC(NIST), (k = 2)	Not Available	15 ns
Frequency Uncertainty w/respect to UTC(NIST), (k = 2)	2×10^{-13} at 1 day	5×10^{-14} at 1 day
Data connection to NIST	Telephone line	Internet
Reporting of Results	Daily printouts of phase plots, monthly calibration report sent via mail	Real-time reporting via Internet, updated every 10 minutes
Customer Service	Phone and email support, replacement parts shipped when necessary via FedEx	Phone and email support, replacement parts shipped when necessary via FedEx

Time By Radio: WWV/WWVH





Time by Radio: WWV/WWVH

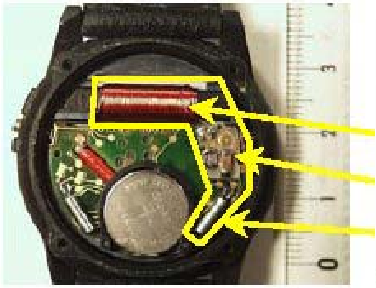
- HF time signal stations operate in the radio spectrum from 3 to 30 MHz (often known as shortwave). WWV is the shortwave station operated by NIST from Fort Collins, Colorado. Its sister station, WWVH, is located on the island of Kauai in Hawaii.
- Both stations broadcast on 2.5, 5, 10, and 15 MHz, and WWV is also available on 20 MHz.
- WWV and WWVH are best known for their audio time announcements. The exact size of the radio audience is unknown. About 2000 users per day listen to the signals by telephone through the Telephone Time-of-Day Service (TTDS).

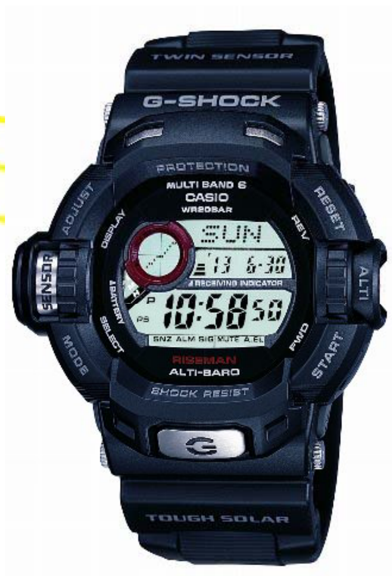
NIST operates two of the five remaining HF Time Signal Stations

Call Sign	Location	Frequencies (MHz)	Controlling NMI
WWV	Fort Collins, Colorado, USA	2.5, 5, 10, 15, 20	National Institute of Standards and Technology (NIST)
WWVH	Kauai, Hawaii, USA	2.5, 5, 10, 15	National Institute of Standards and Technology (NIST)
BPM	Lintong, China	2.5, 5, 10, 15	National Time Service Center (NTSC)
CHU	Ottawa, Canada	3.33, 7.85, 14.67	National Research Council (NRC)
HLA	Taejon, Korea	5	Korean Research Institute of Standards and Science (KRISS)

Time By Radio: WWVB

WWVB Radio Controlled Clocks





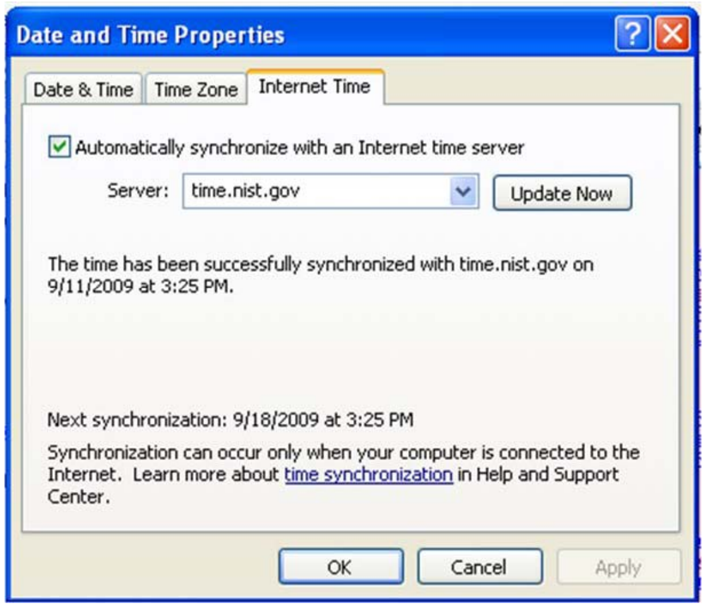
- Low frequency time signal stations operate at frequencies ranging from about 40 to 80 kHz.
- WWVB broadcasts on 60 kHz with 70 kW of power from Fort Collins, Colorado.
- Between 50 and 100 million WWVB radio controlled clocks are believed to be in operation.
- Casio expects to sell 2 million WWVB compatible wristwatches in 2009.

LF Time Signal Stations

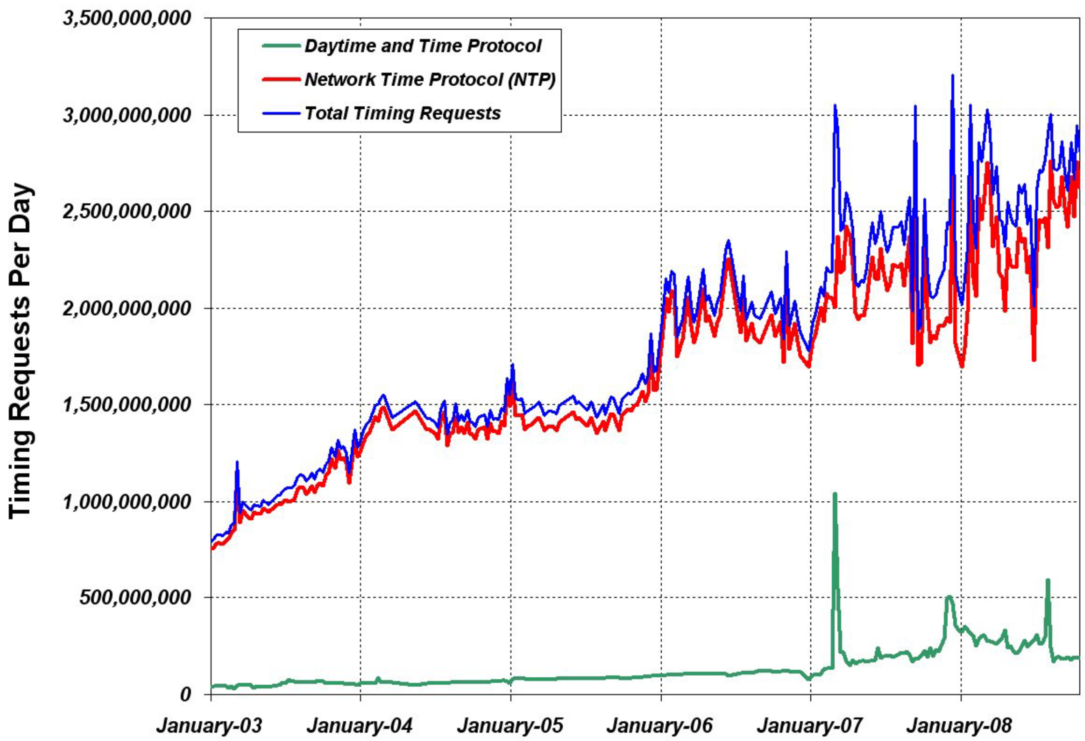
Call Sign	Location	Frequency (kHz)	Controlling NMI
WWVB	**Fort Collins, Colorado, USA**	**60**	**National Institute of Standards and Technology (NIST)**
BPC	Lintong, China	68.5	National Time Service Center (NTSC)
DCF77	Mainflingen, Germany	77.5	Physikalisch-Technische Bundesanstalt (PTB)
HBG	Prangins, Switzerland	75	Swiss Federal Office of Metrology and Accreditation (METAS)
JJY	Japan	40, 80	National Institute of Information and Communications Technology (NICT)
MSF	Rugby, United Kingdom	60	National Physical Laboratory (NPL)
RBU	Moscow, Russia	66.67	Institute of Metrology for Time and Space (IMVP)

Internet Time Service (ITS)

- One of the world's most popular time distribution services. The ITS synchronizes more than 100 million computer clocks every day.
- 22 servers located around the United States.
- Client software is built into common operating systems: Windows XP and Vista, Mac, Unix.



Internet Time Service (ITS)

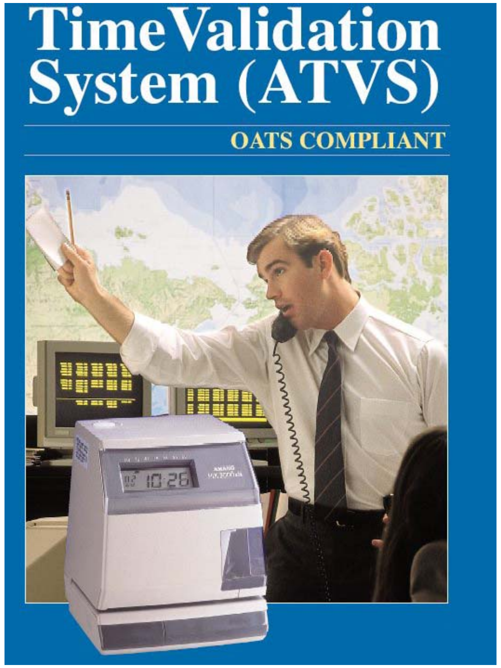


- Over 90% of ITS users request time in NTP format.
- NTP refers to the Network Time Protocol, the most widely used mechanism for time distribution via the Internet, defined by the RFC-1305 standard.
- The uncertainty is usually about 50 milliseconds.
- On peak traffic days, the NIST NTP servers handle more than 3 billion timing requests

National Web Clock (time.gov)

- Handles about 400,000 timing requests per day on average
- Accurate to within a few tenths of a second
- An easy way for users to compare their clocks and watches to UTC(NIST)

Automated Computer Time Service (ACTS)



Amano Time Validation System (ATVS)

The PIX-3000xN Time Validation Unit and the PIX-COM Time Synchronization Software have been specially designed by Amano in compliance with the Order Audit Trail System (OATS) rules.

REQUIREMENT	OATS COMPLIANCE	✔ ATVS SOLUTION
Imprint format	• Y2K compliance and prints seconds YYYY/MM/DD HH:MM SS	✔ 1998/02/20 16:51 21s YYYY/MM/DD HH:MM SS
Time synchronization	• Time synchronization with Atomic time from NIST* at least once per day	✔ 1998/02/20 16:48 33 ← • Self-validation mark • Self-validation Time Synchronization
Time deviation	• Within 3 seconds deviation per day	✔ • Less than 2.5 seconds deviation per day

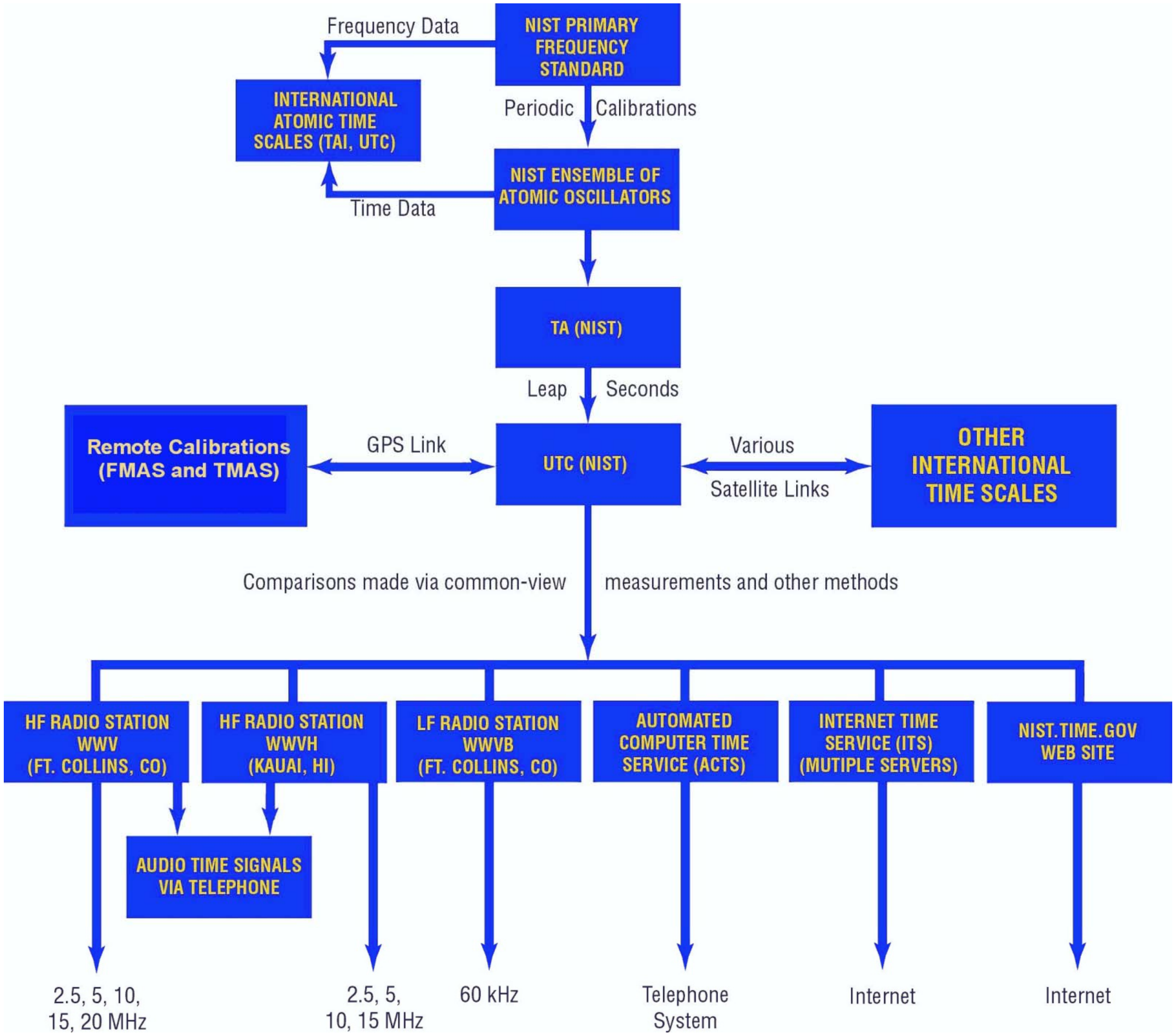
* National Institute of Standards and Technology (NIST), Boulder, CO

- The Automated Computer Time Service that delivers time over telephone lines.
- ACTS synchronizes computer clocks and standalone clocks through ordinary telephone lines using analog modems.
- Not used for frequency. The time uncertainty is about +/- 15 milliseconds.
- Popularity has decreased due to Internet NTP servers, but ACTS still synchronizes about 5000 computer clocks per day.
- Many ACTS customers are brokerage houses involved in stock market transactions.

Distributed UTC(NIST) Signals

Signal Source	Time Uncertainty (microseconds)	Frequency Uncertainty (1 day)	Notes	Clocks Synchronized or Measured Per Day (estimated)
TMAS	< 0.015	5×10^{-14}	Remote calibration service for paying customers.	10
FMAS	Not Applicable	2×10^{-13}	Remote calibration service for paying customers	35
WWVB	100	1×10^{-12}	Free Broadcast Service	50 to 100 million
WWV/WWVH	1000	1×10^{-9}	Free Broadcast Service	1 million
ACTS	5000	Not Applicable	Free Broadcast Service	5000
ITS	10000	Not Applicable	Free Broadcast Service	> 100 million
TTDS	30000	Not Applicable	Free Broadcast Service	2000
Time.gov web clock	200000	Not Applicable	Free Broadcast Service	400,000

The Distribution of UTC(NIST)



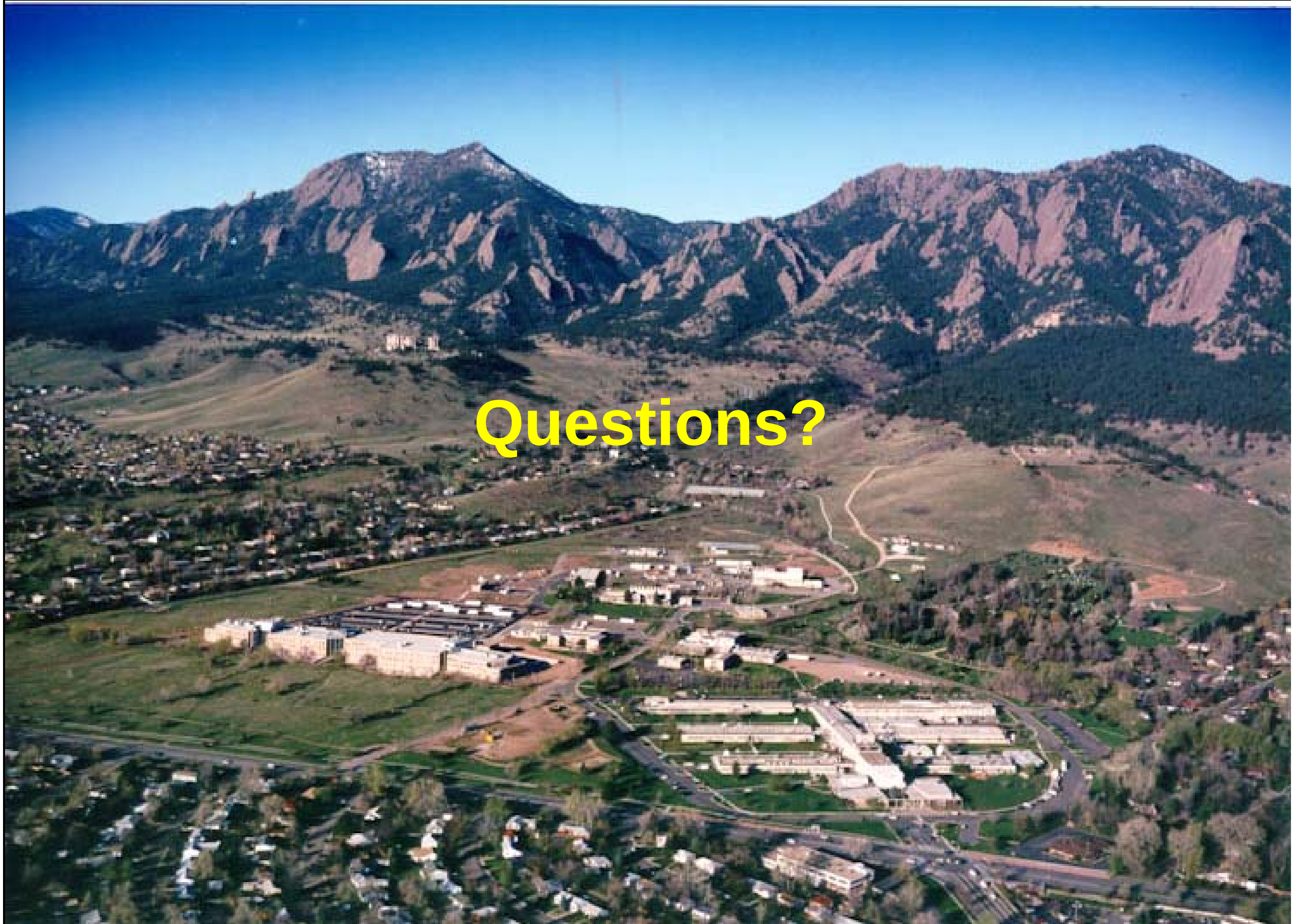
Summary

The UTC(NIST) time scale is an important part of a world infrastructure of time and frequency that ensures traceability to the International System of units (SI).

Establishing *traceability* provides evidence that measurements are being made **correctly.**

Through its time scale and services, NIST:

- synchronizes many millions of clocks each day
- helps the private and public sectors meet their legal and technical time and frequency requirements
- provides calibration services to paying industrial time users with the most demanding requirements


Questions?