Role of the ITU-R in Time Scale Definition and Dissemination

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Ron Beard, Chairman
ITU-R Working Party 7A

Study Group 7-Science Services
Working Party 7A
Broadcast Time and Frequency Services

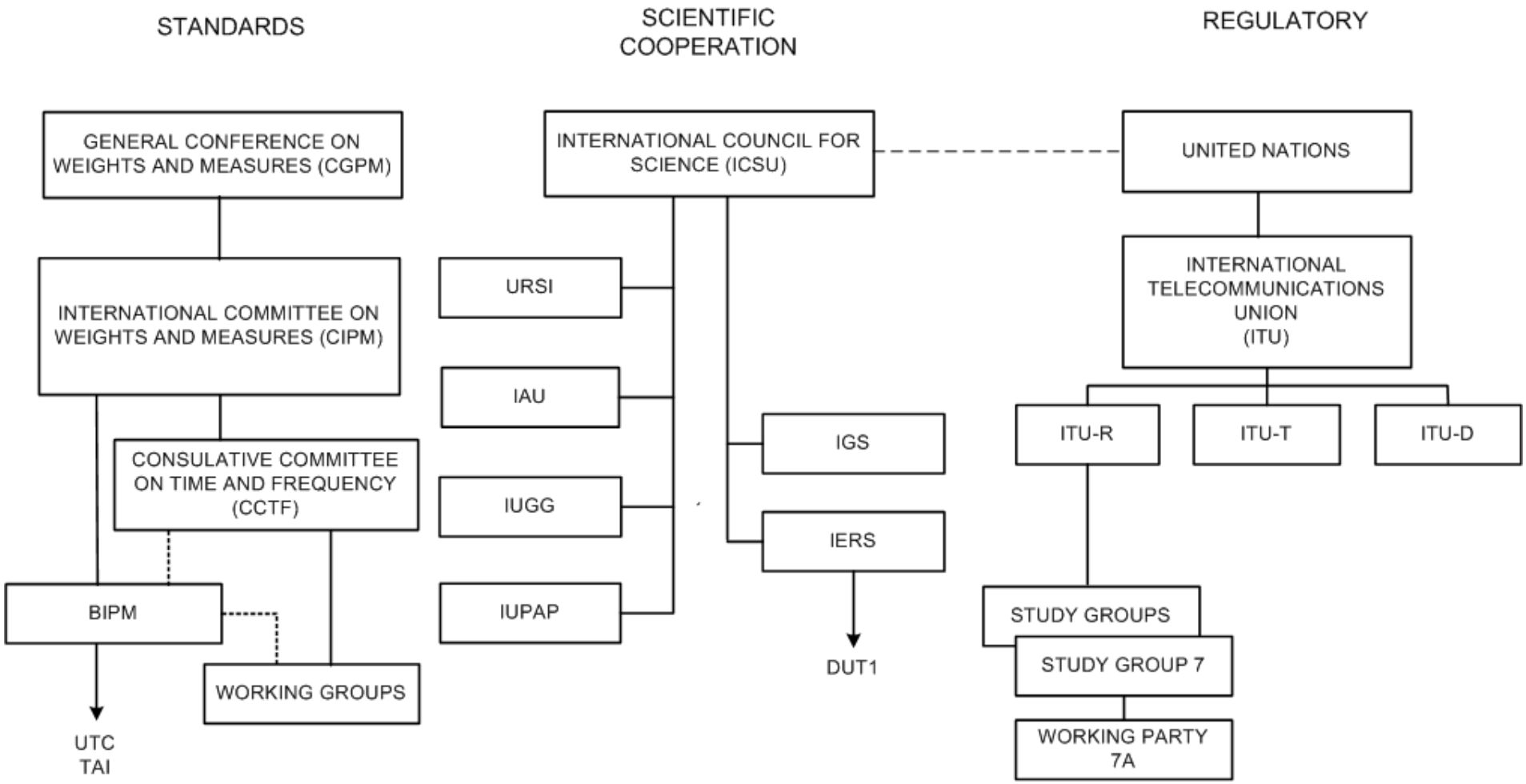
Responsible for Time and Frequency Signal (TFS) Services both terrestrial and satellite

Maintains questions, TF series of recommendations, reports, opinions and handbooks covering fundamentals of TFS generation, measurements and data processing

Topics include

- **Terrestrial TFS transmissions, including HF,VHF and UHF**
- **Television broadcasting**
- **Microwave links**
- **Coaxial and optical cables**
- **Space based including navigation, communications and metrological satellites**
- **Frequency standards, clocks and TFS measurements systems**
- **TFS performance characterization**
- **Time scales and time codes**

ITU-R Relationship with other Agencies



ITU-R RECOMMENDATION TF.460-6
STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS
(1970-1974-1978-1982-1986-1997-2002)

To maintain worldwide coordination of standard frequency and time signals

Disseminate standard frequency and time signals in conformity with the SI second

Continuing need for close cooperation with IMO, ICAO, CGPM, BIPM, IERS, and ICSU

Continuing need for UT immediate availability to an uncertainty of 0.1 second

All standard-frequency and time-signal emissions conform as closely as possible to UTC

Time signals should not deviate from UTC by more than 1 ms; that the standard frequencies should not deviate by more than 1 part in 10^{10}

TAI - Reference atomic time scale based on SI second as realized on a rotating geoid. Continuous scale from origin 1 Jan 1958

UTC – Timescale maintained by the BIPM, assisted by IERS, as basis for coordinated dissemination of standard frequency and time signals. Corresponds exactly in rate with TAI but differs by integral number of seconds. UTC scale adjusted by insertion or deletion of seconds to ensure approximate agreement with UT1

DUT1 - Dissemination to include *predicted difference* UT1 – UTC (values given by IERS in integral multiples of 0.1 s)

Leaps Seconds may be introduced as the last second of a UTC month December and June Preferred, March and September second choice

Time Scales Origins

1834 - Mean Solar Time introduced at Greenwich with publication of Nautical Almanac and Ephemerides

1870 – U.S. introduced time zones for Railroads time table

1884 - *International Meridian Conference* recognized Prime Meridian at Greenwich, Universal Day (not to interfere with local or other standard time) to be Mean Solar Day to begin at Midnight on the initial meridian)

1912 – Bureau International de l'Heure (BIH) created by international conference in France to form a single approximation of theoretical Universal Time known as Definitive Time

1919 – BIH recognized by the International Astronomical Union (IAU)

1925 – Ephemerides introduced day beginning at midnight, termed Greenwich Mean Civil Time (GMCT), or Greenwich Mean Time (GMT)

1948 – Universal Time (UT) adopted by IAU, NBS Atomic clock in operation

1952 – Ephemeris Time (ET) based on Sidereal Year defined by IAU

1956 – Ephemeris Second defined by CIPM as 1/13 556 925.9747 of tropic year for Jan 0 at 12 h Ephemeris Time

Atomic Time Scales Origins

1955 – NPL Cesium Atomic clock became operational, Commercial Cesium Standards in following year

1960 – Atomic Time introduced and coordination of UTC begun by BIH

1962 - UTC system was formalized by International Radio Consultative Committee (CCIR) Both frequency offsets and fractional (less than 1 s) steps were applied to maintain agreement with UT2 within about 0.1 s

1967 – SI second defined by CGPM, BIH Atomic time recommended by IAU

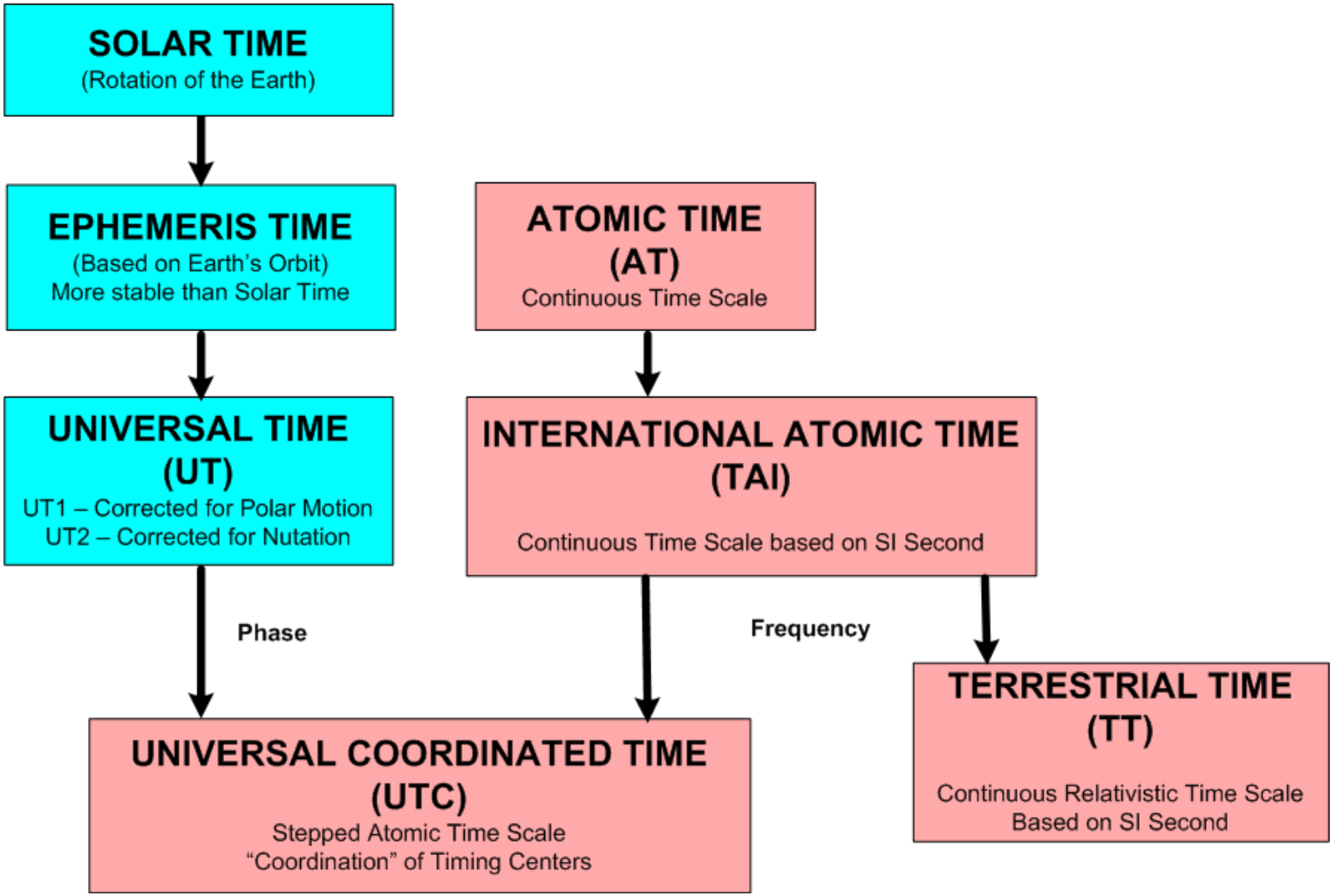
1970 - International Atomic Time (TAI) defined by CIPM, ratified by CGPM in 1971,

1971 - Coordinated Universal Time (UTC) defined by International Telecommunications Union (CCIR) present UTC system was adopted, with 1 s (leap second) steps but no frequency offsets to maintain agreement with UT1 within 0.9 s

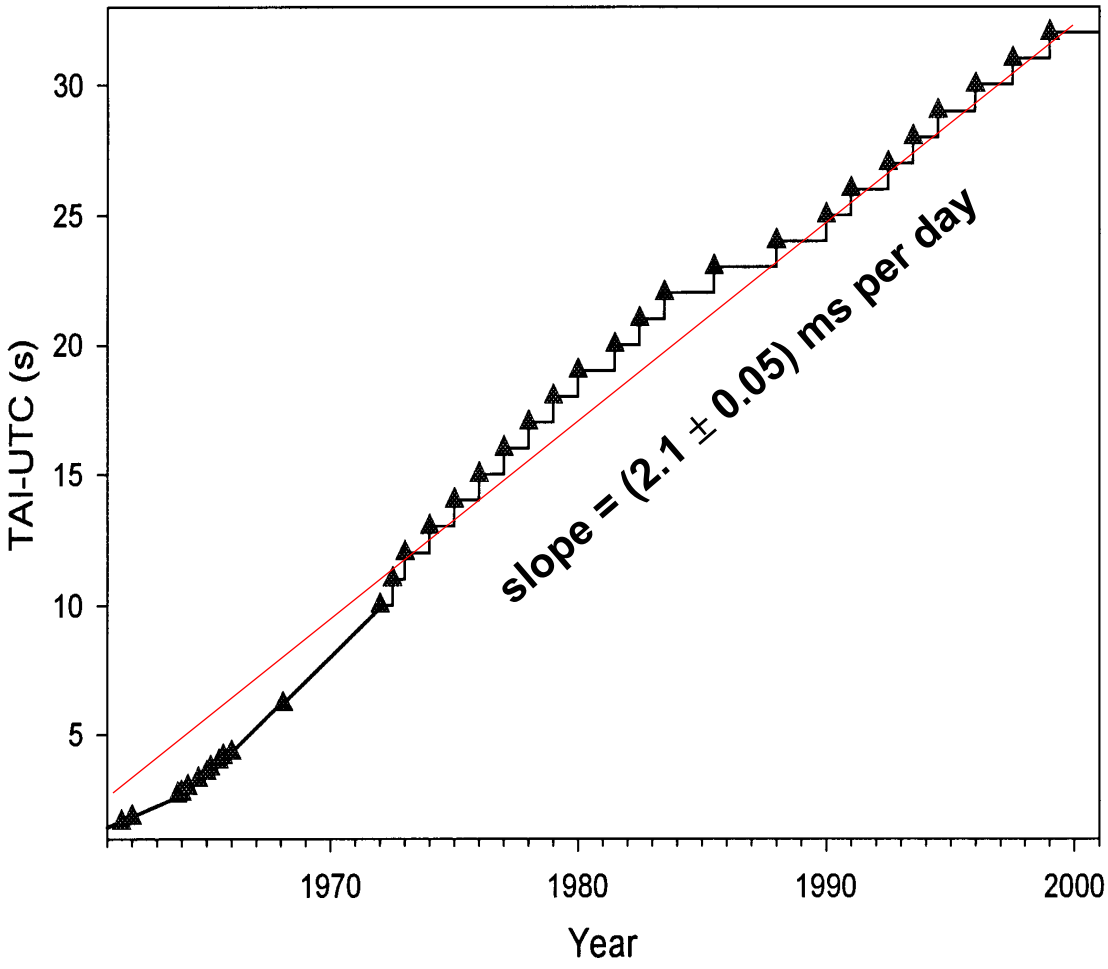
1971 - Coordinated Universal Time (UTC) recognized by CGPM

1988 – UTC responsibility assumed by BIPM, astronomical and geodetic aspects assumed by IERS

TIME SCALES


SOLAR TIME
(Rotation of the Earth)
EPHEMERIS TIME
(Based on Earth's Orbit)
More stable than Solar Time
UNIVERSAL TIME (UT)
UT1 – Corrected for Polar Motion
UT2 – Corrected for Nutation
ATOMIC TIME (AT)
Continuous Time Scale
INTERNATIONAL ATOMIC TIME (TAI)
Continuous Time Scale based on SI Second
Phase
Frequency
UNIVERSAL COORDINATED TIME (UTC)
Stepped Atomic Time Scale
"Coordination" of Timing Centers
TERRESTRIAL TIME (TT)
Continuous Relativistic Time Scale
Based on SI Second

UTC SINCE 1961



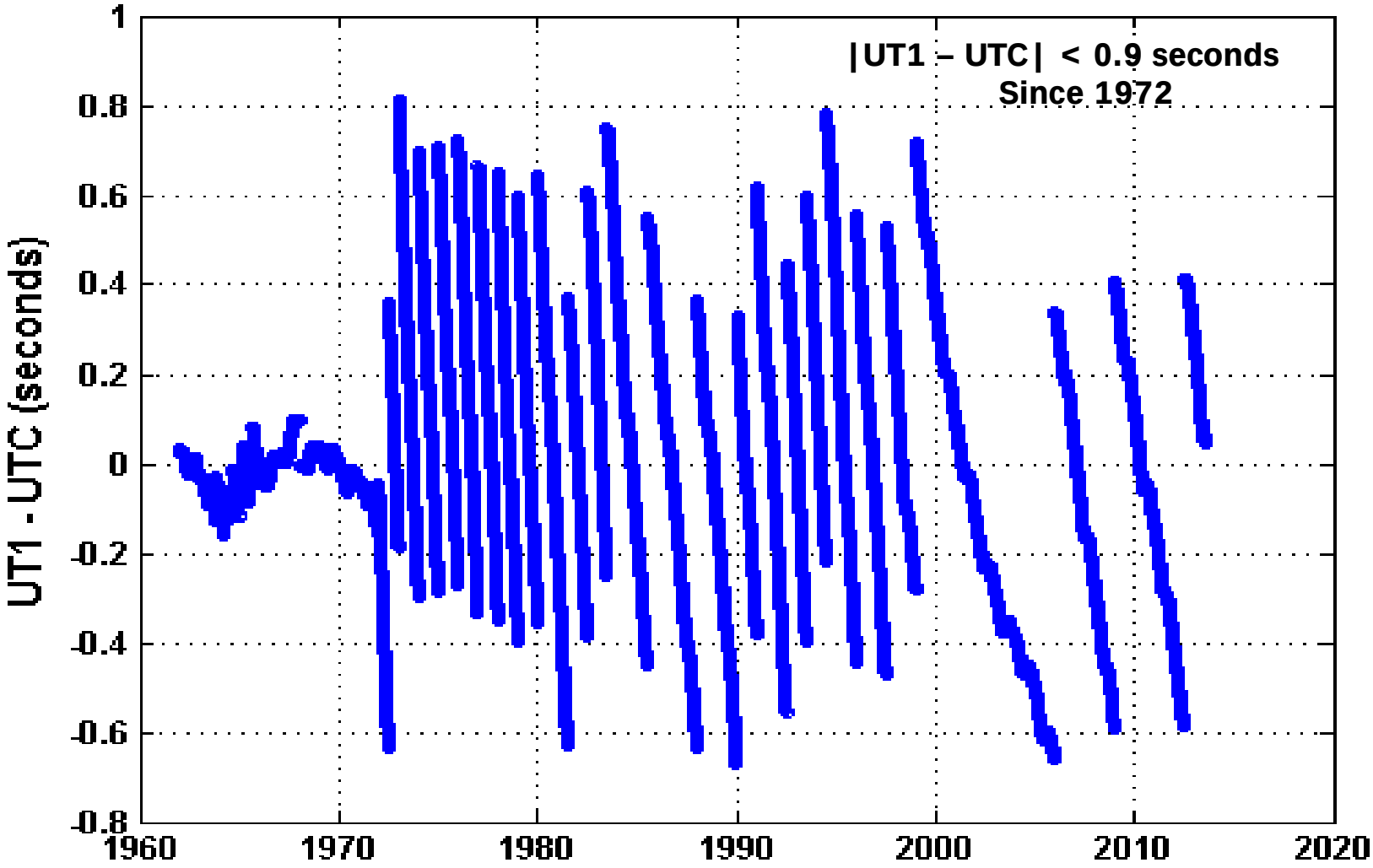
In 1972 ΔT = 42.23 s.

Then TAI – UTC set = 10 s

25 leap seconds have been added since 1972

Currently TAI – UTC = 35 s

UT1 - UTC


|UT1 – UTC| < 0.9 seconds
Since 1972
UT1 - UTC (seconds)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
1960
1970
1980
1990
2000
2010
2020

Time Scale Applications

- **TRADITIONAL**
  - Astronomical – Days based on rotation of the earth and relationship of celestial bodies with location.
  - Nautical – Time used for determination of longitude and observation of stars for positioning by celestial observation
  - Coordination of Telephone networks
  - Electronic Navigation systems
  - Civil – Day used for daily activities and agriculture (seasons)

- **PRESENT**
  - Positional Astronomy – Earth orientation & Satellite Orbit Determination
  - Civil – Day used for daily activities and agriculture (seasons)
  - Coordination of Radio Broadcasts and Frequency Generation
  - Coordination of Telecommunications systems
  - Operation of mobile telecommunications systems (cell phones)
  - Regulation of electrical power grids
  - Data collection of distributed sensor networks, geophysical and meteorological
  - Global Navigation Satellite Systems operation and precise time dissemination
  - Time tagging electronic data and messages in Computer Networks

Director, BIPM to Secretary General, ITU (Letter 1999)

The Consultative Committee for Time and Frequency (CCTF) has concerns to raise since the ITU-R is responsible for the Definition of UTC

Issues were raised in the CCTF concerning discontinuities in UTC creating problems in coordinating telecommunications systems

Time as used in navigation satellite and telecommunications systems could possibly lead to multiple independent timekeeping systems (e.g. GPS Time) vice UTC

Difficulties in computer systems and networks to adjust for time steps or leap seconds

ITU-R issued new Question ITU-R 236/7, The Future of The UTC Time Scale

ITU-R Question 236/7
The Future of The UTC Time Scale
(2000)

1. What are the requirements for globally-accepted time scales for use both in navigation and telecommunications systems, and for civil time-keeping?
    - Accuracy, Stability, Based on the SI Second
    - Uniformity, Accessibility
    - Reliability
    - Availability
    - Civil / National Timekeeping

2. What are the present and future requirements for the tolerance limit between UTC and UT1?
    - |UT1 – UTC| Tolerance of 0.9 seconds
    - Could a Greater Tolerance be Accommodated?

3. Does the current leap second procedure satisfy user needs, or should an alternative procedure be developed?
    - Availability of Leap Second Information for Users
    - Alternatives Used (Establishing System Independent Time)
    - Relationship of Telecom & NAVSAT System Internal Time to Time Scales

ITU-R Studies and Activities

Assessment of developments in radio- and tele-commnication indicated needs

- **Internal time in systems are driven by need for "Real-time" accuracy and precision**
- **"Local Time" determined by statistical process of many standards/clocks are being employed in new systems**
- **Telecommunications capabilities needing distributed syntonized operation (CDMA Network) are increasing**

Special outreach sessions at Technical conferences (PTTI, IEEE-IFCS, CGSIC, EFTF)

Surveys by other groups: URSI, IAU, IERS, U.S. NIST, CRL, U.S. Gov Data Call

ITU-R Surveys and call for participation (Letters to Sector Members)

- **IAU, URSI, CCTF, IAUGG, and Nations, IAU Working Group, URSI Commission J Working Group, AAS Working Group**

Special Colloquium Hosted at IEN, Torino

- **Software impact identified to that controlling telescopes and astrodynamic orbit determination as a concern, especially cost of modification**
- **Cost estimates provided spanned orders of magnitude**

CCTF Recommendations provided to ITU-R

System Time Keeping Needs

- **Traditional timekeeping is a post processed value**
  - **UTC has been post processed time scales delayed from 30 to 60 days**
  - **More Real-Time values becoming available from BIPM**
- **Electronic systems are filled with oscillators and clocks generating time and frequency data that must be correlated across systems and nations in "Real-Time"**
- **Reference Time needs to be continuous and available on demand ("Real-Time")**
- **Systems are adopting their own "system time".... e.g., GPS TIME**
- **The increasing number of systems could potentially result in a multiplicity of "system time scales"**
- **A single Common Reference Time would encourage wider system use**

Alternatives Studied

Create a new time scale, possibly named International Time (TI)

- **Eliminate UTC and replace with TI**

Use TAI instead of UTC

- **TAI is metrologic scale and not distributed**
- **Transition could result in major time step**

Consider Adoption of GPS Time as the official international time scale

- **GPS Time is a system real time internal time scale**
- **Derived from system clocks not global timing centers**
- **Rate and time steps can be changed in accord with system demands**

Increase maximum tolerance of DUT1

- **One hour would be similar to Daylight Savings Time (Summer Time)**

Modify UTC to a continuous atomic time scale by stopping insertion of leap second adjustments

RA and WRC-12 Results

Draft Revised Recommendation ITU-R TF460-6 was proposed to modify UTC to a continuous atomic time scale and discussed at Radiocommunication Assembly and forwarded to World Radiocommunication Conference (WRC-12)

WRC-12 established Resolution 653, which:

recognized that a change in the reference time-scale may have operational and therefore economic consequences

invited the ITU-R to conduct further studies into:

the feasibility of achieving a continuous reference time-scale for dissemination by radiocommunication systems

issues related to the possible implementation of a continuous reference time-scale (including technical and operational factors)

to report to WRC-15 on Agenda item 1.14 : "to consider the feasibility of achieving a continuous reference time-scale, whether by the modification of coordinated universal time (UTC) or some other method, and take appropriate action, in accordance with Resolution 653"

WRC-12 Resolution 653

Future of the Coordinated Universal Time time-scale

Resolution 653 calls for notification of other organizations of Agenda item 1.14 (CGPM, CCTF, BIPM, IERS, IMO, ICAO, IUGG, URSI, ISO, IAU, & WHO)

Director of Radiocommunications Bureau to include presentation on the topic in Radiocommunications World Seminars

Invites administrations to participate in studies by submitting contributions to ITU-R