International Committee on
Global Navigation Satellite Systems

Continuous UTC And Its Impact NavIC Perspective

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Introduction: Time & Its Measuring

Time is a fundamental physical quantity that measure the duration of events.

Time can be described based on the three Primary Methods:

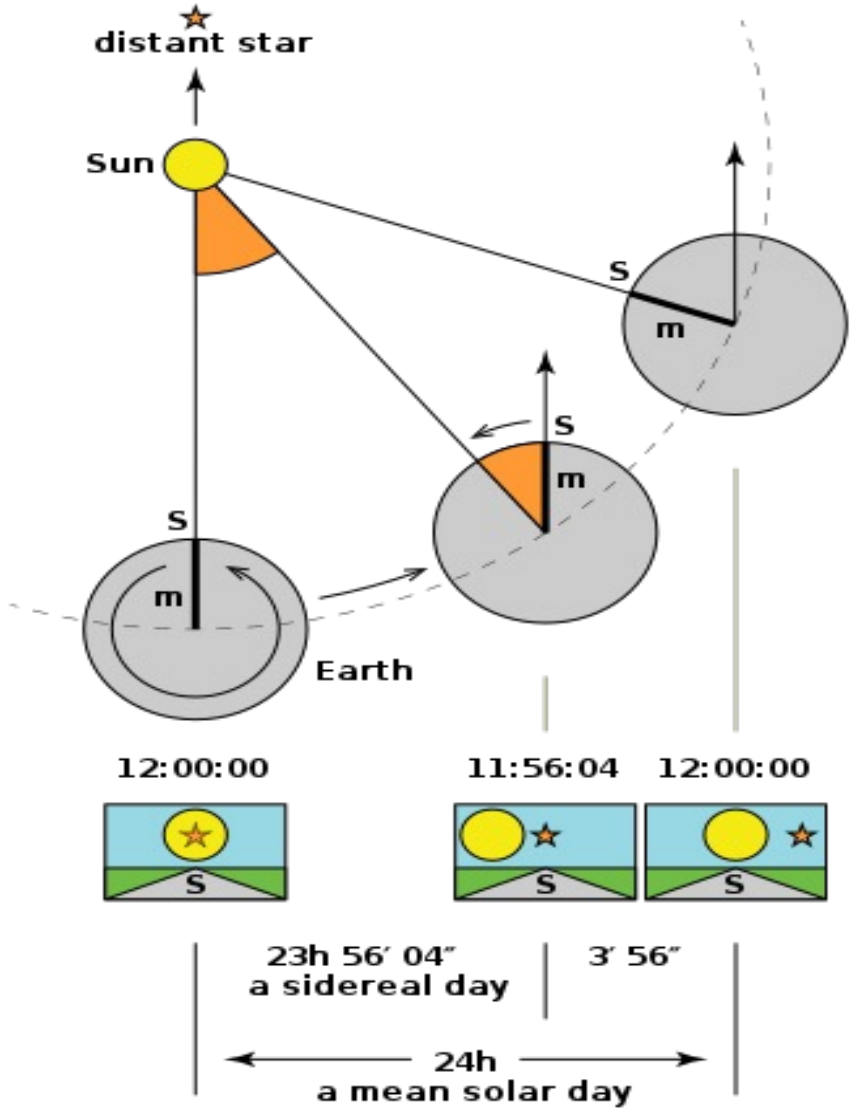
- Time based on rotation of Earth,
- Time based on celestial motion of Moon and other Planets,
- Time based on Quantum mechanics of Atom

Time Based on Earth Rotation :

The Sun ' s position in the sky has always been an obvious means to keep track of time.

- **Solar time** is based on the position of the sun. It is the time we all use where a day is defined as 24 hours.
- **Sidereal time** is based on the earth rotation about its axis with respect to the 'fixed' stars ,which are at very large distance from the Earth. It takes approximately 4 minutes less than a solar day.

1 sidereal day = 23 hours, 56 minutes, 4.1 sec.

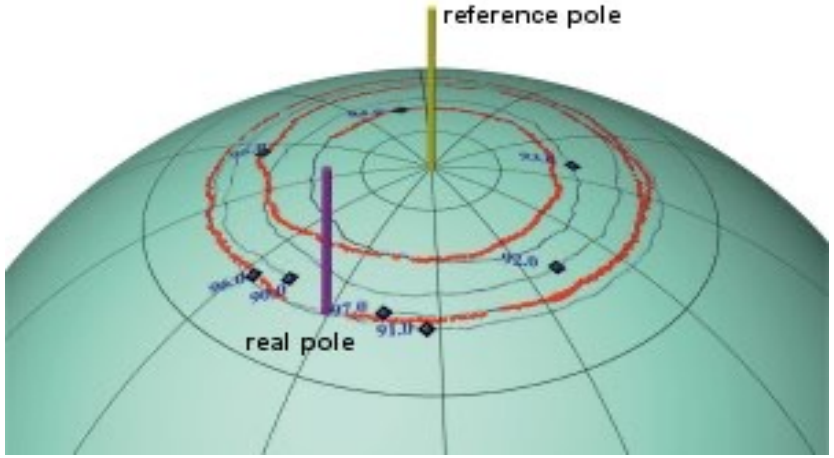


Universal Time

Universal Time (UT) is a time standard based on Earth's rotation. It is a modern continuation of Greenwich Mean Time(GMT), i.e., the mean solar time on the Prime meridian at Greenwich, England.

- **UT0** is a direct measure of universal time as observed at a given point on the Earth's surface.
- **UT1:** UT0 observations collected from different locations and they are corrected for polar motion.
- **UT2:** UT1 is further corrected empirically for annual and semiannual variations in the rotation rate of the Earth to provide a more uniform time-scale.

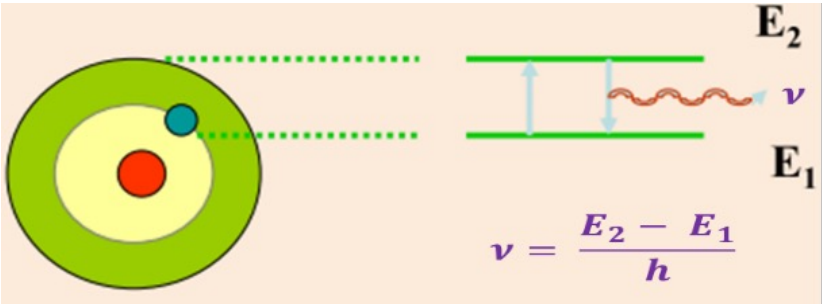
Polar Motion



Not to scale

International Atomic Time(TAI)

The timescale derived based on nearly 400 atomic clocks situated in timing laboratories that are placed all over the world. Time is derived based on ensemble of these atomic clocks output with the weighted average. This time-scale is established and maintained by the BIPM.

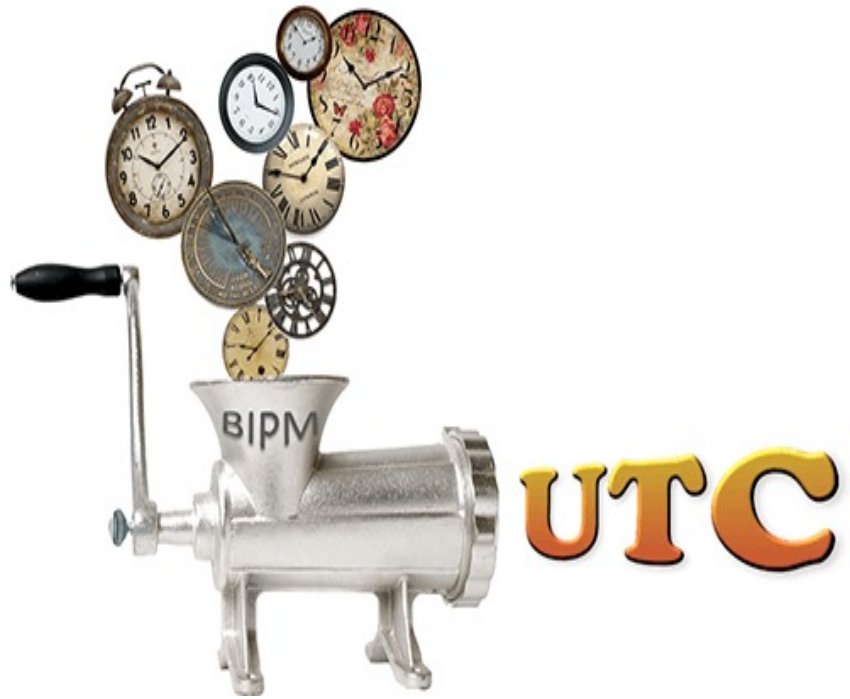


Basic definition of time: Second :The duration of 9,192,631,770 periods of the radiation corresponding to the transition between two hyperfine levels of the ground state of the cesium-133 atom.

Coordinated Universal Time (UTC)

It is the primary time standard by which the world regulates clocks and time. It is generated based on atomic clocks (TAI) . This is the standard time reference for civilian, derived based on atomic time and corrected for earth rotation.

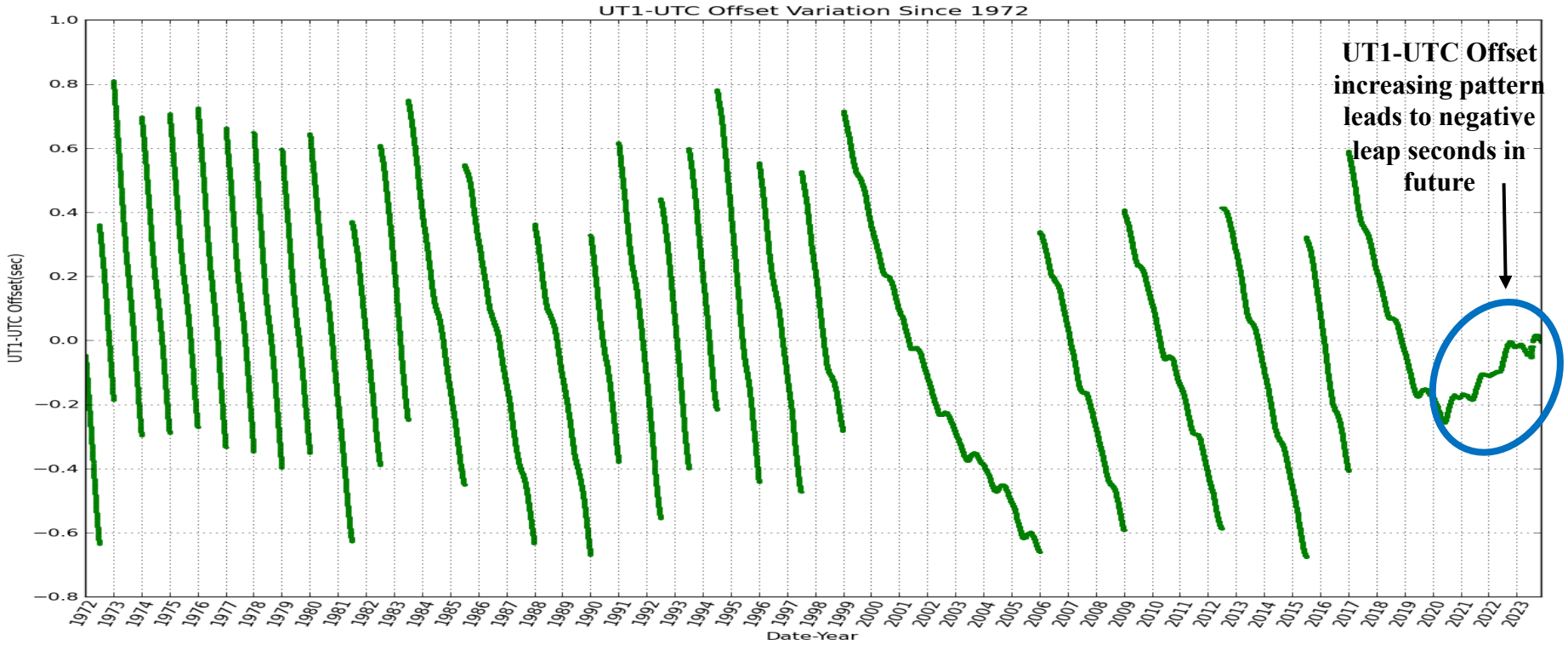
- Difference between Timescale Based on Earth Rotation (UT1) & Timescale Based on Atomic time (UTC) is Leap Second



Leap Second

Leap second is added to UTC to accommodate slowing down effect of earth rotation.

- Earth Slowdown rate is nearly 1.4 milliseconds in a day.
- The main reason for slowdown of earth : **Tidal friction**, **Major earthquakes, movement of earth crust relative to its core** , any other events that cause significant **redistribution of mass.**
- Leap second is scheduled if the UT1-UTC exceeds 0.9sec.
- Adding Leap second : **23:59:60**



Leap Seconds Addition since 1972

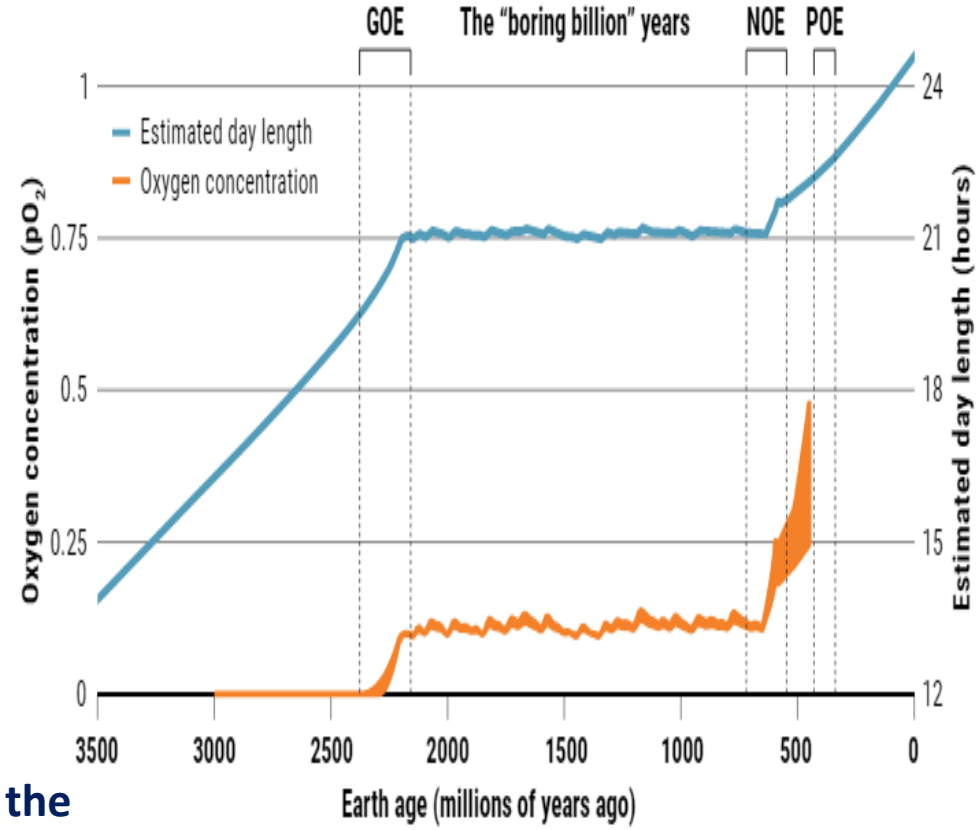
Year	30 Jun	31 Dec
1972	+1	+1
1973	0	+1
1974	0	+1
1975	0	+1
1976	0	+1
1977	0	+1
1978	0	+1
1979	0	+1
1981	+1	0
1982	+1	0
1983	+1	0
1985	+1	0
1987	0	+1
1989	0	+1
1990	0	+1
1992	+1	0
1993	+1	0
1994	+1	0
1995	0	+1
1997	+1	0
1998	0	+1
2005	0	+1
2008	0	+1
2012	+1	0
2015	+1	0
2016	0	+1
Year	30 Jun	31 Dec
Total	11	16
	27	
Current TAI – UTC		
37		

Is Earth Slowing Down or Moving Fast ?

Background: **A billion years Ago Earth day was only 19hrs , 600 million years ago it was around 22 hours. In general over long periods the observation of the earth rotation is slowing down.**

Possible Reasons For slowing Down:

- Tidal Frictions caused by Moon ,Earth Slowdown rate is nearly 1.4 milliseconds in a day.
- Major earthquakes
- Oxidation in the atmosphere due to cyanobacteria (green-blue algae)



Possible Reasons For Speeding Up:

This is still a mystery but some theories suggest that it could be because of the

- Melting of the glaciers

Is Earth Slowing Down or Moving Fast ?...Contd

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- Motions of our planet's inner molten core
- Seismic activity such as the 9.0 earthquake which hit Japan in 2011 shifted Earth's axis by 6.7 inches speeding up rotation by about 1.8 microseconds
- 'Chandler wobble,' which is a small deviation in the Earth's axis of rotation.

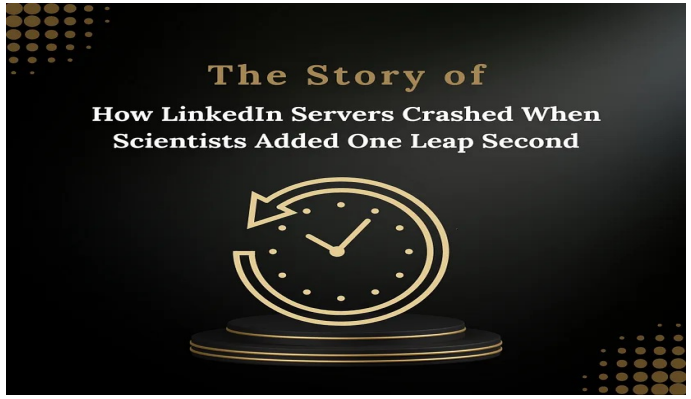
The faster rotation of Earth has consequences because it could lead to the introduction of the negative leap second in order to keep the rate that the Earth orbits the Sun consistent with measurements from atomic clocks.

*Images source: open source websites

Leap second problems

Time synchronization is more important in today's 5G networks, time-sensitive networking for automated vehicles or controlling robots in smart factories. Leap second has issues for IT industries ,Communication networks, Airlines etc.

Reddit, linkedln and Mozilla are Down in 2012



Cloudflare's DNS service outage in 2017

The Qantas airline in Australia had to delay 50 of its flights

***Images source: open source websites**

Continuous UTC Impact On Astronomy

- **Astronomical applications that use the current definition of UTC to access UT1 would be impacted by any change in the definition of UTC.**
  - The rotation angle of the Earth in a celestial reference system is described by the angle UT1. The current definition of UTC ensures that the difference between UT1 and UTC (i.e., UT1-UTC) remains under 0.9 seconds, which allows easy access to UT1 through UTC for those applications that do not need high precision.
- **Currently UTC is used as low accuracy UT1 in many astronomical calculations, so UTC to be replaced by UT1 in the software.**
  - Terrestrial telescopes, antennas, and other instruments pointed in precise directions
  - Astronomical data in almanacs and websites employing the current definition of UTC
  - The provision of observed or predicted values and parameters to describe the orientation of the Earth with respect to astronomical reference systems.

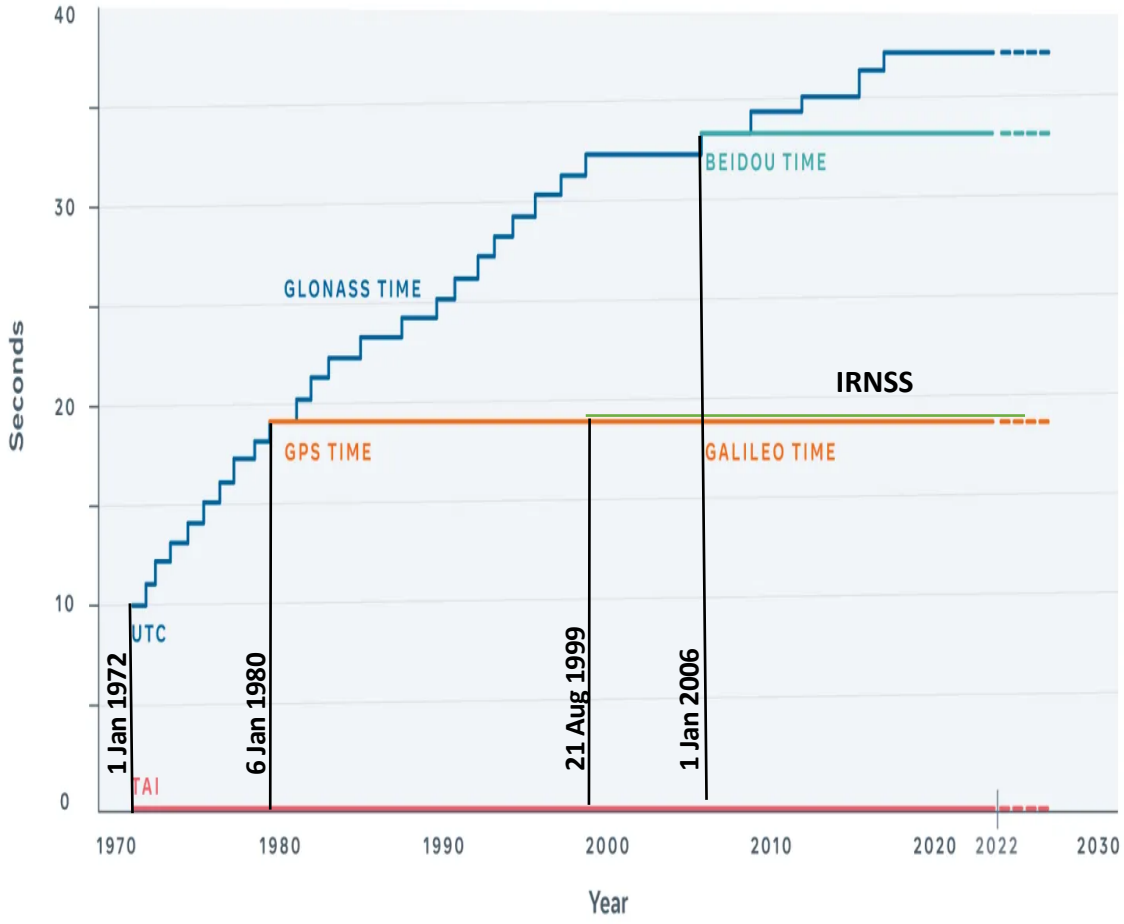
Precise Time Keeping For IRNSS/NavIC

IRNSS Network timing Facility (IRNWT) is a precise timing generation facility based on the ensemble of cesium (Cs) and Hydrogen Masers (AHM/PHM) atomic clocks, with appropriate time and frequency measurement equipments.

The NavIC Time has started from 22 August 1999 (after week rollover from Jan 1980) and was ahead of UTC by 13 sec. It is continuous timescale with out leap seconds correction.

- The NavIC Timescale is continuously steered to the reference timescale to UTC(NPLI)at NPLI, Delhi maintaining the required accuracy and stability.
- The Traceability to UTC is achieved through available Circular-T offsets for UTC-UTC(NPLI).

Offset between TAI and GNSS constellations



*The images are taken from open source website

Continuous UTC impact on NavIC

- **Impact of Continuous UTC on UT1-UTC difference in MT02/MT11:**

  Current broadcast can allow upto 1 minute of ut1-utc offset.

- **Impact of Continuous UTC on Orbit Modeling :**

  Orbit modeling and propagation utilizes the existing value of ut1-utc for the required epoch and day. If the IERS convention is same before and after Continuation of UTC, then there will be no impact.

- **All the internal definitions of UTC time for measurements tracking (Two way/Laser) and optical angles are to be modified to reference time for ease of handshaking.**

The existing SIS ICD field can support the offset of UT1 and UTC up to -64 to +63sec. The scenario of crossing this limit may take a century (average a leap second is added in ~ 21 months).

*Spare bits available to represent **UT1-UTC even up to 1hour (Calls for ICD change)***

NaviC Time Offsets And UT1-UTC Offset in Broadcast

SNO	Message Type	Broadcast Contents	Signal Type
1	9	A. NavIC-UTC B. Leap Second Current and Future	L5 and S
2	26	A. NavIC-UTC B. NavIC-UTC(NPLI) C. Leap Second Current and Future	L5 and S
3	17	A. NavIC-UTC B. NavIC-UTC(NPLI) C. Leap Second Current and Future	L1
4	10	UT1-UTC along with earth Orientation parameters data	L1
5	11	UT1-UTC along with earth Orientation parameters data	L5 and S

Thank You