IAU Division I Working Group "Nomenclature for Fundamental Astronomy" (NFA)

NFA WG EXPLANATORY DOCUMENT (DRAFT 3, 18 March 2005)

PART B3): GLOSSARY

This Glossary is part B3 of the NFA explanatory documents; it has to be considered in association with part B1 of these NFA documents which provides a chart illustrating the various transformations, and part B2 which provides a table, in various categories, summarizing the list of suggested symbols and abbreviations.

This document has resulted from detailed NFA WG discussions from October 2003 to February 2005 starting from a list that was originally mainly constructed by consulting the documents provided in the references.

The Glossary is divided into three sections. Section 1 contains the terms used in the IAU 2000 Resolutions along with a few newly proposed definitions, making a set of definitions for best implementing the resolutions. Section 2 a list of other terms where the definitions in section 1 have some impact together with some more general terms. Section 3 is an alphabetic list of the acronyms used in these definitions. Finally, there is a list of references.

The definitions provided in section 1 are compliant with IAU 2000 Resolutions including relativity, but this may not be the case for definitions in sections 2 that were made prior to the resolutions.

Note that the following definitions are provided with capitals, but this does not mean that they must be used with capitals.

1. Definition of terms used in the IAU 2000 Resolutions on reference systems and related concepts, including the new terms necessary for implementing the resolutions

(*the newly proposed are underlined*)

Barycentric Celestial Reference System (BCRS): a system of barycentric space-time coordinates for the solar system within the framework of General Relativity with metric tensor specified by the IAU 2000 Resolution B1.3. Formally, the metric tensor of the BCRS does not fix the coordinates completely, leaving the final orientation of the spatial axes undefined. However, for all practical applications, unless otherwise stated, the BCRS is assumed to be oriented according to the ICRS axes.

Barycentric Coordinate Time (TCB): the coordinate time of the BCRS; it is related to Geocentric Coordinate Time (TCG) and Terrestrial Time (TT) by relativistic transformations that include secular terms.

Barycentric Dynamical Time (TDB): a coordinate time defined originally to serve as an independent time argument of barycentric ephemerides and equations of motion. TDB was defined by the IAU 1976 resolutions to have no secular drift relative to Terrestrial Time (TT). However, because of the arbitrary distinction between secular and long-period variations and the changing nature of the periodic variations, no unique interpretation exists, and TDB can be realized only through an ephemeris. (See also Barycentric Ephemeris Time).

Barycentric Ephemeris Time (T_{eph}): an independent time argument of barycentric ephemerides. Such a time scale is a linear function of TCB, and each ephemeris defines its own version. The scaling between T_{eph} and TCB is chosen so that T_{eph} and TT remain, on the average, as close as possible for the time span covered by the particular ephemeris. At some level of accuracy, Teph and TDB implementations can be used interchangeably.

Celestial Ephemeris Origin (CEO): see the Celestial Intermediate Origin (CIO).

Celestial Intermediate Origin (CIO): origin for right ascension on the intermediate equator in the celestial intermediate reference system. It is the "non-rotating origin" (q.v.) in the GCRS that is recommended by the IAU 2000 Resolution B 1.8, where it was designated the Celestial Ephemeris Origin.

CIO locator: The CIO was initially set close to the mean equinox at J2000.0 but it reacts to the precession-nutation of the CIP by gradually and slowly moving away from the GCRS prime meridian according to the kinematical property of the "non-rotating origin". The CIO position is modelled using the quantity s, which apart from a fixed offset, is the difference between the GCRS and CIO right ascensions of the intersection of the GCRS and intermediate equators. By 2100 the CIO will be within 0.1 arcsecond of the GCRS meridian

CIO right ascension and declination: see intermediate right ascension and declination.

Celestial Intermediate Pole (CIP): geocentric equatorial pole defined by IAU 2000 Resolution B1.7 as being the intermediate pole, in the transformation from the GCRS to the ITRS, separating nutation from polar motion. The motion of the CIP is realized by the IAU 2000A precession-nutation plus time-dependent corrections provided by the IERS. It replaced the CEP on 1 January 2003. The motion of the CIP is defined so that its nutational motions with periods less than 2 days are modeled by their equivalent polar motion with respect to the terrestrial system.

Celestial Intermediate Reference System (CIRS): geocentric reference system related to the GCRS by a time-dependent rotation taking into account precession-nutation. It is defined by the intermediate equator (of the CIP) and CIO on a specific date. It is similar to the system based on the true equator and equinox of date, but the equatorial origin is at the CIO. Since the acronym for this system is close to another acronym (namely ICRS), it is suggested that wherever possible the complete name is used.

celestial pole offsets: time-dependent corrections to the precession-nutation model, determined by observations. The IERS provides the celestial pole offsets in the form of the differences, dX and dY, of the CIP coordinates in the GCRS with respect to the IAU 2000A precession-nutation model (i.e. the CIP is realized by the IAU 2000A precession-nutation plus these celestial pole offsets). In parallel the IERS also provides the offsets, $d\psi$ and $d\varepsilon$, in longitude and obliquity with respect to the IAU 1976/1980 precession/nutation model.

celestial pole offsets at J2000.0: offset of the direction of the CIP at J2000.0 (i.e. provided by the IAU 2000A precession-nutation) with respect to the GCRS (see frame bias).

Earth Rotation Angle (ERA): angle measured along the intermediate equator of the Celestial Intermediate Pole (CIP) between the Terrestrial Intermediate Origin (TIO) and the Celestial Intermediate Origin (CIO), positively in the retrograde direction. It is related to UT1 by a conventionally adopted expression in which ERA is proportional to UT1 (see IAU Resolution B1.8). Its time derivative is the Earth's angular velocity. Previously, it has been referred to as the Stellar Angle.

equation of the origins: distance between the equinox and the CIO along the intermediate equator; it is the CIO right ascension of the equinox; alternatively the difference between the Earth rotation angle and Greenwich apparent sidereal time (ERA – GAST).

equinox right ascension: right ascension that is measured from the equinox; also simply called right ascension.

frame bias: the three offsets of the celestial intermediate reference system with respect to the GCRS; the first two offsets are the celestial pole offsets at J2000.0 and the third is the offset in right ascension of the mean dynamical equinox of J2000.0 (q.v.).

Geocentric Celestial Reference System (GCRS): a system of geocentric space-time coordinates within the framework of General Relativity with metric tensor specified by the IAU 2000 Resolution B1.3. The GCRS is defined such that its spatial coordinates are kinematically non-rotating with respect to those of the BCRS. The equations of motion of, for example, an Earth satellite, with respect to the GCRS will contain relativistic Coriolis forces that come mainly from geodesic precession. The spatial orientation of the GCRS is defined by that of the BCRS, that is, unless otherwise stated, by the orientation of the ICRS.

Geocentric Coordinate Time (TCG): coordinate time of the GCRS. It is related to Terrestrial Time (TT) by a conventional linear transformation (see TT).

GCRS CIP coordinates: direction cosines of the CIP in the GCRS; they are currently expressed in the form of X and Y coordinates, in arcseconds, the values of which represent the corresponding angles with respect to the polar axis of the GCRS.

Geocentric Terrestrial Reference System (GTRS): a system of geocentric space-time coordinates within the framework of General Relativity, co-rotating with the Earth, and related to the GCRS by a spatial rotation which takes into account the Earth orientation parameters. It replaces the previously defined CTRS (q.v.).

ICRS place: a star direction in ICRS coordinates.

ICRS declination: declination measured from the ICRS equator.

ICRS right ascension: right ascension measured from the ICRS origin on the ICRS equator.

Intermediate Equator: equatorial plane through the center of the Earth and perpendicular to the direction of the Celestial Intermediate Pole (CIP) at some epoch (it is synonymous to instantaneous equator or true equator of date, or equator of the CIP).

intermediate place: direction of an object in the celestial intermediate reference system (e.g. intermediate right ascension and declination), analogous to an apparent place in the equinox based system, but the origin for intermediate right ascension is at the CIO.

intermediate right ascension and declination: angular coordinates measured in the Celestial Intermediate Reference System at a specific time. They specify a geocentric direction that differs from the ICRS direction by annual parallax, gravitational light deflection due to the solar system bodies, except the Earth, annual aberration, and the time-dependent rotation describing the transformation from the GCRS to the celestial intermediate reference system (they are similar to apparent right ascension and declination when referring to the equinox based system). Note that intermediate declination is identical to apparent declination.

International Celestial Reference Frame (ICRF): conceptually a set of extragalactic objects whose adopted positions and uncertainties realize the ICRS axes and give the uncertainties of the axes. Also the name of the radio catalog whose 212 defining sources are currently the most accurate realization of the ICRS. Note that the orientation of the ICRF catalog was carried over from earlier IERS radio catalogs and was within the errors of the standard stellar and dynamic frames at the time of adoption. Successive revisions of the ICRF are intended to minimize rotation from its original orientation. Other realizations of the ICRS have specific names (e.g. Hipparcos Celestial Reference Frame).

International Celestial Reference System (ICRS): the idealized barycentric coordinate system to which celestial positions are referred. It is kinematically non-rotating with respect to the ensemble of distant extragalactic objects. It has no intrinsic orientation but was aligned close to the mean equator and dynamical equinox of J2000.0 for continuity with previous fundamental reference systems. Its

orientation is independent of epoch, ecliptic or equator and is realized by a list of adopted coordinates of extragalactic sources.

International Terrestrial Reference Frame (ITRF): conceptually a realization of ITRS by a set of instantaneous coordinates (and velocities) of reference points distributed on the topographic surface of the Earth (mainly space geodetic stations and related markers). Currently the ITRF provides a model for estimating, to high accuracy, the instantaneous positions of these points, which is the sum of conventional corrections provided by the IERS Convention center (solid Earth tides, pole tides, ...) and of a "regularized" position. At present, the latter is modeled by a piecewise linear function, the linear part accounting for such effects as tectonic plate motion, post-glacial rebound, and the piecewise aspect representing discontinuities such as seismic displacements. The initial orientation of ITRF is that of the BIH Terrestrial System at epoch 1984.0.

International Terrestrial Reference System (ITRS): is a specific GTRS for which the co-rotation condition is defined as no residual rotation with regard to the Earth's surface and the geocenter is understood as the center of mass of the whole Earth system, including oceans and atmosphere (IUGG Resolution 2, Vienna 1991). It was aligned close to the mean equator of 1900 and the Greenwich meridian, for continuity with previous terrestrial reference systems. The ITRS is the recommended system to express positions on the Earth.

ITRS CIP coordinates (also called pole coordinates): direction cosines of the CIP in the ITRS. They are currently expressed in the form of x and y coordinates, in arcseconds, the values of which represent the corresponding angles with respect to the polar axis of the ITRS. The sign convention is such that x is positive towards the x-origin of the ITRS and y is in the direction 90° to the west of x.

Non-rotating origin: in the context of the GCRS or the ITRS this is the point on the intermediate equator such that its instantaneous motion with respect to the system (GCRS or ITRS as appropriate) has no component along the intermediate equator (i.e. its instantaneous motion is perpendicular to the intermediate equator). It is called CIO and TIO in the GCRS and ITRS, respectively.

offset in right ascension: GCRS right ascension of the inertial dynamical mean equinox of J2000.0.

polar motion: motion of the CIP in the ITRS. It includes the motion, in the absence of external torque, of the Earth's pole with respect to the Earth's crust (whose main components are Chandlerian and annual terms) and sub-daily variations caused by ocean tides not included in the polar motion values distributed by the IERS. These, therefore, are to be added after interpolation for the required date using a model provided by the IERS Conventions. It also includes nutational motions with periods less than 2 days that are modelled by their equivalent polar motion with respect to the terrestrial system

position of the CIP in the GCRS (see GCRS CIP coordinates): according to the definition of the CIP, this position results from (i) the part of precession-nutation (q.v.) with periods greater than 2 days, and (ii) the retrograde diurnal part of polar motion (including the free core nutation, FCN) and (iii) the frame bias.

position of the CIP in the ITRS (see ITRS CIP coordinates): according to the definition of the CIP, this position results from (i) the part of polar motion (q.v.) which is outside the retrograde diurnal band in the ITRS and (ii) the motion in the ITRS corresponding to nutations with periods less than 2 days.

precession-nutation: theoretically, the ensemble of effects of external torques on the motion of the Earth's axis in space (see the separate entries for precession and nutation below), or alternatively, the forced motion of the pole due to those external torques; it is the largest part of the motion of the CIP in the GCRS. The model currently recommended (IAU Resolution B1.6) is the IAU 2000A precession-

nutation that represents the CIP (note that an abridged model, designated IAU 2000B, is available for those who only need a model at the 1 mas level).

Stellar Angle: see the Earth Rotation Angle.

Terrestrial Dynamical Time (TDT): see Terrestrial Time.

Terrestrial Ephemeris Origin (TEO): see Terrestrial Intermediate Origin.

Terrestrial Intermediate Origin (TIO): origin of longitude in the intermediate terrestrial reference system. It is the "non-rotating origin" in the ITRS that is recommended by the IAU 2000 Resolution B 1.8, where it was designated Terrestrial Ephemeris Origin.

TIO locator: The TIO was initially set at the ITRS origin of longitude, but it reacts to polar motion by gradually and slowly moving away from that point according to the kinematical property of the "non-rotating origin". The TIO position is modelled using the quantity s', which, apart from a fixed offset, is the difference between the ITRS and instantaneous longitudes of the intersection of the ICRS and intermediate equators. The s' rate, which is due to current polar motion, is of the order of 40 μas/cy.

Terrestrial Intermediate Reference System (TIRS): geocentric reference system related to the celestial intermediate reference system by a rotation of ERA (Earth rotation angle) about the CIP axis. It is defined by the intermediate equator, CIP and TIO at a specific date. Since the acronym for this system is close to another acronym (namely ITRS), it is suggested that wherever possible the complete name is used.

Terrestrial Time (TT): a coordinate time whose mean rate is close to the mean rate of the proper time of an observer located on the rotating geoid. At 1977 January 1d 0h 0m 0s TAI the value of TT was exactly 1977 January 1.0003725 days. The unit of TT is the SI second or a day of 86 400 SI seconds. It is related to the Geocentric Coordinate Time (TCG) by a conventional linear transformation provided by IAU Resolution B1.9. TT may be used as the independent time argument for geocentric ephemerides. An accurate realization of TT is TT (TAI) = TAI + 32.184 s. In the past TT was also called Terrestrial Dynamical Time (TDT).

Universal Time (UT1): expression for the angle of the Earth's rotation about the CIP axis defined by its conventional linear relation to the Earth Rotation Angle (ERA). It is related by a mathematical formula to Greenwich apparent sidereal time. It is determined by observations (currently from VLBI observations of the diurnal motions of distant radio sources) and the corrections for non-uniform rotation are taken into account through the quantity *UT1–UTC*, which is provided by the IERS.

2. Other Terms

aberration: the apparent angular displacement of the observed position of a celestial object from its geometric position, caused by the finite velocity of light in combination with the motions of the observer and of the observed object. Annual aberration is due to the motion of the Earth around the Sun, while diurnal aberration is due to the Earth's rotation. In compiling star catalogs, it has often been the practice not to remove the secular part of stellar aberration.

apparent place: A geocentric position (e.g. apparent right ascension and declination) in the true equinox and equator of date reference system at a specific time in TCG or TT.

apparent right ascension and declination: angular coordinates in the true equator and equinox of date reference system at a specific time in TCG or TT. They are geocentric positions differing from the ICRS positions by annual parallax, gravitational light deflection due to the solar system bodies, except the Earth, annual aberration, and the time-dependent rotation describing the transformation

from the GCRS to the celestial intermediate reference system (they are similar to intermediate positions in the CIO based system but the apparent right ascension origin is at the equinox).

astrometric place: direction of a solar system body formed by applying the correction for the barycentric motion of this body during the light time to the geometric geocentric position referred to the ICRS. Such a position is then directly comparable with the astrometric position of star formed by applying the corrections for proper motion and annual parallax to the catalog direction at J2000. The gravitational deflection of light is ignored.

barycentric: centered at the solar system barycenter.

catalog equinox: the intersection of the hour circle of zero right ascension of a star catalog with the celestial equator.

catalog place: a star catalog position.

Celestial Ephemeris Pole (CEP): used from 1984 to 2003 with the IAU 1980 Theory of Nutation as the reference pole for nutation and polar motion; the axis of figure for the mean surface of a model Earth in which the free motion has zero amplitude. This pole was originally defined as having no nearly-diurnal nutation with respect to a space-fixed or Earth-fixed coordinate system and being realized by the IAU 1980 nutation. It was afterwards determined by VLBI observations including the celestial pole offsets. It is now replaced by the CIP which is defined by IAU 2000 Resolution B1.7.

Conventional International Origin: the international origin of polar motion adopted for use by the former International Latitude Service (ILS). It was defined in 1967 by an adopted set of astronomical latitudes of the 5 stations of the ILS. It approximately coincided with the mean pole of 1903.0. The current origin of polar motion is the ITRF pole. The acronym CIO for this origin should be avoided.

Conventional Terrestrial Reference System (CTRS): term used in the IUGG Resolution N°2 (1991) for designating the ideal terrestrial system to be defined from a geocentric non-rotating system by a spatial rotation. It is proposed to replace this designation by GTRS.

declination: angular distance north or south of the celestial equator. It is measured along the hour circle passing through the celestial object. Declination is usually given in combination with right ascension or hour angle.

dynamical mean equinox: the ascending node of the ecliptic on the mean equator. The mean equinox of epoch (to which the recent analytical and numerical solutions for the Moon and planets refer) corresponds to the definition of the ecliptic in its "inertial" sense. It differs by 93.66 mas from the "rotational dynamical mean equinox of J2000.0" (i.e. the FK5 equinox).

ecliptic: the plane perpendicular to the mean orbital angular momentum vector of the Earth-Moon barycenter. There is no unique interpretation; an ecliptic is defined by means of certain of the angles of the precession theory.

ephemeris meridian: a fictitious meridian that rotates independently of the Earth at the uniform rate implicitly defined by Terrestrial Time (TT).

Ephemeris time (ET): the time scale used prior to 1984 as the independent variable in gravitational theories of the solar system, with its unit and origin conventionally defined. It was superseded by TT and TDB.

epoch: a fixed date used to reckon time for expressing time varying quantities. It was traditionally expressed in terms of Besselian date, marked by the prefix B (e.g. B1950.0), with the tropical year as unit. It was given in Newtonian absolute time and could be associated with the use of Ephemeris Time. It is now expressed in the system of Julian date, marked by the prefix J (e.g. J2000.0), with the

Julian year of 365.25 days as unit. The term is also used as to refer a particular instant in time such as the 'epoch of observation'.

equation of the equinoxes: the right ascension of the mean equinox referred to the true equator and equinox; alternatively the difference between apparent sidereal time and mean sidereal time (GAST – GMST).

equinox: either of the two points at which the ecliptic intersects the celestial equator; also the time at which the Sun passes through either of these intersection points; i.e. when the apparent longitude of the Sun is 0° or 180°. When required, the equinox can be designated by the ephemeris of the Earth from which it is obtained (e.g. vernal equinox of DE 405). By 2100 the equinox will have moved 1.4 degrees from the ICRS meridian, due to the precession of the equinoxes.

fixed ecliptic: The ecliptic of a given ephemeris at an adopted epoch. Such a fixed ecliptic has a specified obliquity and crosses the ICRS equator at a specified offset from the ICRS origin.

geocentric: referring to the center of the Earth.

geodesic precession and nutation: the largest components (in fact the only non-negligible ones) of the relativistic rotation of the GCRS with respect to a dynamically non-rotating geocentric reference system in the framework of General Relativity. Geodesic precession is the secular part of the rotation and geodesic nutation is the periodic part. Geodesic precession and nutation are included in the IAU 2000 precession-nutation model which provides the rotation between the celestial intermediate reference system and the GCRS.

Greenwich mean sidereal time (GMST): Greenwich hour angle of the mean equinox defined by a conventional relationship involving Earth rotation angle or equivalently UT1.

Greenwich sidereal time (GST): Greenwich apparent sidereal time (GAST), the hour angle of the true equinox from the Terrestrial Intermediate Origin (TIO) meridian (Greenwich or International meridian).

J2000.0: defined in the framework of General Relativity by IAU Resolution C7 (1994) as being the event (epoch) at the geocenter and at the date 2000 January 1.5 TT = Julian Date 2451545.0 TT. Note that this event has different dates in different time scales.

mean equator: equator associated with a celestial pole whose direction is determined only by the precession portion of the precession-nutation transformation**.**

mean place: position of an object on the celestial sphere referred to the mean equator and equinox at a standard epoch.

moving celestial reference system: celestial reference system defined by the intermediate equator (alternatively true equator) and the CIO, or equinox. The coordinates are right ascension and declination with the origin and epoch to be specified.

natural place: the direction of a light ray from a source seen by an observer who is fixed in the BCRS but momentarily coincident with the geocenter; this direction includes the effects of parallax and light deflection, but not aberration.

nutation: the periodic part of the motion of the pole of rotation of a freely rotating body that is undergoing torque from external gravitational forces.

observed place: a topocentric place that includes the effect of refraction.

parallax: the difference in apparent direction of an object as seen from two different locations; annual parallax refers to the difference in directions as seen from the barycenter and the geocenter, while

diurnal parallax refers to the component of parallax due to the observer's separation from the geocenter.

pole coordinates: angular coordinates of the pole with respect to the terrestrial system.

precession: the uniformly progressing motion of the pole of rotation of a freely rotating body, undergoing torque from external gravitational forces. In the case of the Earth, the precession of the equator is caused by the Sun, the Moon and planets acting on the Earth's equatorial bulge; the precession of the equinox results both from the precession of the equator and the precession of the ecliptic, which is the secular part of the motion of the ecliptic with respect to the fixed ecliptic.

proper place: direction of an object in the GCRS (e.g. right ascension and declination); geocentric place that is corrected for light-time, light deflection, annual parallax and annual aberration.

reference frame: practical realization of a reference system, usually as a catalog of positions and motions of a certain number of fiducial points. For instance, the ICRF is the realization of the ICRS, where the ICRF points have no proper motions.

reference system: theoretical concept of a system of coordinates, including time and standards, necessary to specify the bases used to specify the position and motion of objects in time and space.

refraction: the bending of a ray of light as it passed through the Earth's atmosphere. Most commonly calculated using pressure, temperature, humidity and wavelength.

right ascension: angular distance measured eastward along the celestial equator from the CIO, or equinox, to the hour circle passing through the celestial object. Right ascension is given either in degrees, or in hours, minutes, and seconds. It is essential that the origin, CIO or equinox, of the right ascension be specified.

sidereal hour angle: 360 minus right ascension in degrees.

sidereal time: the measure of the angle defined by the apparent diurnal motion of the equinox; hence, a measure of the rotation of the Earth with respect to the celestial reference frame rather than the Sun. It is often expressed in hours, minutes, and seconds, one hour being equal to 15 degrees.

topocentric: a place that is centered at the surface of the Earth and dependent on the geographic location.

true equator of date: see celestial intermediate equator.

true equinox of date: intersection of the ecliptic with the intermediate (true) equator and designated by the ephemeris of the Earth from which it is obtained (e.g. true equinox of DE 405).

Universal Time (UT): a measure of time that conforms, within a close approximation, to the mean diurnal motion of the Sun and serves as the basis of all civil timekeeping. The term "UT" is used to designate either a member of the family of Universal Time scales (e.g. UTC), or the UT1 parameter for the Earth's angle of rotation (see UT1).

UT1 – UTC: difference between the UT1 parameter derived from observation and the uniform time scale UTC, currently defined as: $UTC=TAI$ + n, where n is an integer number of seconds, such that $UT1 - UTC<0.9$ s.

4. List of acronyms used in the Glossary

BCRS	Barycentric Celestial Reference System	ICRF	International Celestial Reference Frame
		ICRS	International Celestial Reference System
CEO	Celestial Ephemeris Origin	ITRF	International Terrestrial Reference Frame
CEP	Celestial Ephemeris Pole	ITRS	International Terrestrial Reference System
CIO	Celestial Intermediate Origin		
CIP	Celestial Intermediate Pole	T_{eph}	Barycentric Ephemeris Time
CIRS	Celestial Intermediate Reference System	TCB	Barycentric Coordinate Time
CTRS	Conventional Terrestrial Reference System	TCG	Geocentric Coordinate Time
		TDB	Barycentric Dynamical Time
ERA	Earth Rotation Angle	TEO	Terrestrial Ephemeris Origin
		TIO	Terrestrial Intermediate Origin
GCRS	Geocentric Celestial Reference System	TIRS	Terrestrial Intermediate Reference System
GTRS	Geocentric Terrestrial Reference System	TT	Terrestrial Time
GMST	Greenwich mean sidereal time	UT	Universal Time
GST	Greenwich sidereal time		

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