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Classification and parameter symbols for orbits and trajectories of spacecraft

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Classification and parameter symbols for orbits and trajectories of spacecraft

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FOREWORD

The standard is translated from the Chinese version of Standard on GB/T 29079-2012 released by Standardization Administration of China (SAC) under the management of State General Administration of Quality Supervision and Inspection and Quarantine. TC 425 is responsible for the translation. In case of any doubt about the contents of English version, the Chinese original shall be considered authoritative.

This standard is drafted in accordance with rules given in GB/T 1.1-2009.

This standard is proposed by China Aerospace Science and Technology Corporation.

This standard is under the jurisdiction of National Technical Committee on Space Technology and Operation of Standardization Administration of China (SAC/TC 425).

INTRODUCTION

This standard belongs to the National Standard System of China Space. The National Standard System of China Space is applicable to the formulation, revision, and management of national standards in the field of space, covering three sectors of space management, space technology, and space application and services and serving as the basis for guiding spacecraft and launch vehicle project management, engineering, space launch services, and in-orbit satellite applications.

During the process of spacecraft research and development in China, there are many concepts involved in various orbits, and there is a large amount of parameter symbols used. Different research and development institutes are not consistent with the use of orbit conception and parameter symbol. This statement brings many repetitions works and exchange barriers for spacecraft research and development. That by strictly defining and regulating the spacecraft orbit classification and related parameters can benefit for unifying the orbit classification and the use of parameter symbol so as to further improve the coordination of spacecraft engineering research and development as well as the consistency and validity of academic communication.

Classification and parameter symbols for orbits and trajectories of spacecraft

1 Scope

This standard defines the classifications of spacecraft orbits and trajectories and the commonly used parameter symbols of spacecraft orbits and trajectories.

This standard applies to the system design, orbit and trajectory design and related technical activities of artificial earth satellite, spaceship, space station, deep space probes and other spacecrafts. It also can be a reference for the orbit and trajectory design of deep space probes which revolution about other celestial body other than earth.

2 Spacecraft orbit and trajectory classification

2.1 Classification of orbit

2.1.1 Classification according to orbit eccentricity

2.1.1.1

circular orbit

an orbit that the eccentricity e meets e=0. The approximate circular orbits which orbital eccentricity close to zero also be called as circular orbit in engineering.

2.1.1.2

elliptical orbit

an orbit that the eccentricity e meets $0 < e < 1$.

2.1.1.3

parabolic orbit

an orbit that the eccentricity e meets $e = 1$.

2.1.1.4

hyperbolic orbit

an orbit that the eccentricity e meets $e > 1$.

2.1.2 Classification according to orbit inclination

2.1.2.1

prograde orbit

an orbit that the orbit inclination i meets $0° \leqslant i < 90°$.

2.1.2.2

retrograde orbit

an orbit that the orbit inclination i meets $90° < i \leqslant 180°$.

2.1.2.3

polar orbit

an orbit that the orbit inclination i meets $i = 90°$.The orbits which orbit inclination close to 90° are also called as polar orbit.

2.1.3 Classification according to orbit altitude

2.1.3.1

Low-Earth Orbit (LEO)

an earth orbit that the orbit altitude is low and usually lower than 2,000 km.

2.1.3.2

High-Earth Orbit (HEO)

an earth orbit that the orbit altitude is high and usually higher than 30,000 km. The elliptical orbits which apogee altitude are higher than 30,000 km are usually classified as the High-Earth Orbit.

2.1.3.3

Middle-Earth Orbit (MEO)

an earth orbit that the orbit altitude is between LEO and HEO.

2.1.4 Classification according to orbital plane precession direction

2.1.4.1

eastern precession orbit

an orbit that $\dot{\Omega}$ which is the change rate for right ascension of ascending node meets of $\dot{\Omega} > 0$. The range of orbit inclination for this kind of orbits is $90° < i < 180°$.

2.1.4.2

western retreat orbit

an orbit that $\dot{\Omega}$ which is the change rate for right ascension of ascending node meets $\dot{\Omega} < 0$. The range of orbit inclination for this kind of orbits is $0° < i < 90°$.

2.1.5 Classification according to different flight stages of spacecraft

2.1.5.1

initial orbit

an orbit that spacecraft injects after being separated from launch vehicle.

2.1.5.2

parking orbit

an orbit that spacecraft stays temporarily for transferring to another orbit.

2.1.5.3

transfer trajectory

a trajectory that spacecraft flight through for transferring from one orbit to another one, and also called as transition trajectory.

2.1.5.4

target orbit

an orbit that spacecraft operates to perform the predetermined mission.

2.1.5.5

disposal orbit

a final orbit that spacecraft enters into after predetermined mission completion or after mission termination due to malfunction.

2.1.6 Main orbits according to special classification

2.1.6.1

equatorial orbit

an orbit that the orbit inclination i meets $i = 0°$ or $i = 180°$, which means the orbital plane coincides with the equator plane of the Earth.

2.1.6.2

critical inclined orbit

an orbit that the orbit inclination i meets $i = 63.435°$ or $i = 116.565°$. For this kind of orbits, the secular perturbation for argument of perigee caused by J_2 which is one of earth gravity terms is zero.

2.1.6.3

Sun-Synchronous Orbit (SSO)

an eastward precession orbit which angular rate of orbital plane precession is equal to the average angular rate of the Sun moving at ecliptic plane.

2.1.6.4

Geosynchronous Orbit (GSO)

an earth satellite prograde orbit which orbital period is equal to rotation period of the Earth.

2.1.6.5

Geostationary Orbit (GEO)

an earth-synchronous orbit that both orbit inclination and eccentricity are equal to zero.

2.1.6.6

recursive orbit

an orbit that the sub-satellite track repeats periodically, and can also be called as a repeated orbit.

2.1.6.7

frozen orbit

an orbit that makes the two average value of argument of perigee and eccentricity remain constant，when the average value of argument of perigee is 90° or 270° and the average value of eccentricity is a specific value.

2.1.6.8

halo orbit

An orbit that spacecraft revolves around the libration point (Lagrange Point) periodically in the restricted three-body problem.

2.2 Classification of return trajectories

2.2.1

ballistic return trajectory

a return trajectory in which spacecraft can only produce a drag but not any lift, or without control of lift, after the Earth atmosphere reentry.

2.2.2

lift return trajectory

a return trajectory in which the lift-drag ratio of spacecraft is more than 0.5, and the direction of lift can be controlled by control of banking angle to adjust trajectory, after the Earth atmosphere reentry.

2.2.3

semi-ballistic return trajectory

a return trajectory in which the lift-drag ratio of spacecraft is not more than 0.5, and the direction of lift can be controlled by control of banking angle to adjust trajectory, after the Earth atmosphere reentry.

3 Parameter symbols of orbits and trajectories of spacecraft

3.1 General

The common parameter symbols of spacecraft orbit and trajectory include geophysical parameter symbols, orbit and trajectories parameters, earth station parameter symbols, and other symbols.

3.2 Symbolic representation methods

3.2.1 Symbol constitution

Usually, a basic symbol can be constituted by one or two Latin or Greek letters, and if necessary, some subscripts and other auxiliary illustrative symbols can be attached, which is shown in Figure 1.

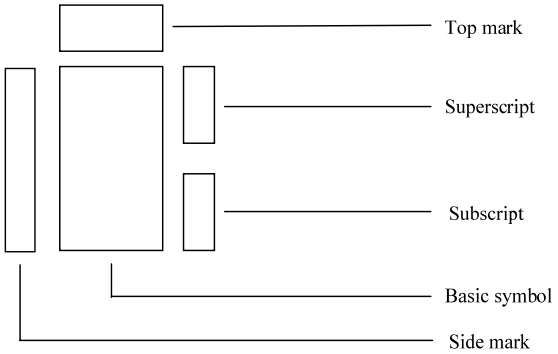

Figure 1 Schematic diagram on symbol constitution

3.2.2 Basic symbols

Basic symbols shall be used to express the basic meaning of parameters.

Example: v represents the velocity.

3.2.3 Auxiliary symbols

3.2.3.1 Subscript

3.2.3.1.1 The subscript shall be a supplement to the basic symbol and a further explanation for the meaning, characteristics or condition of parameters.

Example: v_0 represents the initial velocity.

3.2.3.1.2 The subscript which characterizes the coordinate system shall be listed usually at the end of subscript symbol.

Example: v_{0x} represents the projection of initial velocity vector in x axis of the coordinate system.

3.2.3.1.3 To avoid misunderstandings, some default symbols may be allowed.

3.2.3.1.4 For common subscripts, see Table 1.

Table 1

No.	Symbol	Description
1	0	Initial value
2	p	Perigee
3	a	Apogee
4	T	Earth station
5	e	Earth
6	s	Sun
7	m	Moon

3.2.3.2 Top-mark

The top-mark shall be used to represent mean value, relative quantity, vector, change rate and others.

Example: $\dot{\Omega}$ represents the change rate of right ascension of ascending node.

3.2.3.3 Superscript

The superscript shall be used to represent normalized value, dimensionless value and others.

3.2.3.4 Side mark

The side mark represents the increment or differentials of physical quantity and others.

Example: the symbol Δv represents the velocity increment.

3.3 Geophysical parameters and symbols

For geophysical parameters and symbols, see Table 2.

Table 2

No.	Parameter name	Symbol	Description
1	Equatorial radius of the earth ellipsoid	R_e	
2	Geometric flattening of the earth ellipsoid	α_e	the ratio of the difference between the semi-major axis length and semi-minor axis length to the semi-major axis length.
3	Earth eccentricity	e_e	the ratio of focal length to the major axis length.
4	Zonal harmonic coefficient	J_n	
5	Tesseral harmonic coefficient	C_{nm}, S_{nm}	
6	Earth gravity constant	GM	also used with μ.
7	Average radius of the earth	R_m	the radius of a sphere which volume is same as that of the earth.
8	Angular velocity of the earth rotation	ω_e	the angular velocity of the earth rotate with its axis of rotation toward east.

3.4 Orbit parameter symbols

3.4.1 Symbols of orbital elements

For symbols of orbital elements, see Table 3.

Table 3

No.	Parameter name	Symbol	Description
1	Semi-major axis	a	half of major axis length in elliptical orbit.
2	Eccentricity	e	the ratio of the distance between two focuses of elliptical orbit to the major axis length of elliptical orbit.
3	Orbit Inclination	i	the intersection angle between the positive normal direction of orbit plane and the direction from the earth center to north celestial pole.
4	Right ascension of ascending node	Ω	the geocentric angle from the vernal equinox to the ascending node in geocentric equatorial coordinate system, and measured from the vernal equinox toward east.
5	Argument of perigee	ω	the geocentric angle from the ascending node to the perigee in orbital plane, and measured from the ascending node to perigee along the movement direction of spacecraft.
6	Time of perigee passage	τ	

3.4.2 Basic orbit parameters and symbols

For basic orbit parameters and symbols, see Table 4.

Table 4

No.	Parameter name	Symbol	Description
1	Time	t	
2	Altitude	h	the distance between spacecraft and sub-satellite point.
3	Right ascension	α	the celestial equator arc length measured from the circle of right ascension through vernal equinox to the circle of right ascension through celestial body (or spacecraft) on a counterclockwise direction along the north celestial pole.
4	Declination	δ	the arc length of circle of right ascension between celestial body (or spacecraft) to celestial equator, measured from the beginning at celestial equator and be positive in direction of north celestial pole.
5	Geodetic longitude	L	the angle between Greenwich meridian plane and the meridian plane through celestial body (or spacecraft), measured eastward from Greenwich meridian plane.
6	Geodetic latitude	B	the angle between the normal of reference ellipsoid through celestial body (or spacecraft) and the equatorial plane, and be positive in north direction.
7	Geocentric latitude	φ	the angle between the equatorial plane and the connection line of celestial body (or spacecraft) and the earth center , and be positive in north direction.
8	Velocity	v	
9	Acceleration	a	

3.4.3 Other orbit parameter symbols

For other orbit parameter symbols, see Table 5.

Table 5

No.	Parameter name	Symbol	Description
1	Orbital period	T	the time for spacecraft moving a circle on orbit.
2	Average angular velocity	n	$n = 2\pi/T$.
3	Argument of latitude	u	the geocentric angular distance between spacecraft and ascending node in orbital plane, measured along the movement direction of spacecraft from the ascending node.
4	True anomaly	f	the geocentric angular distance between spacecraft and perigee in orbital plane, measured along the movement direction of spacecraft from the perigee.
5	Eccentric anomaly	E	the geocentric angular distance between perigee and intersection point that reverse extended perpendicular line of spacecraft to

No.	Parameter name	Symbol	Description
			major axis intersects with circumscribed circle of orbit ellipse, measured along the movement direction of spacecraft from the perigee.
6	Semi-latus rectum	p	half of chord length which passes through the focus and is perpendicular to the major axis of ellipse.
7	Self-minor axis	b	half of minor axis length in elliptical orbit.
8	Geocentric distance	r	the distance from the earth's center to spacecraft.
9	Geocentric distance of perigee	r_p	the distance from the earth's center to perigee.
10	Geocentric distance of apogee	r_a	the distance from the earth's center to apogee.
11	Geocentric distance of sub-satellite point	R_s	the distance from the earth's center to sub-satellite point.
12	Mean anomaly	M	$M = n(t - \tau)$.

3.5 Parameter symbols of the earth station

For parameter symbols of the earth station, see Table 6.

Table 6

No.	Parameter name	Symbol	Description
1	Geodetic longitude of earth station	L_T	
2	Geodetic latitude of earth station	B_T	
3	Geocentric latitude of earth station	φ_T	
4	Elevation	E	the angle between the local horizontal plane and the connection line of the earth station and spacecraft, and be positive in upward direction.
5	Azimuth	A	the angle between the north direction and the projection of connection line of the earth station and spacecraft in the horizontal plane, measured clockwise from North.
6	Slant range	ρ	the distance from the earth station to spacecraft.