TECHNICAL REPORT

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Space systems — Best practices for orbit elements at payload — LV separation

Systèmes spatiaux — Meilleures pratiques pour les éléments en orbite à charge utile — Séparation LV

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Foreword

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information.

The committee responsible for this document is ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Introduction

This Technical Report will provide a recommendatory method for post-launch assessment of the orbit elements precision at separation, which is conductive to improving international communication effect and reducing the risks from errors resulting from miscommunication. It can estimate the orbit elements precision at separation, provide the reference for fuel capacity design of launch vehicle and spacecraft, and then help to reduce the manufactory costs of rocket and payload.

Space systems — Best practices for orbit elements at payload — LV separation

1 Scope

This Technical Report provides the best practices for orbit elements at payload-LV separation. It includes orbit elements and calculation conditions, calculation method of orbit elements and their errors at elliptical orbit insertion of various payloads. The fit between the actual and expected values of orbit elements can be used as a criterion of commercial launch.

There are many different sets of orbit elements. Each is best suited for a particular application. The traditionally used set of orbital elements is called the set of Keplerian elements. This Technical Report gives the calculation method of Keplerian elements and the transformation method of all the other orbit elements, in order to satisfy different user's need.

Affected by terrestrial gravitational perturbation, lunisolar gravitation perturbation and other factors, orbit elements change slowly after orbit injection. Orbit elements calculation methods after separation are not included in this Technical Report.

The technical communication and specific progress for orbit elements is relatively easy to be agreed on by applying this Technical Report, which can contribute to avoiding possible disputes.

2 Symbols and abbreviated terms

2.1 Abbreviated terms

BIPM Bureau International des Poids et Mesures

CTP Conventional Terrestrial Pole

GAST Greenwich Apparent Sidereal Time

GMST Greenwich Mean Sidereal Time

GCRF Geocentric Celestial Reference Frame

GPS Global Positioning System

IERS International Earth Rotation and Reference System Service

IRM International Reference Meridian

ITRF International Terrestrial Reference Frame

ITRS International Terrestrial Reference System

LGEIF Launch Geocentric Equatorial Inertial Frame

LV Launch Vehicle

PZ90 Acronym of Russian Parametry Zemli 1990

SI International System of Units

TAI International Atomic Time

TCG Geocentric Coordinate Time

TDT Terrestrial Dynamical Time

THF Topocentric Horizon Frame

UT1 Universal Time

UTC Coordinated Universal Time

WGS84 World Geodetic System, 1984

2.2 Symbols

a semimajor axis

a_e earth semimajor axis of terrestrial ellipsoid IERS used in ITRS

b semiminor axis

E eccentric anomaly

e eccentricity

GM_e earth gravitational parameter used in ITRS

h_a apogee altitude

h_p perigee altitude

i inclination

M mean anomaly

n mean motion of satellite

p semilatus rectum

r_a apogee radius

r_p perigee radius

S_0 GAST at the time of payload – LV separation

T period

t_p time interval between the launch moment and the perigee passing

t_{SEP} time interval between the launch moment and the payload – LV separation

u argument of latitude

V velocity

V_x, V_y, V_z projection of velocity in LGEIF

x, y, z projection of position in LGEIF

α_e flattening of the earth

θ true anomaly

φ_{e0} geocentric latitude at launch point

λ_0 longitude at launch point

λ_N longitude of the ascending node in LGEIF

ω argument of perigee

ω_e angular velocity of the earth

Ω right ascension of the ascending node

3 Orbit elements and calculation conditions

3.1 Orbit elements

Six independent orbit elements describe the orbit of a satellite. Two elements describe orbit size and shape, three elements describe orbit orientation, and one element describes orbit location.

Orbit size and shape parameters include the following:

a) semimajor axis;

b) eccentricity;

c) semiminor axis;

d) semilatus rectum;

e) perigee radius;

f) apogee radius;

g) perigee altitude;

h) apogee altitude;

i) period;

j) mean motion.

Orbit orientation parameters include the following:

a) inclination;

b) right ascension of the ascending node;

c) argument of perigee;

d) longitude of the ascending node.

Satellite location parameters include the following:

a) true anomaly;

b) eccentric anomaly;

c) mean anomaly;

d) time past perigee;

e) time past ascending node;

f) argument of latitude.

The orbit elements are shown in Figure 1.

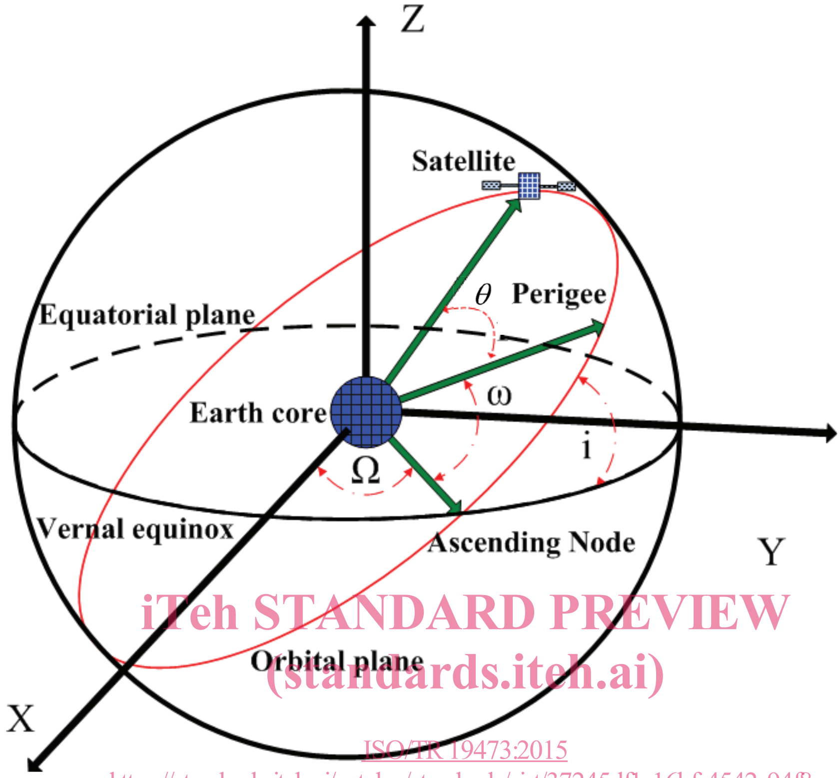

Figure 1 — Orbit elements

The orbit ellipse geometry is shown in Figure 2.

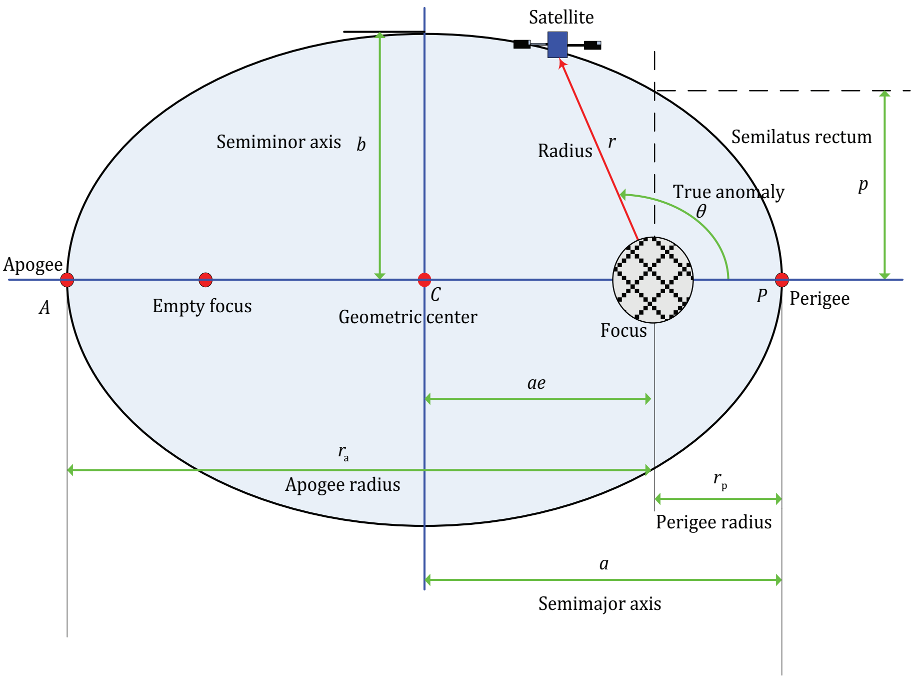

Figure 2 — Ellipse geometry

3.2 Data source

3.2.1 General

Calculation of orbit elements at separation uses velocity vector and position vector. Ground-based or space-based external measurements should be used.

3.2.2 Guideline of correction about the external measurements

a) Correction about lift-off time

Unified timer start point about different instruments is suggested to be specified. The timer start point needs to be corrected by lift-off time.

b) Correction about tracking point

Tracking point of different measurement instruments at flight region is suggested to be provided. The tracking point is usually transformed into LV navigation system coordinate frame. The data of tracking point correction is usually provided by system engineering department.

c) Correction about exception value

The measurement data need to pass a reasonable test and exception value needs to be deleted if necessary.

d) Correction about measurement data

The measurement data correction includes radio measurement and optical measurement. The measurement data based on ship is suggested to include ship drift position correction, ship deformation correction, and ship attitude correction.

e) Data format

Data format is based on decade float point and the bit numbers are determined by measurement accuracy and measurement mission.

3.2.3 External measurement data accuracy

a) Considering the need for flight test.

b) Considering the need for flight test result and injection accuracy.

c) Considering the need for external measurement accuracy.

d) Considering the accuracy, economy, and configuration about external measurement instrument in the flight region.

3.3 Coordinate systems and time systems

3.3.1 Coordinate systems

a) True Greenwich Frame

- The origin is located at the Earth's centre of mass (including oceans and atmosphere).
- The Z axis coincides with the instantaneous earth's axis of rotation and points northward.
- The x-axis is directed vertical to the Z axis and make X-Z plane coinciding with the plane of the true Greenwich meridian.
- The y-axis completes a right-handed system.