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Terms and symbols for flight dynamics – Part I : aircraft motion relative to the air

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FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO Member Bodies). The work of developing International Standards is carried out through ISO Technical Committees. Every Member Body interested in a subject for which a Technical Committee has been set up has the right to be represented on that Committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the Technical Committees are circulated to the Member Bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 1151 (originally draft No. 2117) was drawn up by Technical Committee ISO/TC 20, *Aircraft and space vehicles.*

It was approved in April 1971 by the Member Bodies of the following countries :

Austria	Greece	South Africa, Rep. of
Belgium	Israel	Spain
Czechoslovakia	Italy	Thailand
Egypt, Arab Rep. of	Japan	Turkey
France	Netherlands	United Kingdom
Germany	New Zealand	U.S.S.R.

No Member Body expressed disapproval of the document.

This International Standard cancels and replaces ISO Recommendation R1151-1969.

Printed in Switzerland

International Standard ISO 1151, *Terms and symbols for flight dynamics — Part I : Aircraft motion relative to the air,* is the first in a series of International Standards, the purpose of which is to define the principal terms used in flight dynamics and to specify symbols for these terms.

Other International Standards in this series, which will be further extended in the future, are at present as follows :

ISO 1152, *Terms and symbols for flight dynamics — Part II : Motions of the aircraft and the atmosphere relative to the Earth.*[1]

ISO 1153, *Terms and symbols for flight dynamics — Part III : Derivatives of forces, moments and their coefficients.*

ISO 2764, *Terms and symbols for flight dynamics — Part IV : Parameters used in the study of aircraft stability and control.*[2]

ISO 2765, *Terms and symbols for flight dynamics — Part V : Quantities used in measurements.*[2]

In these International Standards, the term "aircraft" denotes an aerodyne having a fore-and-aft plane of symmetry. This plane is determined by the geometrical characteristics of the aircraft. When there are more than one fore-and-aft planes of symmetry, the reference plane of symmetry is arbitrary and it is necessary to indicate the choice made.

Angles of rotation, angular velocites and moments about any axis are positive clockwise when viewed in the positive direction of the axis.

All the axis systems used are three-dimensional, orthogonal and right-handed, which implies that a clockwise (positive) rotation through $\pi/2$ about the x-axis brings the y-axis into the position previously occupied by the z-axis.

Numbering of sections and clauses

Each of these International Standards represents a part of the whole study on terms and symbols for flight dynamics.

To permit easier reference to a section or a clause from one part to another, a decimal numbering has been adopted which begins in each International Standard with the number of the part it represents.

1) In course of transformation into an International Standard. (At present, ISO/R 1152.)

2) At present at the stage of draft.

CONTENTS

Terms and symbols for flight dynamics – Part I : aircraft motion relative to the air

1.0 INTRODUCTION

This International Standard deals with the motion of the aircraft in an atmosphere at rest or in uniform motion.

To fully account for the effects of aeroelasticity and of the Earth's curvature would necessitate more detailed consideration of certain aspects of the definitions given, although these have been framed in such a way that they can be more generally interpreted. The definitions of the axes apply as they stand when the Earth's surface is treated as a plane, that is, when the Earth's radius is taken as infinite, and, in the case of the body axes, when the aircraft is treated as rigid.

1.1 AXIS SYSTEMS

No.	Term	Definition	Symbol
1.1.1	Earth-fixed axis system	A system with both origin O_o and axes fixed with respect to the Earth, chosen to suit the problem.	x_o, y_o, z_o
1.1.2	Normal earth-fixed axis system	An earth-fixed axis system (1.1.1) in which the z_o-axis is vertically downward.	x_o, y_o, z_o but x_g, y_g, z_g is an accepted alternative.
1.1.3	Aircraft-carried earth axis system	A system in which each axis has the same direction as the corresponding earth-fixed axis, with origin O, fixed in the aircraft, usually at the centre of gravity.	x_o, y_o, z_o
1.1.4	Aircraft-carried normal earth axis system	A system in which each axis has the same direction as the corresponding normal earth-fixed axis, with origin O, fixed in the aircraft, usually at the centre of gravity.	x_o, y_o, z_o but x_g, y_g, z_g is an accepted alternative.
1.1.5	Body axis system	Axis system fixed in the aircraft with origin O, usually the centre of gravity, containing the longitudinal axis, the transverse axis and the normal axis according to the following definitions :	x, y, z
	Longitudinal axis	An axis in the plane of symmetry or, if the origin lies outside this, in a parallel plane through the origin, and in some suitable forward direction.	x
	Transverse axis	An axis normal to the plane of symmetry, and positive to starboard.	y
	Normal axis	An axis in the plane of symmetry or, if the origin lies outside this, in the parallel plane through the origin, normal to the longitudinal axis, positive in the ventral sense (when viewed from the origin O).	z
1.1.6	Air-path axis system	Axis system with aircraft fixed origin O, usually the centre of gravity, and containing the following axes :	x_a, y_a, z_a
	x_a-axis (air-path axis)	An axis in the direction of the aircraft velocity (1.3.1).	x_a
	y_a-axis	An axis normal to the air-path axis and the z_a-axis defined below. It is positive to starboard.	y_a
	z_a-axis	An axis in the plane of symmetry, or, if the origin lies outside this, in the parallel plane through the origin and normal to the air-path axis. In normal flight conditions it is therefore ventral (when viewed from the origin O).	z_a

1.2 ANGLES

Orientation of the aircraft velocity with respect to the body axis system (see Figure 1).

No.	Term	Definition	Symbol
1.2.1	Angle of sideslip	The angle that the aircraft velocity (1.3.1) makes with the plane of symmetry of the aircraft. It is positive when the aircraft velocity component along the transverse axis (1.1.5) is positive. It has by convention the range $-\frac{\pi}{2} \leqslant \beta \leqslant \frac{\pi}{2}$	β
1.2.2	Angle of attack	The angle between the longitudinal axis (1.1.5) and the projection of the aircraft velocity (1.3.1) on the plane of symmetry. It is positive when the aircraft velocity component along the normal axis (1.1.5) is positive. It has by convention the range $-\pi < \alpha \leqslant \pi$	α

Transition from the aircraft-carried normal earth axis system to the body axis system is effected by the rotations Ψ, Θ, Φ defined below, taken in that order (see Figure 2).

NOTE — Analogous angles can be defined with respect to any aircraft-carried earth axis system. The same symbols Ψ, Θ, Φ, with appropriate suffixes as necessary, may then be used. On the other hand, the terms azimuth angle, inclination angle and bank angle refer only to the special case where the z_o-axis is vertical.

No.	Term	Definition	Symbol
1.2.3	Azimuth angle	The rotation (positive if clockwise) about the z_o (z_g)-axis which brings the x_o (x_g)-axis into coincidence with the projection of the longitudinal axis (1.1.5) on the horizontal plane through the origin O.	Ψ
1.2.4	Inclination angle (elevation)	The rotation in a vertical plane, following the rotation Ψ (1.2.3) and which brings the displaced x_o (x_g)-axis into coincidence with the longitudinal axis (1.1.5). It is positive when the x-axis lies above the horizontal plane through the origin O. It has by convention the range $-\frac{\pi}{2} \leqslant \Theta \leqslant \frac{\pi}{2}$	Θ
1.2.5	Bank angle	The rotation (positive if clockwise) about the longitudinal axis (1.1.5) which brings the displaced y_o (y_g)-axis into its final position y from the position it reached after rotation through Ψ (1.2.3).	Φ

Transition from the aircraft-carried normal earth axis system to the air-path axis system is effected by the rotations χ_a, γ_a and μ_a defined below, taken in that order (see Figure 3).

No.	Term	Definition	Symbol
1.2.6	Air-path azimuth angle (air-path track angle)	The rotation (positive if clockwise) about the z_o (z_g)-axis which brings the x_o (x_g)-axis into coincidence with the projection of the air-path x_a-axis (1.1.6) on the horizontal plane through the origin *O*.	χ_a
1.2.7	Air-path inclination angle (air-path climb angle)	The rotation in a vertical plane, following the rotation χ_a (1.2.6) which brings the displaced x_o (x_g)-axis into coincidence with the air-path x_a-axis (1.1.6). It is positive when the x_a-axis lies above the horizontal plane through the origin *O*. It has by convention the range $-\frac{\pi}{2} \leqslant \gamma_a \leqslant \frac{\pi}{2}$	γ_a
1.2.8	Air-path bank angle	The rotation (positive if clockwise) about the air-path x_a-axis (1.1.6) which brings the displaced y_o (y_g)-axis into its final position y_a from the position it reached after rotation through χ_a (1.2.6).	μ_a

1.3 VELOCITIES AND ANGULAR VELOCITIES

No.	Term	Definition	Symbol
1.3.1	Aircraft velocity	The velocity of the origin *O* of the body axis system (1.1.5) (usually the centre of gravity) relative to the air unaffected by the aerodynamic field of the aircraft. The corresponding scalar quantity is the airspeed.	$\vec{V}$ (V)
1.3.2	Speed of sound	The velocity of propagation of a sound wave in the ambient air unaffected by the aerodynamic field of the aircraft.	a
1.3.3	Mach number	The ratio of the airspeed (1.3.1) to the speed of sound (1.3.2). Equal to V/a	*M* is recommended. However the symbols *Ma* and $\mathcal{M}$ may be used if otherwise there would be a possibility of confusion.

No.	Term	Definition	Symbol
1.3.4	Aircraft velocity components	The components of the velocity $\vec{V}$, for any of the axis systems used.	
		In the axis systems 1.1.1 to 1.1.4 :	
		component along the x_o-axis	u_o
		component along the y_o-axis	v_o
		component along the z_o-axis	w_o
		In the body axis system (1.1.5) :	
		component along the longitudinal axis	u
		component along the transverse axis	v
		component along the normal axis	w
		NOTE — In the air-path axis system (1.1.6) the component along the x_a-axis is $u_a = V$.	In certain computations the velocity components may be written V_i where i is a dummy subscript.
1.3.5	Aircraft angular velocity	The angular velocity (corresponding scalar quantity) of the body axis system (1.1.5) relative to the Earth.	$\vec{\Omega}$ (Ω)
1.3.6	Angular velocity components	The components of the angular velocity $\vec{\Omega}$, for any of the axis systems.	
		In the axis systems 1.1.1 to 1.1.4 :	
		component about the x_o-axis	p_o
		component about the y_o-axis	q_o
		component about the z_o-axis	r_o
		In the body axis system (1.1.5) :	
	Rate of roll	component about the longitudinal axis	p
	Rate of pitch	component about the transverse axis	q
	Rate of yaw	component about the normal axis	r
			In certain computations the angular velocity components may be written Ω_i where i is a dummy subscript.

No.	Term	Definition	Symbol
1.3.7	Normalized angular velocities	The normalized form of the components of the angular velocity (1.3.5), formed as follows : In the body axis system (1.1.5) :	
	Normalized rate of roll	$\frac{pl}{V}$	p^*
	Normalized rate of pitch	$\frac{ql}{V}$	q^*
	Normalized rate of yaw	$\frac{rl}{V}$	r^*
		where l is the reference length (1.4.6). Similar normalized quantities can be formed for the other axis systems.	Analogous quantities using a constant reference speed in place of V (1.3.1) may also be defined. These require different symbols.

1.4 AIRCRAFT INERTIA, GEOMETRIC AND DYNAMIC CHARACTERISTICS

No.	Term	Definition	Symbol
1.4.1	Aircraft mass	The current mass of the aircraft.	m
1.4.2	Moments of inertia	The moments of inertia of the aircraft with respect to the body axes x, y, z (1.1.5). Moment of inertia about the longitudinal axis is $\int (y^2 + z^2)\mathrm{d}m$ Moment of inertia about the transverse axis is $\int (z^2 + x^2)\mathrm{d}m$ Moment of inertia about the normal axis is $\int (x^2 + y^2)\mathrm{d}m$	I_x I_y I_z (A, B, C are acceptable alternatives)
1.4.3	Products of inertia	The products of inertia of the aircraft with respect to the body axes x, y, z (1.1.5). These are : $\int yz\,\mathrm{d}m$ $\int zx\,\mathrm{d}m$ $\int xy\,\mathrm{d}m$	I_{yz} I_{zx} I_{xy} (D, E, F are acceptable alternatives)
1.4.4	Radius of gyration	The square root of the ratio of the moment of inertia to the aircraft mass (1.4.1) : for the longitudinal axis (1.1.5) $\sqrt{I_x/m}$ for the transverse axis (1.1.5) $\sqrt{I_y/m}$ for the normal axis (1.1.5) $\sqrt{I_z/m}$	r_x r_y r_z

No.	Term	Definition	Symbol
1.4.5	Reference area	An area used in forming various non-dimensional quantities. For the complete aircraft the most commonly used reference area is the gross wing area (i.e. the area obtained by continuing the edges within the fuselage and the nacelles). NOTE — Hinge moment coefficients are not usually based on this reference area.	S
1.4.6	Reference length	A length used in forming non-dimensional coefficients of the aerodynamic moments and various normalized quantities. In a given document this length has a specified constant value. In the absence of a length having some aerodynamic significance the choice should correspond to an easily established geometric feature. NOTE — Hinge moment coefficients are not usually based on this reference length.	l
1.4.7	Wing span	The distance between the two planes parallel to the plane of symmetry, tangential to the wing surface and lying wholly outside the aircraft.	b
1.4.8	Normalized mass	Non-dimensional coefficient defined as follows : $$\frac{m}{\frac{1}{2}\rho_e S l}$$ where m is the aircraft mass (1.4.1); ρ_e is a datum (air) density (3.3.2); S is the reference area (1.4.5); l is the reference length (1.4.6).	μ (m^*)
1.4.9	Dynamic unit of time	A quantity defined as follows : $$\frac{m}{\frac{1}{2}\rho_e V_e S} = \frac{\mu l}{V_e}$$ where m is the aircraft mass (1.4.1); ρ_e is a datum (air) density (3.3.2); V_e is a datum speed (3.3.1); S is the reference area (1.4.5); l is the reference length (1.4.6); μ is the normalized mass (1.4.8).	τ
1.4.10	Aerodynamic unit of time	A quantity defined as follows : $$\frac{l}{V_e}$$ where l is the reference length (1.4.6); V_e is a datum speed (3.3.1).	τ_A