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Flight dynamics — Concepts, quantities and symbols —

Part 1:
Aircraft motion relative to the air

Mécanique du vol — Concepts, grandeurs et symboles —

Partie 1: Mouvement de l'avion par rapport à l'air

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established 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. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 1151-1 was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles.*

This fourth edition cancels and replaces the third edition (ISO 1151-1 : 1985) of which it constitutes a technical revision: this fourth edition includes Draft Addenda ISO/DIS 1151-1/DAD 1, circulated in 1986 (addition of a symbol to 1.5.4, 1.6.1.3 and 1.6.2.9; new sub-clauses 1.4.10, 1.4.11, 1.5.10 to 1.5.13 and 1.10) and ISO/DIS 1151-1/DAD 2, circulated in 1986 (addition of annex B).

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

ISO 1151, *Flight dynamics — Concepts, quantities and symbols*, comprises, at present, seven parts:

Part 1 : Aircraft motion relative to the air.

Part 2 : Motions of the aircraft and the atmosphere relative to the Earth.

Part 3 : Derivatives of forces, moments and their coefficients.

Part 4 : Parameters used in the study of aircraft stability and control.

Part 5 : Quantities used in measurements.

Part 6 : Aircraft geometry.

Part 7 : Flight points and flight envelopes.

ISO 1151 is intended to introduce the main concepts, to include the more important terms used in theoretical and experimental studies and, as far as possible, to give corresponding symbols.

In all the parts comprising ISO 1151, the term "aircraft" denotes a vehicle intended for atmosphere or space flight. Usually, it has an essentially port and starboard symmetry with respect to a plane. That plane is determined by the geometric characteristics of the aircraft. In that plane, two orthogonal directions are defined: fore-and-aft and dorsal-ventral. The transverse direction, on the perpendicular to that plane, follows.

When there is a single plane of symmetry, it is the reference plane of the aircraft. When there is more than one plane of symmetry, or when there is none, it is necessary to choose a reference plane. In the former case, the reference plane is one of the planes of symmetry. In the latter case, the reference plane is arbitrary. In all cases, it is necessary to specify the choice made.

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

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

The centre of gravity coincides with the centre of mass if the field of gravity is homogeneous. If this is not the case, the centre of gravity can be replaced by the centre of mass in the definitions of ISO 1151; in which case, this should be indicated.

Numbering of sections and clauses

With the aim of easing the indication of references from a section or a clause, a decimal numbering system has been adopted such that the first figure is the number of the part of ISO 1151 considered.

Contents

Flight dynamics — Concepts, quantities and symbols —

Part 1:
Aircraft motion relative to the air

1.0 Introduction

This part of ISO 1151 gives basic definitions and deals with aircraft motion relative to the atmosphere, assumed to be at rest or in translational motion at constant velocity relative to the Earth. 1)

The aircraft is assumed to be rigid. However, most of the definitions can be applied to the case of a flexible aircraft.

When account is taken of the variations at the Earth's surface in the direction of the vertical (local direction of acceleration due to gravity), the term given in the sub-clauses and figures in question is qualified by the term "local".

1.1 Axis systems

No.	Term	Definition	Symbol
1.1.1	Earth-fixed axis system	A system with both the origin and axes fixed relative to the Earth, and chosen as appropriate.	$x_o y_o z_o$
1.1.2	Normal earth-fixed axis system	An earth-fixed axis system (1.1.1) in which the z_o-axis is oriented according to the downward vertical passing through the origin.	$x_o y_o z_o$ NOTE — However, $x_g y_g z_g$ is an acceptable 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 the origin fixed in the aircraft, usually 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 the origin fixed in the aircraft, usually the centre of gravity.	$x_o y_o z_o$ NOTE — However, $x_g y_g z_g$ is an acceptable alternative.
1.1.5	Body axis system 2)	A system fixed in the aircraft, with the origin, usually the centre of gravity, consisting of the following axes:	xyz
	Longitudinal axis	An axis in the reference plane (see foreword on p. iii) or, if the origin is outside that plane, in the plane through the origin, parallel to the reference plane.	x
	Transverse axis	An axis normal to the reference plane and positive to starboard.	y
	Normal axis	An axis completing the system. NOTE — This axis lies in the reference plane or is parallel to that plane. It is positive in the ventral sense.	z

1) The motions of the atmosphere for which this assumption does not hold true will be examined in another part of ISO 1151.

2) Usually, the origins of the axis systems defined in 1.1.5, 1.1.6 and 1.1.7 coincide. If that is not the case, it is necessary to distinguish the different origins by appropriate suffixes.

No.	Term	Definition	Symbol
1.1.6	Air-path axis system[1]	A system with the origin fixed in the aircraft, usually the centre of gravity, consisting of 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; lateral air-path axis; cross-stream 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; normal air-path axis	An axis — in the reference plane or, if the origin is outside that plane, parallel to the reference plane, and — normal to the air-path axis. The positive direction of this axis is chosen so as to complete the orthogonal, right-handed system $x_a y_a z_a$.	z_a
1.1.7	Intermediate axis system[1]	A system with the origin fixed in the aircraft, usually the centre of gravity, consisting of the following axes:	$x_e y_e z_e$
	x_e-axis	The projection of the air-path axis on the reference plane, or, if the origin is outside that plane, on the plane through the origin, parallel to the reference plane.	x_e
	y_e-axis	An axis normal to the reference plane and positive to starboard. NOTE — This axis coincides with the transverse axis (1.1.5) or is parallel to it.	y_e
	z_e-axis	An axis completing the axis system. NOTE — This axis coincides with the normal air-path axis (1.1.6) or is parallel to it.	z_e

1) Usually, the origins of the axis systems defined in 1.1.5, 1.1.6 and 1.1.7 coincide. If that is not the case, it is necessary to distinguish the different origins by appropriate suffixes.

1.2 Angles

1.2.1 Orientation of the aircraft velocity with respect to the body axis system (see figure 1)

No.	Term	Definition	Symbol
1.2.1.1	Angle of sideslip	The angle which the aircraft velocity (1.3.1) makes with the reference plane of the aircraft. It is positive when the aircraft velocity component along the transverse axis (1.1.5) is positive. According to convention, it has the range: $-\frac{\pi}{2} \leqslant \beta \leqslant \frac{\pi}{2}$	β
1.2.1.2	Angle of attack	The angle between the longitudinal axis (1.1.5) and the projection of the aircraft velocity (1.3.1) on the reference plane. It is positive when the aircraft velocity component along the normal axis (1.1.5) is positive. According to convention, it has the range: $-\pi < \alpha \leqslant \pi$	α

1.2.2 Transition from the aircraft-carried normal earth axis system to the body axis system

This transition is achieved by three rotations, defined below, performed in the following order: Ψ, Θ, Φ (see figure 2).

NOTE — Similar angles may 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. However, the terms "azimuth angle", "inclination angle" and "back angle" refer only to the specific case where the z_o-axis is vertical.

No.	Term	Definition	Symbol
1.2.2.1	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.	Ψ
1.2.2.2	Inclination angle	The rotation in a vertical plane, following the Ψ rotation (1.2.2.1), which brings the displaced $x_o(x_g)$-axis into coincidence with the longitudinal axis (1.1.5). It is positive when the positive portion of the x-axis lies above the horizontal plane through the origin. According to convention, it has the range: $-\frac{\pi}{2} \leqslant \Theta \leqslant \frac{\pi}{2}$	Θ
1.2.2.3	Bank angle	The rotation (positive, if clockwise) about the longitudinal axis (1.1.5), brings the displaced $y_o(y_g)$-axis into its final position y from the position it reached after the Ψ rotation (1.2.2.1).	Φ

1.2.3 Transition from the aircraft-carried normal earth axis system to the air-path axis system

This transition is achieved by three rotations, defined below, performed in the following order: χ_a, γ_a, μ_a (see figure 3).

No.	Term	Definition	Symbol
1.2.3.1	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.	χ_a
1.2.3.2	Air-path inclination angle; air-path climb angle	The rotation in a vertical plane, following the χ_a rotation (1.2.3.1), 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 positive portion of the x_a-axis lies above the horizontal plane through the origin. According to convention, it has the range: $-\frac{\pi}{2} \leqslant \gamma_a \leqslant \frac{\pi}{2}$	γ_a
1.2.3.3	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 the χ_a rotation (1.2.3.1).	μ_a

1.3 Velocities and angular velocities

No.	Term	Definition	Symbol
1.3.1	Aircraft velocity Airspeed	The velocity of the origin 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 magnitude of the aircraft velocity.	$\vec{V}$ 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

No.	Term	Definition	Symbol
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. The symbols Ma and $\mathscr{M}$ may be used if there is likely to be any confusion.
1.3.4	Aircraft velocity components	The components of the aircraft velocity (1.3.1), $\vec{V}$, 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 $u_a = V$.	The velocity components may be written V_i, where i is a number or letter subscript.
1.3.5	Aircraft angular velocity	The angular velocity of the body axis system (1.1.5) relative to the Earth.	$\vec{\Omega}$
	Aircraft angular speed	The magnitude of aircraft angular velocity.	Ω
1.3.6	Angular velocity components	The components of the aircraft angular velocity (1.3.5), $\vec{\Omega}$, for any of the axis systems used.	
		In the axis systems 1.1.1 to 1.1.4:	
		component along the x_o-axis	p_o
		component along the y_o-axis	q_o
		component along the z_o-axis	r_o
		In the body axis system (1.1.5):	
	Rate of roll	component along the longitudinal axis	p
	Rate of pitch	component along the transverse axis	q
	Rate of yaw	component along the normal axis	r
			The angular velocity components may be written Ω_i, where i is a number or letter subscript.

No.	Term	Definition	Symbol
1.3.7	Normalized angular velocities	The normalized form of the components of the aircraft angular velocity (1.3.5), defined 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); V is the airspeed (1.3.1). Similar normalized quantities can be formed for the other axis systems.	Similar 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, reference quantities and reduced parameters

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 xyz (1.1.5). Moment of inertia about the longitudinal axis: $\int(y^2 + z^2)\mathrm{d}m$	I_x
		Moment of inertia about the transverse axis: $\int(z^2 + x^2)\mathrm{d}m$	I_y
		Moment of inertia about the normal axis: $\int(x^2 + y^2)\mathrm{d}m$	I_z NOTE — 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 xyz (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} NOTE — D, E, F are acceptable alternatives.

No.	Term	Definition	Symbol
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
1.4.5	Reference area	An area used to define the aerodynamic coefficients and various normalized quantities. In a given document, one single reference area will be used the value of which shall be specified. NOTE — Although hinge moment coefficients are usually defined using specific reference areas, it may be more appropriate, in some cases, to use the single reference area adopted for the aircraft.	S
1.4.6	Reference length	A length used to define the aerodynamic moment coefficients and various normalized quantities. It is recommended, in a given document, that one single reference length be used the value of which shall be specified. NOTES 1 It is, however, acceptable to introduce two different reference lengths as regards the longitudinal motion and the lateral motion. These lengths shall also be specified. 2 Although hinge moment coefficients are usually defined using specific reference lengths, it may be more appropriate, in some cases, to use the single reference length adopted for the aircraft.	l
1.4.7	Normalized mass	A non-dimensional coefficient defined as follows: $\frac{m}{\frac{1}{2}\varrho_e S l}$ 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 or m^*
1.4.8	Dynamic unit of time	A quantity defined as follows: $\frac{m}{\frac{1}{2}\varrho_e V_e S} = \frac{\mu l}{V_e}$ 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 (1.4.7).	τ

No.	Term	Definition	Symbol
1.4.9	Aerodynamic unit of time	A quantity defined as follows: $\dfrac{l}{V_e}$ where l is the reference length (1.4.6); V_e is a datum speed (3.3.1).	τ_A
1.4.10	Inertia matrix	A symmetrical matrix the structure of which is as follows: $\boldsymbol{I} = \begin{pmatrix} I_x & -I_{xy} & -I_{zx} \\ -I_{xy} & I_y & -I_{yz} \\ -I_{zx} & -I_{yz} & I_z \end{pmatrix}$	$\boldsymbol{I}$
1.4.11	Inverse inertia matrix	The inverse of the inertia matrix (1.4.10). A symmetrical matrix the structure of which is as follows: $\boldsymbol{I}^{-1} = \boldsymbol{J} = \begin{pmatrix} J_{11} & J_{12} & J_{13} \\ J_{21} & J_{22} & J_{23} \\ J_{31} & J_{32} & J_{33} \end{pmatrix}$ where $J_{11} = (I_y I_z - I_{yz}^2)/\Delta$ $J_{22} = (I_z I_x - I_{zx}^2)/\Delta$ $J_{33} = (I_x I_y - I_{xy}^2)/\Delta$ $J_{12} = (I_{xy} I_z + I_{yz} I_{zx})/\Delta$ $J_{23} = (I_{yz} I_x + I_{zx} I_{xy})/\Delta$ $J_{31} = (I_{zx} I_y + I_{xy} I_{yz})/\Delta$ $J_{21} = J_{12}$ $J_{32} = J_{23}$ $J_{13} = J_{31}$ $\Delta = I_x I_y I_z - 2 I_{xy} I_{yz} I_{zx} - I_x I_{yz}^2 - I_y I_{zx}^2 - I_z I_{xy}^2$	$\boldsymbol{J}$

1.5 Forces, moments, coefficients and load factors

No.	Term	Definition	Symbol
1.5.1	Resultant force	The resultant vector of the system of forces acting on aircraft, including the airframe aerodynamic forces and propulsion forces, but excluding the gravitational, inertial and reaction forces due to contact with the Earth's surface.	$\vec{R}$
1.5.2	Components of the resultant force	The components of the resultant force vector, $\vec{R}$. In the body axis system (1.1.5):	
		component along the longitudinal axis	X
		component along the transverse axis	Y
		component along the normal axis	Z
		In the air-path axis system (1.1.6):	
		component along the x_a-axis	X_a
		component along the y_a-axis	Y_a
		component along the z_a-axis	Z_a

No.	Term	Definition	Symbol
1.5.3	Force coefficients	Non-dimensional coefficients of the components of the resultant force (1.5.2), defined as follows: In the body axis system (1.1.5): X force coefficient: $\frac{X}{\frac{1}{2}\varrho V^2 S}$ Y force coefficient: $\frac{Y}{\frac{1}{2}\varrho V^2 S}$ Z force coefficient: $\frac{Z}{\frac{1}{2}\varrho V^2 S}$ In the air-path axis system (1.1.6): X_a force coefficient: $\frac{X_a}{\frac{1}{2}\varrho V^2 S}$ Y_a force coefficient: $\frac{Y_a}{\frac{1}{2}\varrho V^2 S}$ Z_a force coefficient: $\frac{Z_a}{\frac{1}{2}\varrho V^2 S}$ where ϱ is the density (5.1.3) of the ambient air, unaffected by the aerodynamic field of the the aircraft; V is the airspeed (1.3.1); S is the reference area (1.4.5). NOTE — These definitions are not usually used in helicopter studies.	 C_X C_Y C_Z C_{Xa} C_{Ya} C_{Za}
1.5.4	Resultant moment	The resultant moment of the system of forces, forming the resultant force (1.5.1), about a reference point, usually the centre of gravity.	$\vec{Q}$

No.	Term	Definition	Symbol
1.5.5	Components of the resultant moment	The components of the resultant moment.	
		In the body axis system (1.1.5):	
	Rolling moment	component about the longitudinal axis	L
	Pitching moment	component about the transverse axis	M
	Yawing moment	component about the normal axis	N
		In the air-path axis system (1.1.6):	
	—	component about the x_a-axis	L_a
	—	component about the y_a-axis	M_a
	—	component about the z_a-axis	N_a
1.5.6	Moment coefficients	Non-dimensional coefficients of the components of the resultant moments (1.5.5), defined as follows:	
		In the body axis system (1.1.5):	
	Rolling moment coefficient	$\frac{L}{\frac{1}{2}\varrho V^2 Sl}$	C_l
	Pitching moment coefficient	$\frac{M}{\frac{1}{2}\varrho V^2 Sl}$	C_m
	Yawing moment coefficient	$\frac{N}{\frac{1}{2}\varrho V^2 Sl}$	C_n
		In the air-path axis system (1.1.6):	
	—	$\frac{L_a}{\frac{1}{2}\varrho V^2 Sl}$	C_{la}
	—	$\frac{M_a}{\frac{1}{2}\varrho V^2 Sl}$	C_{ma}
	—	$\frac{N_a}{\frac{1}{2}\varrho V^2 Sl}$	C_{na}
		where	
		ϱ is the density (5.1.3) of the ambient air, unaffected by the aerodynamic field of the aircraft;	
		S is the reference area (1.4.5);	
		V is the airspeed (1.3.1);	
		l is the reference length (1.4.6).	
		NOTE — These definitions are not usually used in helicopter studies.	
1.5.7	Total load factor vector	The ratio of the resultant force (1.5.1) to the magnitude of the weight of the aircraft, defined by the relationship:	$\vec{n}_t$
		$\vec{n}_t = \frac{\vec{R}}{mg}$	
		where	
		m is the aircraft mass (1.4.1);	
		g is the acceleration due to gravity at the point considered on the trajectory.	
		NOTES	
		1 The qualification "total" and the suffix t can be omitted, if there is not likely to be any confusion with the load factor, defined in 1.5.9.	
		2 A similar load factor can be defined for take-off and landing conditions, by introducing in the numerator the sum of the resultant force (1.5.1) and the ground contact forces.	

No.	Term	Definition	Symbol
1.5.8	Components of the total load factor vector	Components of the total load factor (1.5.7), $\vec{n_t}$, defined as follows: In the body axis system (1.1.5): component along the longitudinal axis: $n_{tx} = \frac{X}{mg}$ component along the transverse axis: $n_{ty} = \frac{Y}{mg}$ component along the normal axis: $n_{tz} = \frac{Z}{mg}$ In the air-path axis system (1.1.6): component along the x_a-axis: $n_{txa} = \frac{X_a}{mg}$ component along the y_a-axis: $n_{tya} = \frac{Y_a}{mg}$ component along the z_a-axis: $n_{tza} = \frac{Z_a}{mg}$ NOTES 1 The qualification "total" and the suffix t can be omitted, if there is not likely to be any confusion with the load factor, defined in 1.5.9. 2 The components of a similar load factor can be defined for take-off and landing conditions, by introducing in the numerator the appropriate components of the sum of the resultant force (1.5.1) and the ground contact forces.	n_{tx} n_{ty} n_{tz} n_{txa} n_{tya} n_{tza}
1.5.9	Load factor	A quantity equal to the ratio $\frac{-Z_a}{mg}$ NOTE — Provided it is specified, the load factor can be defined by the ratio $\frac{-Z}{mg}$	n

No.	Term	Definition	Symbol
1.5.10	Specific resultant[1)]	Ratio of the resultant force (1.5.1), $\vec{R}$, to the aircraft mass (1.4.1), m, defined by the following relationship: $\vec{r} = \frac{\vec{R}}{m}$ NOTE — A similar specific resultant can be defined for take-off and landing conditions, by introducing in the numerator the sum of the resultant force (1.5.1) and the ground contact forces.	$\vec{r}$
1.5.11	Components of the specific resultant	Components of the specific resultant (1.5.10), $\vec{r}$, defined as follows: In the body axis system (1.1.5): component along the longitudinal axis: $r_x = \frac{X}{m}$ component along the transverse axis: $r_y = \frac{Y}{m}$ component along the normal axis: $r_z = \frac{Z}{m}$ In the air-path axis system (1.1.6): component along the x_a-axis: $r_{xa} = \frac{X_a}{m}$ component along the y_a-axis: $r_{ya} = \frac{Y_a}{m}$ component along the z_a-axis: $r_{za} = \frac{Z_a}{m}$ NOTES — The components of a similar specific resultant can be defined for take-off and landing conditions, by introducing in the numerator the appropriate components of the sum of the resultant force (1.5.1) and the ground contact forces.	r_x r_y r_z r_{xa} r_{ya} r_{za}

1) The term "specific force", sometimes used for this quantity, shall be avoided.

No.	Term	Definition	Symbol
1.5.12	Specific resultant moment	Product of the inverse inertia matrix, (1.4.11), $\boldsymbol{J}$, by the resultant moment (1.5.4), $\vec{Q}$: $\vec{q} = \boldsymbol{J} \cdot \vec{Q}$ NOTE — A similar specific resultant moment can be defined for take-off and landing conditions, by adding the resultant moment of the ground contact forces to the resultant moment, $\vec{Q}$.	$\vec{q}$
1.5.13	Components of the specific resultant moment	Components of the specific resultant moment (1.5.12), $\vec{q}$, defined as follows in the body axis system (1.1.5): $q_x = J_{11} \cdot L + J_{12} \cdot M + J_{13} \cdot N$ $q_y = J_{21} \cdot L + J_{22} \cdot M + J_{23} \cdot N$ $q_z = J_{31} \cdot L + J_{32} \cdot M + J_{33} \cdot N$ NOTE — The components of a similar specific resultant moment can be defined for take-off and landing conditions, by adding the components of the resultant moment of the ground contact forces to the components of the resultant moment (1.5.4), $\vec{Q}$.	 q_x q_y q_z

1.6 Thrust, resultant moment of propulsive forces, airframe aerodynamic force, airframe aerodynamic moment, and their components

The system of forces acting on the aircraft, the resultant of which is defined in 1.5.1 and the resultant moment of which is defined in 1.5.4, excluding forces due to gravity, inertia and ground contact, may only be separated on an arbitrary basis into thrust forces due to the propulsive system and aerodynamic forces due to the airframe. It is impossible to define a general rule for the separation. The rule adopted shall be specified for each particular case.

In the following paragraphs, definitions are given for:

— the thrust (the resultant force of the system attributed to the propulsive system) and its components, the resultant moment of propulsive forces and its components.

— the airframe aerodynamic force and its components, the airframe aerodynamic moment and its components.

1.6.1 Thrust, resultant moment of propulsive forces, and their components

No.	Term	Definition	Symbol
1.6.1.1	Thrust	The resultant vector of the system of forces attributed to the propulsive system (see the introduction to 1.6). NOTE — It may be convenient, in some cases, to take into account the individual components of the thrust at the inlet and outlet of each engine.	$\vec{F}$
1.6.1.2	Components of the thrust	Components of the thrust, $\vec{F}$. In the body axis system (1.1.5): component along the longitudinal axis component along the transverse axis component along the normal axis In the air-path system (1.1.6): component along the x_a-axis component along the y_a-axis component along the z_a-axis	 F_x F_y F_z F_{xa} F_{ya} F_{za}

No.	Term	Definition	Symbol
1.6.1.3	(Resultant) moment of propulsive forces	The resultant moment of the system of forces attributed to the propulsive system (see 1.6.1.1 and the introduction to 1.6) relative to a point fixed in the aircraft, usually the centre of gravity. NOTE — This force system may include forces on the airframe generated by the propulsion system and which are not included in the thrust.	$\vec{Q}^{\mathrm{F}}$
1.6.1.4	Components of the (resultant) moment of propulsive forces	Components of the resultant moment of propulsive forces. In the body axis system (1.1.5): component about the longitudinal axis component about the transverse axis component about the normal axis In the air-path axis system (1.1.6): component about the x_{a}-axis component about the y_{a}-axis component about the z_{a}-axis	 L^{F} M^{F} N^{F} $L_{\mathrm{a}}^{\mathrm{F}}$ $M_{\mathrm{a}}^{\mathrm{F}}$ $N_{\mathrm{a}}^{\mathrm{F}}$

1.6.2 Airframe aerodynamic force, airframe aerodynamic moment, and their components

No.	Term	Definition	Symbol
1.6.2.1	(Airframe) aerodynamic force	The resultant vector of the system of forces attributed to the airframe (see the introduction to 1.6).	$\vec{R}^{\mathrm{A}}$ NOTE — Where there is no possibility of confusion, the superscript A may be omitted.
1.6.2.2	Components of the (airframe) aerodynamic force	Components of the airframe aerodynamic force, $\vec{R}^{\mathrm{A}}$. In the body axis system (1.1.5): component along the longitudinal axis component along the transverse axis component along the normal axis In the air-path axis system (1.1.6): component along the x_{a}-axis component along the y_{a}-axis component along the z_{a}-axis	 X^{A} Y^{A} Z^{A} $X_{\mathrm{a}}^{\mathrm{A}}$ $Y_{\mathrm{a}}^{\mathrm{A}}$ $Z_{\mathrm{a}}^{\mathrm{A}}$ NOTE — Where there is no possibility of confusion, the superscript A may be omitted.
1.6.2.3	Axial force	The component of $\vec{R}^{\mathrm{A}}$ (1.6.2.1) along the x-axis of the body axis system (1.1.5), but in the reverse direction, i.e.: $-X^{\mathrm{A}}$	1)

1) See the table in annex A.

No.	Term	Definition	Symbol
1.6.2.4	Transverse force; side force	The component of $\vec{R}^A$ (1.6.2.1) along the y-axis of the body axis system (1.1.5), i.e.: $+Y^A$	1)
1.6.2.5	Normal force	The component of $\vec{R}^A$ (1.6.2.1) along the z-axis of the body axis system (1.1.5), but in the reverse direction, i.e.: $-Z^A$	1)
1.6.2.6	Drag	The component of $\vec{R}^A$ (1.6.2.1) along the x_a-axis of the air-path axis system (1.1.6), but in the reverse direction, i.e.: $-X_a^A$	1)
1.6.2.7	Cross-stream force; lateral force	The component of $\vec{R}^A$ (1.6.2.1) along the y_a-axis of the air-path axis system (1.1.6), i.e.: $+Y_a^A$	1)
1.6.2.8	Lift	The component of $\vec{R}^A$ (1.6.2.1) along the z_a-axis of the air-path axis system (1.1.6), but in the reverse direction, i.e.: $-Z_a^A$	1)
1.6.2.9	(Airframe) aerodynamic moment	The resultant moment of the system of forces attributed to the airframe (see 1.6.2.1 and the introduction to 1.6) relative to a point fixed in the aircraft, usually the centre of gravity.	$\vec{Q}^A$
1.6.2.10	Components of the (airframe) aerodynamic moment	Components of the airframe aerodynamic moment. In the body axis system (1.1.5): component about the longitudinal axis component about the transverse axis component about the normal axis In the air-path axis system (1.1.6): component about the x_a-axis component about the y_a-axis component about the z_a-axis	 L^A M^A N^A L_a^A M_a^A N_a^A NOTE — Where there is no possibility of confusion, the superscript A may be omitted.

1) See the table in annex A.

NOTE — In the absence of agreement on suitably simple symbols, the forces considered in 1.6.2.3 to 1.6.2.8 are expressed in terms of the symbols of 1.6.2.2. In order to aid discussions on a national basis geared towards drawing up an international set of symbols, a table showing the correspondence between the symbols in use or coming into use, in various countries, is given in annex A.

1.7 Coefficients of the components of the thrust, of the resultant moment of propulsive forces, of the airframe aerodynamic force and of the airframe aerodynamic moment

In definitions 1.7.1.1 to 1.7.2.8:

ϱ is the density (5.1.3) of the ambient air, unaffected by the aerodynamic field of the aircraft;

V is the airspeed (1.3.1);

S is the reference area (1.4.5);

l is the reference length (1.4.6).

1.7.1 Coefficients of the components of the thrust, and of the resultant moment of propulsive forces

No.	Term	Definition	Symbol
1.7.1.1	—	Non-dimensional coefficients of the components of the thrust (1.6.1.2), defined as follows:	
		In the body axis system (1.1.5):	
		$\frac{F_x}{\frac{1}{2}\varrho V^2 S}$	C_X^F
		$\frac{F_y}{\frac{1}{2}\varrho V^2 S}$	C_Y^F
		$\frac{F_z}{\frac{1}{2}\varrho V^2 S}$	C_Z^F
		In the air-path axis system (1.1.6):	
		$\frac{F_{xa}}{\frac{1}{2}\varrho V^2 S}$	C_{Xa}^F
		$\frac{F_{ya}}{\frac{1}{2}\varrho V^2 S}$	C_{Ya}^F
		$\frac{F_{za}}{\frac{1}{2}\varrho V^2 S}$	C_{Za}^F
1.7.1.2	—	Non-dimensional coefficients of the components of the resultant moment of propulsive forces (1.6.1.4), defined as follows:	
		In the body axis system (1.1.5):	
		$\frac{L^F}{\frac{1}{2}\varrho V^2 S l}$	C_l^F
		$\frac{M^F}{\frac{1}{2}\varrho V^2 S l}$	C_m^F
		$\frac{N^F}{\frac{1}{2}\varrho V^2 S l}$	C_n^F
		In the air-path axis system (1.1.6):	
		$\frac{L_a^F}{\frac{1}{2}\varrho V^2 S l}$	C_{la}^F
		$\frac{M_a^F}{\frac{1}{2}\varrho V^2 S l}$	C_{ma}^F
		$\frac{N_a^F}{\frac{1}{2}\varrho V^2 S l}$	C_{na}^F

1.7.2 Coefficients of the components of the airframe aerodynamic force and of the airframe aerodynamic moment

No.	Term	Definition	Symbol
1.7.2.1	—	Non-dimensional coefficients of the components of the airframe aerodynamic force (1.6.2.2), defined as follows: In the body axis system (1.1.5): $\frac{X^A}{\frac{1}{2}\varrho V^2 S}$ $\frac{Y^A}{\frac{1}{2}\varrho V^2 S}$ $\frac{Z^A}{\frac{1}{2}\varrho V^2 S}$ In the air-path axis system (1.1.6): $\frac{X_a^A}{\frac{1}{2}\varrho V^2 S}$ $\frac{Y_a^A}{\frac{1}{2}\varrho V^2 S}$ $\frac{Z_a^A}{\frac{1}{2}\varrho V^2 S}$	C_X^A C_Y^A C_Z^A C_{Xa}^A C_{Ya}^A C_{Za}^A NOTE — Where there is no possibility of confusion, the superscript A may be omitted.
1.7.2.2	Axial force coefficient	A non-dimensional coefficient defined as follows: $\frac{\text{Axial force}}{\frac{1}{2}\varrho V^2 S}$ where the axial force is as defined in 1.6.2.3.	1)
1.7.2.3	Transverse force coefficient; side force coefficient	A non-dimensional force coefficient defined as follows: $\frac{\text{Transverse force}}{\frac{1}{2}\varrho V^2 S}$ where the transverse force is as defined in 1.6.2.4.	1)
1.7.2.4	Normal force coefficient	A non-dimensional coefficient defined as follows: $\frac{\text{Normal force}}{\frac{1}{2}\varrho V^2 S}$ where the normal force is as defined in 1.6.2.5.	1)

1) See the table in annex A.

No.	Term	Definition	Symbol
1.7.2.5	Drag coefficient	A non-dimensional coefficient defined as follows: $$\frac{\text{Drag}}{\frac{1}{2}\varrho V^2 S}$$ where the drag is as defined in 1.6.2.6.	1)
1.7.2.6	Cross-stream force coefficient; lateral force coefficient	A non-dimensional coefficient defined as follows: $$\frac{\text{Cross-stream force}}{\frac{1}{2}\varrho V^2 S}$$ where the cross-stream force is as defined in 1.6.2.7.	1)
1.7.2.7	Lift coefficient	A non-dimensional coefficient defined as follows: $$\frac{\text{Lift}}{\frac{1}{2}\varrho V^2 S}$$ where the lift is as defined in 1.6.2.8.	1)
1.7.2.8	—	Non-dimensional coefficients of the components of the airframe aerodynamic moment (1.6.2.10), defined as follows: In the body axis system (1.1.5): $$\frac{L^A}{\frac{1}{2}\varrho V^2 S l}$$ $$\frac{M^A}{\frac{1}{2}\varrho V^2 S l}$$ $$\frac{N^A}{\frac{1}{2}\varrho V^2 S l}$$ In the air-path axis system (1.1.6): $$\frac{L_a^A}{\frac{1}{2}\varrho V^2 S l}$$ $$\frac{M_a^A}{\frac{1}{2}\varrho V^2 S l}$$ $$\frac{N_a^A}{\frac{1}{2}\varrho V^2 S l}$$	C_l^A C_m^A C_n^A C_{la}^A C_{ma}^A C_{na}^A NOTE — Where there is no possibility of confusion, the superscript A may be omitted

1) See the table in annex A.

1.8 Forces and moments involved in the control of the aircraft[1]

1.8.1 Control force and control moment

The motion of the aircraft is determined by changes in the resultant force (1.5.1) and/or in the resultant moment (1.5.4).

No.	Term	Definition	Symbol
1.8.1.1	Controlling force	The change in the resultant force (1.5.1) intended to control the motion of the aircraft. NOTE — Direct force control is the method consisting of changing the resultant force directly by control forces (for example: direct lift control, direct lateral force control, change in the thrust vector). Direct force control is quite distinct from the method consisting of changing the resultant force by changes of aircraft attitude under the effect of control moments (1.8.1.2).	—
1.8.1.2	Controlling moment	The change in the resultant moment (1.5.4) intended to control the motion of the aircraft.	—

1.8.2 Motivators

The control forces and control moments are created by means of motivators.

A motivator is an output component of the aircraft control system and an input component for the aircraft motion.

No.	Term	Definition	Symbol
1.8.2.1	Motivator	A device, or set of devices, provided to create a control force (1.8.1.1) and/or a control moment (1.8.1.2), and brought into play by means of the aircraft control system. The motivators may be of several types (for example, aerodynamic motivators, jet motivators, propulsion motivators). The motivator consists of one or several movable components the angular or linear positions of which are determined by the aircraft control system. NOTES 1 It is recommended that the motivator be designated by reference to the resultant force component and/or the resultant moment component that it changes (for example, pitch motivator). 2 The same movable component can be a component of different motivators (for example, the elevon is a component of the pitch motivator and the roll motivator).	—
1.8.2.2	Aerodynamic motivator	A motivator (1.8.2.1) consisting of a movable aerodynamic surface (6.5) or of one or several movable components (6.0.2) of an aerodynamic surface. The control forces (1.8.1.1) or control moments (1.8.1.2), generated through an aerodynamic motivator, are components of the airframe aerodynamic force (1.6.2.1) or the airframe aerodynamic moment (1.6.2.9).	—

1) The term "control" is used in the sense of an input to a system.

1.8.3 Deflections of aerodynamic motivators

The following definitions refer to the positions of the motivators and not those of the piloting controls.

No.	Term	Definition	Symbol
1.8.3.1	Neutral position of a motivator component	Particular setting (6.1.10 to 6.1.15) of the motivator component (1.8.2.1) in question which shall be specified.	—
1.8.3.2	Geometric deflection of a motivator component	In the case where the setting of a motivator component (6.1.10 to 6.1.15) may be completely defined by a suitably chosen geometric parameter, the geometric deflection is the variation of that parameter relative to the value it takes when the component is in the neutral position (1.8.3.1). NOTES 1 The deflection may be an angular or linear variation of the setting. 2 The positive direction of the geometric deflection of a motivator component cannot be defined in the same way for all motivator components, but it should be specified in each particular case not covered by this part of ISO 1151 (see 1.8.3.6).	$\delta \ldots$ NOTE — The symbol δ is followed by one or several alpha-numeric suffixes which characterize the element considered.
1.8.3.3	Hinge line (of a motivator component)	In the case where the variation of the setting (6.1.10 to 6.1.15) of the motivator component in question is only a rotation, the hinge line is the straight line about which that component pivots.	—
1.8.3.4	Hinge line axis (of a motivator component)	Axis carrying the hinge line (1.8.3.3) the orientation of which is chosen according to convention. If the hinge line is approximately parallel to an axis of the main part (see 6.0.2) to which the motivator component belongs (1.8.2.1), the hinge line axis is orientated along that axis.	—
1.8.3.5	Reference axis system (of a motivator component)	Reference axis system (6.1.9) for the motivator component. In the case where a hinge line axis (1.8.3.4) exists, that axis is one of the axes of the reference axis system.	—
1.8.3.6	Deflection angle (of a motivator component)	Angle characterizing the geometric deflection of a motivator component (1.8.3.2) which moves about a hinge line (1.8.3.3). The positive direction of deflection angles is the positive direction of rotations about the hinge line axis (1.8.3.4).	$\delta \ldots$ (see 1.8.3.2)
1.8.3.7	Motivator deflection	When the motivator consists of a single component, the motivator deflection is identical to the geometric deflection (1.8.3.2) of that component. When the motivator consists of several components, an equivalent motivator deflection may be defined with a view to its use in the equations of aircraft motion. The definition of equivalence shall be specified.	δ_i [1)]
1.8.3.8	Longitudinal force motivator deflection	The motivator deflection (1.8.3.7) producing a control force (1.8.1.1) mainly in the direction of the longitudinal axis (1.1.5).	δ_X
1.8.3.9	Transverse force motivator deflection	The motivator deflection (1.8.3.7) producing a control force (1.8.1.1) mainly in the direction of the transverse axis (1.1.5).	δ_Y
1.8.3.10	Normal force motivator deflection	The motivator deflection (1.8.3.7) producing a control force (1.8.1.1) mainly in the direction of the normal axis (1.1.5).	δ_Z

1) Associated with each motivator is a principal effect that changes one of the components of the resultant force (1.5.2) or the resultant moment (1.5.5). In the symbol assigned to the motivator deflection (1.8.3.7), the suffix relates to that principal effect.

No.	Term	Definition	Symbol
1.8.3.11	Roll motivator deflection	The motivator deflection (1.8.3.7) producing a control moment (1.8.1.2) mainly about the longitudinal axis (1.1.5).	δ_l or ξ
1.8.3.12	Pitch motivator deflection	The motivator deflection (1.8.3.7) producing a control moment (1.8.1.2) mainly about the transverse axis (1.1.5).	δ_m or η
1.8.3.13	Yaw motivator deflection	The motivator deflection (1.8.3.7) producing a control moment (1.8.1.2) mainly about the normal axis (1.1.5).	δ_n or ζ

1.8.4 Control force coefficients and control moment coefficients

No.	Term	Definition	Symbol
1.8.4.1	Aerodynamic control force	The control force (1.8.1.1) created by aerodynamic motivators (1.8.2.2).	—
1.8.4.2	Components of the aerodynamic control	Components of the aerodynamic control force (1.8.4.1) in a reference axis system. NOTE — According to the problem in question, the reference axis system may be one of those given in clause 1.1 or a special axis system (for example, 1.8.3.5).	—
1.8.4.3	Aerodynamic control force coefficient	Non-dimensional coefficients of the components of the aerodynamic control force (1.8.4.2), defined as follows: $\dfrac{\text{Component of the aerodynamic control force}}{\frac{1}{2}\varrho V^2 S}$ where ϱ is the density of the air (5.1.3); V is the airspeed (1.3.1); S is the reference area (1.4.5). NOTE — Aerodynamic control force coefficients may be defined using the particular reference quantities appropriate to the problem in question.	—
1.8.4.4	Aerodynamic control moment	The control moment (1.8.1.2) created by aerodynamic motivators (1.8.2.2).	—
1.8.4.5	Components of the aerodynamic control moment	Components of the aerodynamic control moment (1.8.4.4) in a reference axis system. NOTE — According to the problem in question, the reference axis system may be one of those given in clause 1.1 or a special axis system (for example, 1.8.3.5).	—
1.8.4.6	Aerodynamic control moment coefficients	Non-dimensional coefficients of the components of the aerodynamic control moment (1.8.4.5), defined as follows: $\dfrac{\text{Component of the aerodynamic control moment}}{\frac{1}{2}\varrho V^2 S l}$ where ϱ is the density of the air (5.1.3); V is the airspeed (1.3.1); S is the reference area (1.4.5); l is the reference length (1.4.6). NOTE — Aerodynamic control moment coefficients may be defined using the particular reference quantities appropriate to the problem in question.	—

Definitions similar to the definitions given in 1.8.4.1 to 1.8.4.6 may be given for control forces (1.8.1.1) and control moments (1.8.1.2) created by motivators other than the aerodynamic motivators (1.8.2.2).

1.9 Forces and moments acting on the motivators

In 1.9.1 to 1.9.3 the definitions are given for the moments acting on the motivators.

Similar definitions may be drawn up for the forces.

No.	Term	Definition	Symbol
1.9.1	Hinge moment (of a motivator component)	The moment of the system of forces acting on the motivator component about its hinge line axis (1.8.3.4), but excluding forces due to the aircraft control system.[1] It is positive in the positive direction of rotation about the axis.	—
1.9.2	Aerodynamic hinge moment (of a motivator component)	Moment of the system of the aerodynamic forces acting on the motivator component about its hinge line axis (1.8.3.4).[1]	M_c
1.9.3	(Aerodynamic) hinge moment coefficient	A non-dimensional coefficient of the aerodynamic hinge moment (1.9.2), defined as follows: $\dfrac{\text{Aerodynamic hinge moment}}{\frac{1}{2}\varrho V^2 S l}$ where ϱ is the density of the air (5.1.3); V is the airspeed (1.3.1); S is the reference area (1.4.5); l is the reference length (1.4.6). NOTE — Hinge moment coefficients may be defined using the particular reference quantities, appropriate to the problem in question.	—

1) The definitions 1.9.1 and 1.9.2 may be generalized in cases where a motivator comprises several components. In such cases, it is necessary to specify the hinge line axis chosen.

1.10 Quantities related to energy

The quantities defined in 1.10.1 to 1.10 are related to the energy of the aircraft with respect to the atmosphere. The zero level of the potential energy is chosen arbitrarily as the geopotential altitude $H = 0$. The total air-path climb speed (1.10.3) and the total air-path climb angle (1.10.4) are directly accessible by flight measurements.

In definitions 1.10.1 to 1.10.4:

V is the airspeed (1.3.1);

m is the aircraft mass (1.4.1);

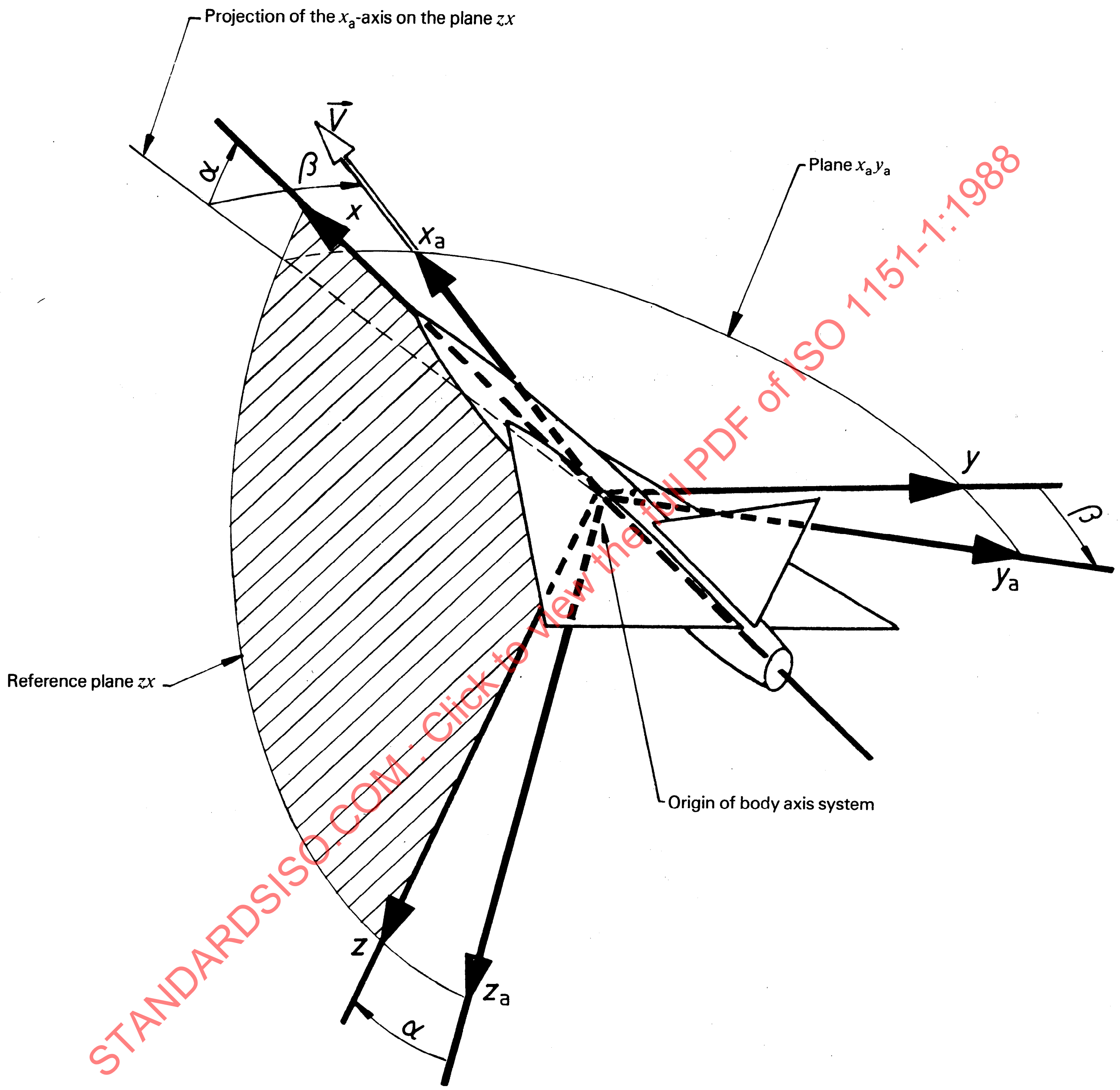
h is the geometric altitude (5.2.1);

H is the geopotential altitude (5.2.2);

$g(h)$ is the acceleration of free fall defined in the standard atmosphere used (ISO 2533) as a function of the geometric altitude h (5.2.1);

g_n is the standard acceleration of free fall (g_n = 9,806 65 m·s^{-2} according to ISO 2533).

No.	Term	Definition	Symbol
1.10.1	Total air-path emergy	Energy defined as follows: $$E_t = mg_nH + \frac{m}{2} V^2$$	E_t
1.10.2	Total air-path altitude	Ratio of the total air-path energy (1.10.1) to the quantity mg_n: $$H_t = H + \frac{1}{2g_n} V^2$$	H_t
1.10.3	Total air-path climb speed	Speed defined as being the scalar product between the total load factor vector (1.5.7) and the aircraft velocity (1.3.1): $$V_{Zt} = \vec{n}_t \cdot \vec{V}$$ NOTE — When the wind is constant and horizontal, the total air-path climb speed is related to the derivative of the total-air altitude (1.10.2) with respect to time by the following relationship: $$V_{Zt} = \frac{g_n}{g(h)} \cdot \frac{dH_t}{dt}$$	V_{Zt} or V_t
1.10.4	Total air-path climb angle	Angle the sine of which is equal to the ratio of the total air-path climb speed (1.10.3) to the airspeed (1.3.1): $$\sin \gamma_t = \frac{V_{Zt}}{V}$$ NOTE — The total air-path climb angle is only defined when the magnitude of the total air-path climb speed is less than or equal to the airspeed.	γ_t

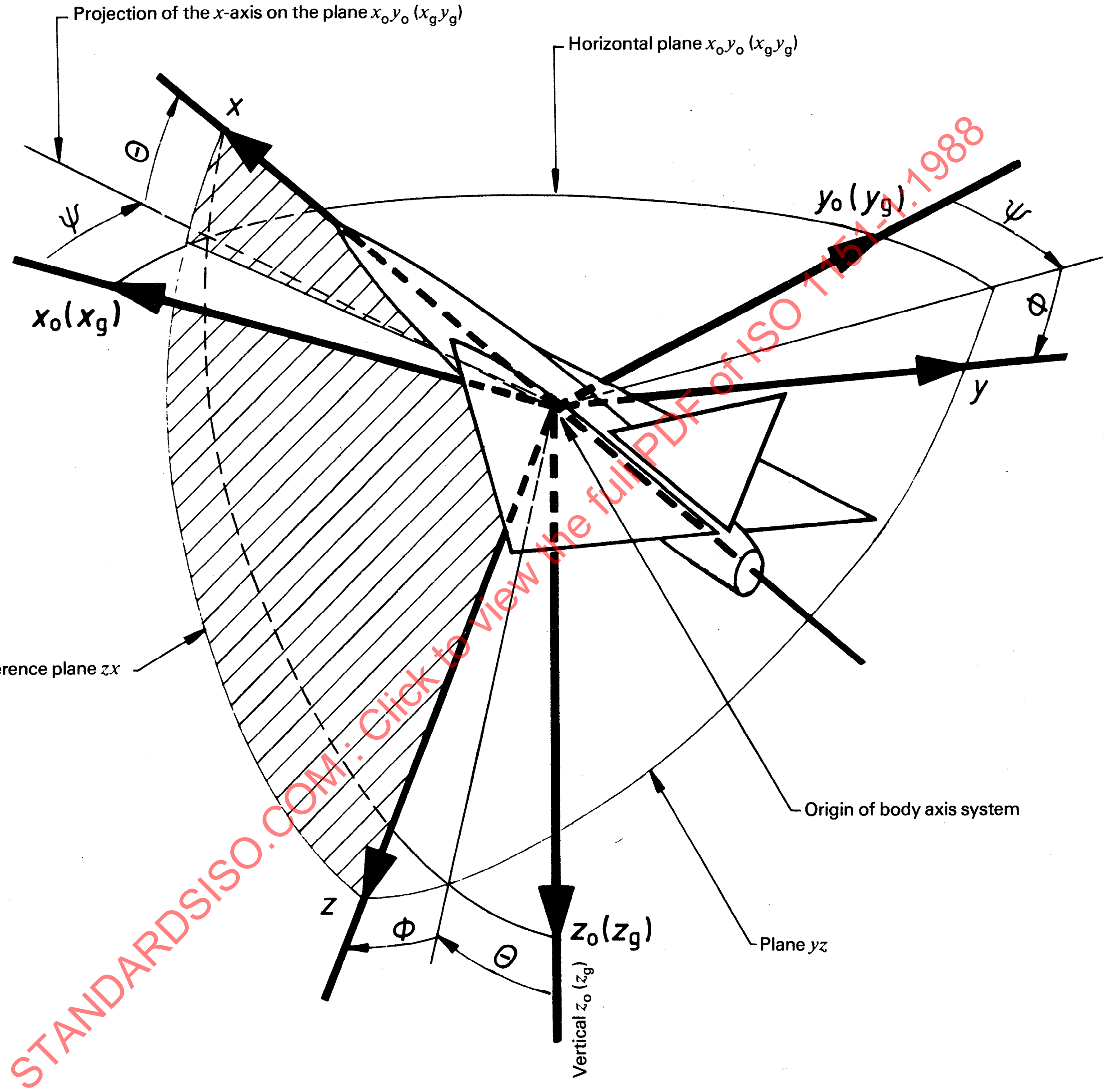


IN BLACK LINES: Body axis system

IN BLUE LINES: Air-path axis system

NOTE — The angles shown are positive. When the origin of the axis systems is not in the reference plane, the zx plane is parallel to it and the angles are unchanged.

Figure 1 — Orientation of the aircraft velocity with respect to the body axis system



IN RED LINES: Aircraft-carried normal earth axis system

IN BLACK LINES: Body axis system

NOTE — The angles shown are positive. When the origin of the axis systems is not the reference plane, the zx plane is parallel to it and the angles are unchanged.

Figure 2 — Orientation of the body axis system relative to the aircraft-carried normal earth axis system