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Proposed American National Standard

Flight Dynamics Model Exchange Standard

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Abstract

This is a standard for the interchange of simulation modeling data between facilities. The initial objective is to allow easy, straightforward exchanges of simulation model information and data between facilities. The standard applies to virtually any vehicle model (ground, air, or space), but most directly applies to aircraft and missiles.

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Contents

Foreword

This standard was sponsored and developed by the AIAA Modeling and Simulation Committee on Standards. Mr. Bruce Jackson of NASA Langley conceived Dynamic Aerospace Vehicle Exchange Markup Language (DAVE-ML). DAVE-ML is the embodiment of the standard in XML. The DAVE-ML reference document, including examples of its use, and the document type definition for the XML implementation are included in this standard (Annex B).

This implementation was then tested by trial exchange of simulation models between NASA Langley Research Center (Mr. Bruce Jackson), NASA Ames Research Center (Mr. Thomas Alderete and Mr. Bill Cleveland), and the Naval Air Systems Command (Mr. William McNamara and Mr. Brent York). Numerous improvements to the standard resulted from this testing.

At the time of approval, the members of the AIAA Modeling and Simulation CoS were:

Bruce Hildreth, Chair	Science Applications International Corporation (SAIC)
Bruce Jackson, DAVE-ML Chair	NASA Langley Research Center
Bimal Aponso	NASA Ames Research Center
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The above consensus body approved this document in Month 201X.

The AIAA Standards Executive Council (VP-Standards Wilson Felder, Chairman) accepted the document for publication in Month 201X.

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Introduction

The purpose of this standard is to clearly define the information and format required to exchange air vehicle simulation models between simulation facilities (see Figure 1). This standard simulation interchange format is implemented in XML and is described fully in Annex B of this document.

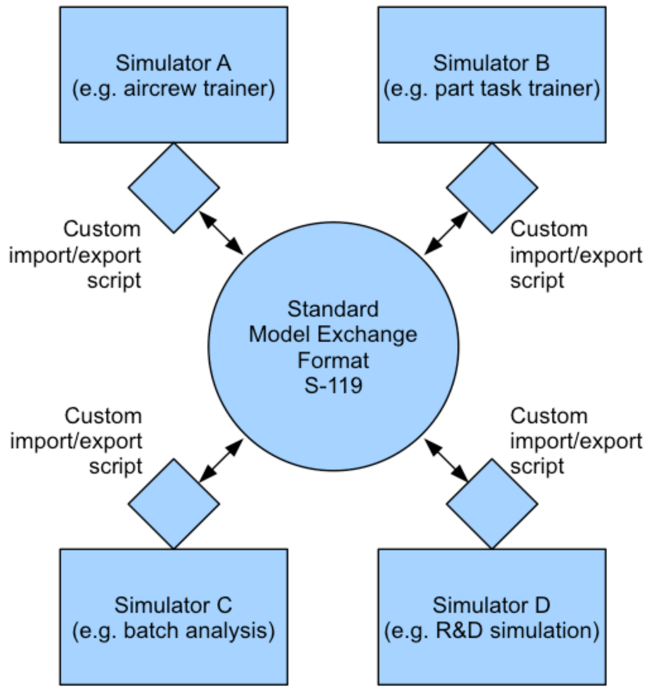

Figure 1 — Model exchange via a standardized format

The standard interchange format includes:

a) Standard variable name definitions — to facilitate the transfer of information by using these standard variables as a “common language.” The interchange format can be used without using standard variable names. However, it will be more difficult because the exported model will have to include explicit definitions of all variables instead of just a subset unique to the particular model.

b) Standard function table definition — to allow easy transfer of nonlinear function tables of arbitrary dimension.

c) Standard coordinate system and reference frame definitions — used by the variable names and function tables to clearly define the information being exchanged.

d) Standard static math equation representation — for definition of static equations forming part of aerodynamic, propulsive, or other models.

A specialized grammar of XML provides a format for the exchange of this information, therefore each organization is required to design import/export tools that comply with the standard one time only.

Use of this standard will result in substantially reduced cost and time necessary to exchange aerospace simulations and model information. Test cases have indicated an order of magnitude reduction in an effort to exchange simple models when utilizing this standard. Even greater benefits could be attained for large or complicated models.

Trademarks

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Simulink ®

MATLAB®

1 Scope

This standard establishes definitions of the information and format used to exchange air vehicle simulations and validation data between disparate simulation facilities. This standard is not meant to require facilities to change their internal formats or standards. With the concept of an exchange standard, facilities are free to retain their well-known and trusted simulation hardware and software infrastructures. The model is exchanged through the standard, so each facility only needs to create import/export tools to the standard once. These tools can then be used to exchange models with any facility at minimal effort, rather than creating unique import/export tools for every exchange.

The standard includes a detailed convention for representing simulation variables. The purpose of this is to unambiguously describe all variables within the model when it is exchanged between two simulation customers or facilities. The variable representation includes explicit specification of all coordinate systems, units, and sign conventions used. XML is used as the mechanism to facilitate automation of the exchange of the information. Based on the definitions in the standard, a list of recommended but nonobligatory simulation variable names is included in Annex A. This list of standard variable names should further simplify the exchange of information, but is not required for use of the standard.

The standard includes capabilities for a model to be self-validating and self-documenting, with the provenance of a model's components included within the model and transferred with it. Statistical descriptions of the quality of a model may also be included.

2 Tailoring

The requirements defined in this standard may be tailored to match the actual requirements of any particular program or project. Tailoring of requirements should be undertaken in consultation with the procuring authority where applicable.

NOTE Tailoring is a process by which individual requirements or specifications, standards, and related documents are evaluated and made applicable to a specific program or project by selection, and in some exceptional cases, modification and addition of requirements in the standards.

The following sections provide further guidance on specific tailoring situations.

2.1 Partial Use of the Standard

2.1.1 General

Not all aspects of this standard may be applicable to all models or simulation applications. The following guidelines are provided to encourage appropriate use of the standard in a number of example situations.

2.1.2 Creating a New Simulation Environment

This situation calls for use of the complete standard. It is hoped that the team developing the new simulation environment would, if necessary, add to the list of standard variables and coordinate systems.

2.1.3 Creating a New Simulation Model in an Existing Simulation Environment

This situation is defined as creating a new system model (aircraft dynamic model for example) that will run in an existing simulation environment. It is expected that this is the most commonly performed work that will see benefit by application of this standard.

In this case the following tailoring guidelines are applicable.

a) Apply the standard to the new development aspects of the project and all the function tables.

b) Assuming that most or all of the standard variable names and coordinate systems are applicable to the simulation, use them for the new code developed for the simulation.

c) In the existing simulation environment that is being reused, for example the equations of motion, there is no need to rewrite the code to use the standard variable names or coordinate systems. However, in most cases the coordinate systems used in existing simulation environments will be covered in the standard coordinate system definitions herein (Section 5). Therefore the standard coordinate systems can easily be referenced when documenting the simulation and interfaces between the new simulation components and those reused.

2.1.4 Creating or Updating a Simulation with a Long Life Expectancy

A pilot training simulator is an excellent example of this type of simulation. This simulation may only be updated every 3—10 years, so at first glance the standard may seem to be less applicable.

In fact the opposite is true. It is because of the infrequent maintenance that application of the standard is critical. In this case, in each new software update, the original developers (or previous updaters) are probably no longer available, and the update is being performed by different personnel. Software developed using the standard should be easier for the new software team to understand. They are working with clear variable definitions with which they are familiar. The function table format is understood and the functions themselves are better documented. The coordinate system definitions are clear. Changes are recorded for the benefit of any future software update.

In simulations with a long expected life, use of the state, state derivative control, and output conventions as part of the variable naming convention becomes critical as these variables form the core of the model and the significant inputs. It is important that the personnel modifying the simulation are able to easily identify the states, state derivatives, and controls.

2.2 Implementing the Standard in a Nonflat or Nonscalar Namespace

The variable naming convention defined within the standard makes no assumption as to the hierarchy of data components, such as object-oriented model implementation or multidimensional storage of matrices and vectors. The standard can accommodate these implementations through the use of a period (.) inserted before the optional domain name (e.g., `aero.bodyForceCoefficient_X`) or through the use of an appropriate indexing mechanism for the chosen implementation language [e.g., `aerobodyForceCoefficient[0]` or `aerobodyForceCoefficient(1)`]. However, it should not be expected that other members of the simulation community maintain implementation-specific conventions. Therefore, on export these variable constructs, should be converted to the flat, scalar namespace defined herein.

2.3 New and Reused Software Tailoring Guidance

The longer the expected life of the simulation, the more helpful the application of the standard becomes. The above tailoring guidelines may be categorized into two common situations: new and reused code.

New simulation code should

a) use coordinate system definitions (Section 5) that coincide with the definitions in the standard;

b) use standard variable names (Section 6) to facilitate consistency and simplify documentation requirements;

c) apply the convention for states, state derivatives, and controls wherever possible; and

d) use standard function tables (Section 7) for all function tables.

NOTE This facilitates consistency in the data, the documentation of the data, and collaboration with other organizations to improve or debug the data.

Reused simulation code should reference the standard only when convenient to document interfaces with new code.

2.4 Creating New Variable Names and Coordinate Systems

The standard variable names and coordinate system definitions are included in the standard to facilitate communication. They provide a “common language” for the exchange. For example, it is not enough to exchange the values of the lift coefficient function. As a minimum, the independent variables used to define the function and their units, sign convention, and reference coordinate system must be defined. This need to precisely define variables is facilitated by having standard variable names and coordinate systems. Of course, new variable names, definitions, and other convenient coordinate systems may be used to exchange models between simulation facilities. However, in such cases, the exporters and importers must carefully define these variables and coordinate systems, or the exchanged model may not produce the desired results. Use of standard variable names and coordinate systems facilitates the exchange.

This standard includes a methodology for creating new standard variables. Its use is encouraged. Annex B provides the URL for submitting additional standard variable names and coordinate systems or comments on existing standard variable names and coordinate systems.

3 Applicable Documents

The following documents contain provisions which, through reference in this text, constitute provisions of this standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies.

AIAA R-004-1992	Atmospheric and Space Flight Vehicle Coordinate Systems
ISO 1151-1:1988	Flight dynamics – Concepts, quantities, and symbols – Part 1: Aircraft motion relative to the air
ISO 1151-2:1985	Flight dynamics – Concepts, quantities, and symbols – Part 2: Motions of the aircraft and the atmosphere relative to the Earth
ISO 1151-3:1989	Flight dynamics – Concepts, quantities, and symbols – Part 3: Derivatives of forces, moments and their coefficients
ISO 1151-4:1994	Flight dynamics – Concepts, quantities, and symbols – Part 4: Concepts, quantities and symbols used in the study of aircraft stability and control
ISO 1151-5:1987	Flight dynamics – Concepts, quantities, and symbols – Part 5: Quantities used in measurements
ISO 1151-6:1982	Terms and symbols for flight dynamics – Part 6: Aircraft geometry
ISO 19111:2007	Geographic information – Spatial referencing by coordinates
ISO 80000-1:2009	Quantities and Units – General
IST-CR-90-50	Distributed Interactive Simulation (DIS Application Protocols, Version 2, March 1994)
www.w3.org/XML	Extensible Markup Language (XML) 1.0 (Fifth Edition), 2008-11-26
www.w3.org/Math	Mathematical Markup Language (MathML) Version 2.0 (Second Edition), 2003-10-21

4 Vocabulary

4.1 Acronyms and Abbreviated Terms

AIAA	American Institute of Aeronautics and Astronautics
AND	aircraft nose down
ANR	aircraft nose right
ANSI	American National Standards Institute
CM	center of mass
DAVE-ML	Dynamic Aerospace Vehicle Exchange Markup Language
DIS	Distributed Interactive Simulation
DTD	Document Type Definition
FE	Flat Earth coordinate system
GE	Geocentric Earth fixed coordinate system
HLA	High Level Architecture
IC	initial condition
ISO	International Organization for Standardization
ISQ	International System of Quantities
MathML	Mathematical Markup Language
MRC	moment reference center
MSL	Mean sea level
RWD	right wing down
SI	Système Internationale d'Unites
URL	Uniform Resource Locator
WGS	World geodetic system
XML	eXtensible Markup Language

4.2 Terms and Definitions

For the purposes of this document, the following terms and definitions apply.

Breakpoint
A value of an independent variable at which the value of its dependent variable is specified, or the x coordinate (or abscissa) of a one dimensional table

Center of mass
This standard uses center of mass (CM) as the default location for several coordinate systems. The long-

standing aeronautical tradition is to refer to this location as the center of gravity (CG). Center of gravity and center of mass are interchangeable for vehicle modeling on or above a large gravitational body in hydrostatic equilibrium like the Earth. However, the difference between CM and CG can become significant when a vehicle maneuvers near small, irregularly shaped gravitational bodies (e.g., asteroids). Thus, center of mass is the more correct term for this important aerodynamic and kinematic reference point.

Confidence interval
An estimate of the computed or perceived accuracy of the data

Coordinate system
A measurement system for locating points in space and attached to a reference frame (Stevens and Lewis, 2003). In this standard they will be orthogonal right-handed triads unless specifically noted.

Dependent variable
An output that is obtained by evaluation of a tabulated function or a MathML expression

EXAMPLE For $C_L(\alpha,\beta)$, C_L is the dependent variable, also called the output.

Function Table
The numeral set of data points used to represent the value of an independent variable as a function of the value(s) of one or more independent variables

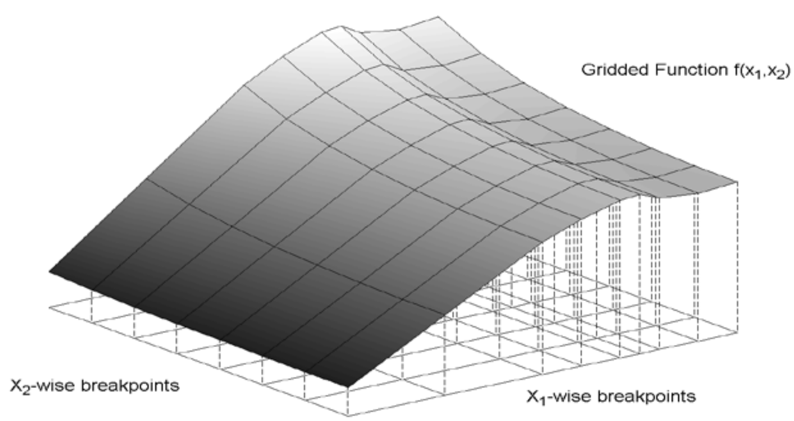
EXAMPLE $C_L(\alpha,\beta)$ may be represented by a function table.

Gridded Table
A multidimensional function table in which all independent variable breakpoints are constant across the function range, but not necessarily evenly spaced

NOTE 1 This is sometimes called an orthogonal table.

NOTE 2 All one-dimensional tables are gridded tables.

EXAMPLE A gridded two-dimensional function



Ground
Smooth surface of the earth at the nadir, not necessarily MSL.

Independent variable
The input(s) to a function table or a MathML expression

EXAMPLE For $C_L(\alpha,\beta)$, α and β are independent variables.

Inertial velocity
The special case of a velocity for which the relative reference and observer coordinate systems are an inertial frame.

Mean Sea Level
The zero elevation reference in the simulation, normally the geoid. Although many simulations treat MSL and the smooth surface of the Earth as equivalent this is not always true. For example, the WGS84 model equates MSL with the geoid, not the smooth surface.

Observer coordinate system
A coordinate system from which motion of a point (a velocity, acceleration, or higher derivative) is observed (or measured). In many cases this coordinate system is in the same reference frame as the relative coordinate system, however in the most general case, may exist in a different frame. The magnitude and direction of velocity (and higher derivatives) differ depending on the observer coordinate system due to the fact that the relative coordinate system may be in motion relative to the observer. Identified in variable names by the "ObsFr" component. If not specified, the observer coordinate system defaults to the same coordinate system as the relative coordinate system.

One-dimensional table
A table whose values are based upon only one independent variable

EXAMPLE $C_L(\alpha)$ may be represented by a one-dimensional table.

Presentation coordinate system
The specific coordinate system in which a variable or vector is presented (or expressed). For example, a specific vector may be presented (expressed) in the body axis coordinate system, the geocentric Earth (ge) coordinate system, or one of the alternatives presented in Section 5. The value of the vector's components (e.g., X, Y, and Z) differs depending on the presentation coordinate system. The presentation frame only determines how the vector is expressed as X, Y, and Z components, as the specific vector of an object is invariant with respect to any arbitrary coordinate frame (i.e., they are contravariant rank one tensors). In other words, the specific vector in two presentation frames differs only by a linear transformation (i.e., a rotation matrix). When one "presents" or "expresses" the vector in a presentation coordinate system, that presentation coordinate system is treated as if it is instantaneously fixed relative to the observer for the given time t (even if the presentation coordinate system is translating and rotating relative to the observer).

The presentation coordinate system is identified in variable names by the initial coordinate system prefix.

Reference coordinate system
The coordinate system that defines the frame of interest of a rotational measurement such as attitude, angular rate, or angular acceleration. Identified in variable names by the "Of" component. If not present, the default reference coordinate system is the body coordinate system.

Reference frame
Frames for short. A general definition for a reference frame is: three or more noncolinear points on a rigid body define a reference frame (Stevens and Lewis, 2003). Unlike a coordinate system, a reference frame has no fixed origin, it is in essence a rigid body wherein all points are fixed in position relative to each other. The location of a point or vector in a frame is expressed using a specified coordinate system. Any number of points or vectors may be expressed with any number of coordinate systems (with no relative motion) in the same frame. For example, the Earth is often a reference frame and may have the geocentric Earth (ge) coordinate system attached to the center, and any number of user defined topodetic coordinate systems (such as runways or launch sites) used to locate and orient fixed objects on the Earth. Note however an object moving on or above the surface of the Earth would be in a different reference frame.

Reference point
The point of interest of a translational measurement such as position, velocity, or acceleration. Identified in variable names by an "`Of`" component. If not specified, the default reference point is the ownship's center of mass.

Relative coordinate system
A coordinate system that defines the origin of a measurement such as position, velocity, or acceleration (translational or rotational). Identified in variable names by the "`Wrt`" component. If not specified, the default relative coordinate system is the same as the presentation coordinate system for translation and the locally-level coordinate system for rotations.

Simulation states (and state derivatives)
In the formulation of a nonlinear simulation model shown as

$$\dot{x} = f_1\{x(t), u(t), w(t)\}$$
$$y = f_2\{x(t), u(t)\}$$

where

$\dot{x}$ represents a vector of the simulation state derivatives

x represents a vector of the simulation states

u represents a vector of the simulation controls

w represents a vector of disturbances

y represents a vector of the simulation outputs.

Static equation
A mathematical statement where the output (left-hand side) does not have direct dependence (right-hand side) on a simulation state

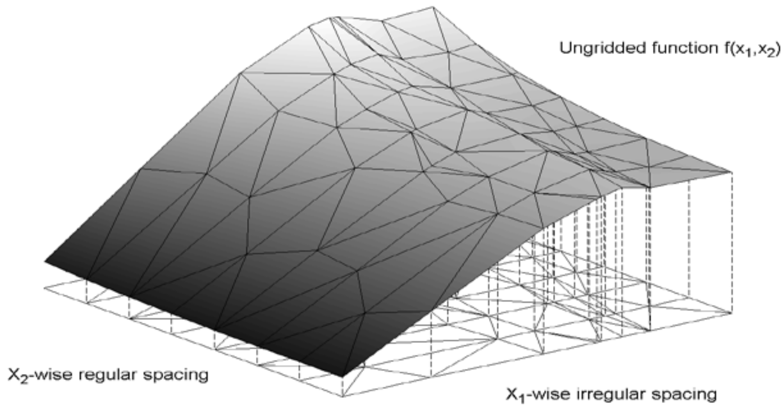
Two-dimensional table
A table whose values are based upon two independent variables

EXAMPLE $C_L(\alpha,\beta)$ may be represented by a two-dimensional table.

Ungridded Table
A multidimensional function table in which the independent variable breakpoints need not be constant across the function range

NOTE This is sometimes called a nonorthogonal table.

EXAMPLE An ungridded two-dimensional function



Velocity
The first derivative of position; in the general case, can be applied to either translational or rotational rate-of-change of position. This term normally applies to translational motion; the rotational equivalent is normally called "angular rate."

5 Standard Simulation Coordinate Systems

5.1 Background / Philosophy

Most of the coordinate system definitions discussed herein were taken from existing standards, the *ANSI/AIAA Recommended Practice for Atmospheric and Space Flight Vehicle Coordinate Systems* (ANSI/AIAA R-004-1992) and the *Distributed Interactive Simulation* (DIS Application Protocols, Version 2, IST-CR-90-50, March 1994). AIAA R-004-1992 is based on ISO 1151-1:1988 and ISO 1151-3:1972.

Coordinate system standards are also reflected in the variable naming convention. When applicable, the coordinate system is included in the variable name (see Section 6).

5.1.1 Coordinate System Conventions

In general, ANSI/AIAA R-004-1992 is the normative reference for coordinate system definitions. These coordinate systems are discussed in Table 1. However, it is important to emphasize the correlation of the AIAA document and the *Distributed Interactive Simulation* (DIS) coordinate systems. The geocentric Earth fixed coordinate system and body coordinate system are both used in DIS and High Level Architecture (HLA) simulations.

5.1.1.1 Geocentric Earth-Fixed Coordinate System

The Geocentric Earth-Fixed Coordinate System (coordinate system 1.1.3 of Table 1) is identical to the DIS "Geocentric Cartesian Coordinate System" (also referred to as "World Coordinate System" in the DIS).

All variables referenced to this coordinate system use "`ge`" as part of their name for the Geocentric Earth-Fixed Coordinate System. This coordinate system is also frequently called "Earth-centered, Earth-fixed."

5.1.1.2 Body Coordinate System

Another standard coordinate system is the Body Coordinate System (coordinate system number 1.1.7 in ANSI/AIAA R-004-1992). This is identical to the DIS "Entity Coordinates System." The body coordinate system is identified in the variable names by "`body.`"

5.1.1.3 Additional Coordinate Systems

In addition to the coordinate systems defined in ANSI/AIAA R-004-1992, this standard has added the Moment Reference Center, Flat Earth, Locally Level, and Vehicle Reference (or Structural) coordinate systems. The Moment Reference Center coordinate system is a special case body coordinate system (number 1.1.7 in ANSI/AIAA R-004-1992, number 1.1.5 in ISO 1151-1:1998). The Flat Earth and Locally Level coordinate systems are respectively variants of the Normal Earth-fixed coordinate system (number 1.1.4 in ANSI/AIAA R-004-1992, number 1.1.2 in ISO 1151-1:1998) and the Vehicle-carried normal Earth coordinate system (number 1.1.6 in ANSI/AIAA R-004-1992, number 1.1.4 in ISO 1151-1:1998). Both these coordinate systems are normally used in conjunction with an assumption that the Earth forms an inertial reference frame. They are useful for simple simulations, and for creating vehicle model validation data. The Vehicle Reference coordinate system is a body coordinate system that may be used to locate vehicle components within the structure of the vehicle.

The moment reference center coordinate (MRC) system may be used to locate objects in the vehicle. Its axes are aligned with the body coordinate system, however, its origin is fixed at the moment reference center of the vehicle while the body coordinate system origin is at the center of mass (CM) and moves as the center of mass (CM) moves.

The moment reference center coordinate system is identified in the variable names by "`mrc.`"

The flat Earth coordinate system is based on a fixed, nonrotating, flat Earth with no mapping to a round Earth coordinate system, and therefore, latitude and longitude are inappropriate (but can be scaled for small maps). The purpose of this coordinate system is to allow, if desired, vehicle checkout simulation to be performed in this coordinate system. This simplifies the use of this standard by simulation facilities that do not normally use a round or oblate spheroidal, rotating Earth model.

The flat Earth coordinate system is identified in the variable names by "`fe.`"

The locally level coordinate system is the reference coordinate system for angles and angular motion. Its origin is fixed at the vehicle center of mass.

The locally level coordinate system is identified in variable names by "`ll.`"

The vehicle reference coordinate system is used to locate vehicle components. It is fixed to the vehicle structure and does not move. The specific definition differs for each vehicle. Sometimes the vehicle system may be the weight and balance reference system for the vehicle. The X origin is often in front of the vehicle, the Y origin in the centerline of the vehicle and the Z origin below the vehicle. The X-axis is often called the fuselage station and is often positive aft, the Y-axis is called the butt line and is often positive to right, and the Z-axis is the waterline and is often positive up. However, these definitions may change with the vehicle and a manufacturing reference system may instead be used.

The vehicle reference system is identified in variable names by "`vrs.`"

5.2 Complete List of Coordinate Systems

The coordinate systems that are referenced are taken largely from paragraph 1.1 of ANSI/AIAA R-004-1992. The moment reference center, flat Earth and locally level coordinate systems for atmospheric flight simulation approximation are additional to that reference. A vehicle reference coordinate system is added for the purpose of locating systems and subsystems in the vehicle. Table 1 is the comprehensive list of coordinate systems that may be used under this standard.

The first column in Table 1 provides the abbreviation recommended for each coordinate system. The coordinate system may be referenced in a variable name by use of its abbreviation. See Section 6 on the variable naming convention.

Table 1 — Standard coordinate systems

Reference Abbreviation	**R-004-1992 Paragraph Number**	**Term**	**Definition**	**Symbol**
`ei` (for Earth-centered inertial)	1.1.1	Geocentric inertial coordinate system (See Appendix D.2 of R-004 for a modification of this system used for launch vehicles.)	An inertial reference system of the FK5 mean equator and equinox of J2000.0 has the origin at the center of the Earth, the X_I-axis being the continuation of the line from the center of the Earth through the center of the Sun toward the vernal equinox, the Z_I-axis pointing in the direction of the mean equatorial plane's north pole, and the Y_I-axis completing the right-hand system. (See Figure 1A in R-004)	$X_I Y_I Z_I$
Not used, this forms a basis for other definitions	1.1.2	Earth-fixed coordinate system	A right-hand coordinate system, fixed relative to and rotating with the Earth, with the origin and axes directions chosen as appropriate.	$x_0 y_0 z_0$
`ge` (also called Earth-centered,	1.1.3	Geocentric Earth-fixed coordinate system	A system with both the origin and axes fixed relative to and rotating with the Earth (1.1.2). The origin is at the center of the Earth, the x_G-axis being the continuation of the line	$x_G y_G z_G$

Reference Abbreviation	R-004-1992 Paragraph Number	Term	Definition	Symbol
Earth-fixed)			from the center of the Earth through the intersection of the Greenwich meridian and the equator, the z_G-axis being the mean spin axis of the Earth, positive to the north, and the y_G-axis completing the right-hand system. (See Appendix D.3 in R-004-1992)	
	1.1.4	Normal Earth-fixed coordinate system	An Earth-fixed coordinate system (1.1.2) in which the z_o-axis is oriented according to the downward vertical passing through the origin (from the origin to the nadir). (See Figure 1C in R-004-1992)	$x_O y_O z_O$
vo	1.1.5	Vehicle-carried orbit-defined coordinate system[a]	A system with the origin fixed in the vehicle, *(the default being the center of mass),* in which the z_o-axis is directed from the spacecraft toward the nadir, the y_o-axis is normal to the orbit plane (positive to the right when looking in the direction of the spacecraft velocity), and the x_o-axis completes the right-hand system. (See Figure 1A in R-004-1992)	$x_O y_O z_O$
ve	1.1.6	Vehicle-carried normal Earth coordinate system[a]	A system in which each axis has the same direction as the corresponding normal Earth-fixed axis, with the origin fixed in the vehicle, *the default being* the center of mass.	$x_O y_O z_O$
body	1.1.7	Body coordinate system[a]	A system fixed in the vehicle, *with the default origin being the center of mass,* consisting of the following axes:	$x\ y\ z$
		Longitudinal axis	An axis in the reference plane or, if the origin is outside that plane, in the plane through the origin parallel to the reference plane, and positive forward.[b] In aircraft or missiles, this is normally from the CM forward towards the nose in the vertical plane of symmetry. It is also normally parallel to the waterline of the vehicle.	x
		Lateral axis	An axis normal to the reference plane and positive to the right of the x-axis (henceforth, positive to the right).	y
		Normal axis	An axis that lies in or parallel to the reference plane, whose positive direction is chosen to complete the orthogonal, right-hand system xyz.	z
mrc	none	A body coordinate	This is a body coordinate system. The default origin is not fixed at the center of	$x_M y_M z_M$

Reference Abbreviation	R-004-1992 Paragraph Number	Term	Definition	Symbol
(for moment reference center)		system (not in R-004)	mass, but at the moment reference center (mrc) and therefore does not move. It consists of the following axes:	
		Longitudinal axis	An axis in the reference plane or, if the origin is outside that plane, in the plane through the origin parallel to the reference plane, and positive forward.[b] In aircraft or missiles, this is normally from the MRC forward towards the nose in the vertical plane of symmetry. It is also normally parallel to the waterline of the vehicle.	
		Lateral axis	An axis normal to the reference plane and positive to the right.	
		Normal axis	An axis that lies in or parallel to the reference plane, whose positive direction is chosen to complete the orthogonal, right-hand system xyz.	
`wind` (for wind coordinate system)	1.1.8	Air-path system[a]	A vehicle carried system with the origin fixed in the vehicle, *located at* the center of mass, consisting of the following axes:	$x_a y_a z_a$
		x_a-axis; air-path axis	An axis in the direction of the vehicle velocity relative to the air	x_a
		y_a-axis; lateral air-path axis; cross-stream axis	An axis normal to the air-path axis and positive to the right of the plane formed by the x_a and z_a axes.	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 the z_a-axis is chosen so as to complete the orthogonal, right-hand system $x_a y_a z_a$.	z_a
`sa` (for stability axis system)	1.1.9	Intermediate coordinate system[a]	A system with the origin fixed in the vehicle, *located at* the center of mass, consisting of the following axes.	$x_s y_s z_s$
		x_s-axis	The projection of the air-path x axis on the	x_s

Reference Abbreviation	R-004-1992 Paragraph Number	Term	Definition	Symbol
			reference plane, or, if the origin is outside that plane, on the plane through the origin, parallel to the reference plane.	
		y_s-axis	An axis normal to the reference plane and positive to the right, coinciding with or parallel to the lateral axis (1.1.7).	y_s
		z_s-axis	An axis that coincides with or is parallel to the normal air-path axis so as to complete the orthogonal right-hand system.	z_s
fp	1.1.10	Flight-path coordinate system[a]	A system with the origin fixed in the vehicle (*at* the center of mass) and in which the x_k-axis is in the direction of the flight-path velocity relative to the Earth. The y_k axis is normal to the plane of symmetry and positive to the right. The z_k axis completes the orthogonal right-hand system	$x_k y_k z_k$
aa	1.1.11	Total-angle-of-attack coordinate system[a] (USA practice: aeroballistic coordinate system.)	A system with the origin fixed in the vehicle, *at* the center of mass, in which the x_t-axis is coincident with the x-axis in the body coordinate system (1.1.7). The y_t-axis is perpendicular to the plane formed by the x_t-axis and the velocity vector, positive to the right. The z_t-axis is formed to complete the orthogonal, right-hand system.	$x_t y_t z_t$
fe	None	Flat Earth system (not in R-004)	The Flat Earth coordinate system origin is situated on the Earth's surface directly under the center of mass of the vehicle at the initialization of the simulation. The X_{FE}-axis points northwards and the Y_{FE}-axis points east-ward, with the Z_{FE}-axis down. The X_{FE} and Y_{FE} axes are parallel to the plane of the flat Earth.	$X_{FE} Y_{FE} Z_{FE}$
ll	None	Locally Level coordinate system (not in R-004)	A vehicle related coordinate system (1.1.6) with the origin instantaneously at the ownship center of mass. The Z_{LL}-axis passes through the vehicle center of mass and points towards the nadir. The X_{LL}-axis is parallel to the smooth surface of the Earth and oriented toward true north in the geometric Earth model. The Y_{LL}-axis is parallel to the smooth surface of the Earth completing the right-hand triad (East). The locally level coordinate system is valid for	$X_{LL} Y_{LL} Z_{LL}$

Reference Abbreviation	R-004-1992 Paragraph Number	Term	Definition	Symbol
			geometric or flat Earth models.	
`vrs`	None	Vehicle Reference system (not in R-004)	A vehicle fixed coordinate system used to locate items in the vehicle. It is often the weight and balance coordinate reference system for the vehicle, or the manufacturing coordinate reference system. The VRS may not be a right-handed coordinate system. X-axis is the longitudinal reference. It may be the Fuselage Station line, normally 0 being in front of the vehicle with the coordinate increasing aft. Y-axis is the lateral reference. It may be the Butt line perpendicular to the vertical symmetric plane of the vehicle and in the geometric center of the vehicle. Positive to the right facing forward (Starboard) Z-axis is the vertical reference. It may be the Waterline and its origin is normally under the vehicle, positive up.	

[a]*By default*, the origins of the coordinate systems selected from ANSI/AIAA-R-004-1992 1.1.5 through 1.1.11 coincide *and are at the center of mass*. If that is not the case, it is necessary to distinguish the different origins by appropriate suffixes and additional coordinate system references.

[b]The reference plane should be a plane of symmetry, or a clearly specified alternative. *This may be specified by the vehicle reference system (`vrs`).*

[c]Italics indicate clarifications to ANSI/AIAA-R-004-1992.

5.3 Summary

This coordinate system standard should be followed for all future equations of motion. It is necessary for unambiguous reference to coordinate systems in simulation variable names.

5.4 References

ANSI/AIAA Recommended Practice R-004-1992, *Atmospheric and Space Flight Vehicle Coordinate Systems*, 28 February 1992.

Distributed Interactive Simulation (DIS Application Protocols, Version 2, IST-CR-90-50, March 1994)

ISO 1151-1:1988, *Flight Dynamics – Concepts, quantities and symbols – Part 1: Aircraft motion relative to the air,* 15 April 1988.

ISO 1151-3:1989, *Flight dynamics – Concepts, quantities, and symbols – Part 3: Derivatives of forces, moments and their coefficients,* 1 April 1989.

6 Standard Simulation Variables

6.1 Background / Philosophy

6.1.1 Rationale for Having Standard Variable Name and Naming Conventions

The standard variable names and coordinate system definitions are part of this standard to facilitate communication. They provide a "common language" for information exchange. For example, to unambiguously exchange a function representing a lift coefficient, the minimum information required to be transmitted includes the independent variables used to define the function (such as angle-of-attack, angle-of-sideslip, Mach number, Reynolds number, and aircraft configuration), their units, their sign conventions, and their reference coordinate systems. Such an exchange will be facilitated by using standard variable names and coordinate systems.

If a model uses standard variable nomenclature the information defining the model data may be exchanged entirely by reference to this standard. Additionally, adherence to the variable naming convention included herein will allow the list of standard variables to grow as needed by the user community. Use of the convention to maintain consistent variable names will ease user workload and maximize the benefits to be obtained from this standard.

Positions, angles, velocities, and angular velocities referred to in this standard are defined in accordance with ANSI/AIAA R-004-1992.

6.2 Variable Naming Convention

The purpose of the naming convention is to provide guidance for the creation of variable names consistent with the standard variable names (Annex A). This will allow expansion of Annex A over time, further expanding the set of names available to facilitate model exchanges.

Variable names are constructed from components that jointly serve to fully define the variable in its particular application. A combined mixed case and underscore variable name convention is used. In variable name components that consist of multiple words, the first letter of each word is capitalized (medial capitals). Where the simulation language in use allows it, and where the logic of the simulation requires it, an underscore may be replaced by a period (.) to indicate an object member, or by parentheses or brackets to indicate an array member.

The following general rules for naming all variables shall be followed.

a) Variables shall have meaningful names.

b) Variable names shall not exceed 63 characters in length. Brief, but complete, names are most effective.

c) Names shall be constructed using US-ASCII 7-bit character encodings.

6.3 Variable Name Methodologies

There are three methods specified for defining variables consistent with this standard. Different methods are described for

a) Position variables (linear or angular), arrays or structures;

b) Motion variables (velocities, accelerations, or higher derivatives, both linear and angular), arrays or structures; and

c) All other variable names.

The naming convention for position variables and for variables describing motion are different than other types of variables because of the general requirements to specify coordinate systems that uniquely define position and velocity. In addition, the following guidelines for capitalization when creating variable names are provided:

d) The first letter in the variable name is lower case. Similarly, the first letter in the prefix and the first component following the prefix are lower case.

e) The first letters in acronyms and abbreviations are capitalized.

f) Distinct components in variable names, after the first component, shall begin with a capital letter.

g) Units are not capitalized unless the unit abbreviation itself is.

6.3.1 The Physical Basis for the Position, Velocity, Acceleration (and Derivatives thereof) Naming Convention

To ground the discussion of variable names it is useful to refer to a standard dynamics text and to review the equation of Coriolis. Figure 2 below shows the derivation of the three-dimensional linear velocity of point p with respect to coordinate system **M** as observed from coordinate system **O**. Coordinate system **M** has translational and rotation motion relative to **O**; in the figure, ω depicts the angular rate of **M** with respect to **O**.

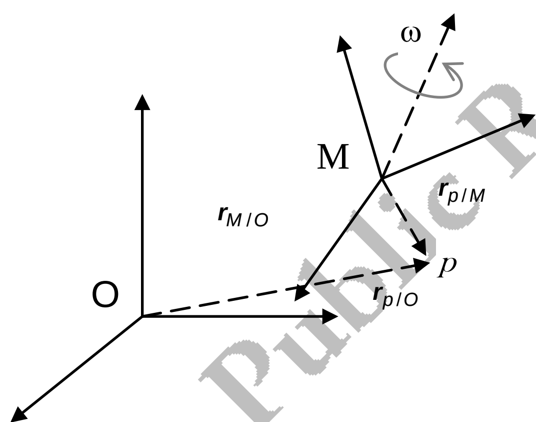


Figure 2 — Rotating reference frames and relative geometry

The velocity of p with respect to **M** as observed from **O** is the vector difference of the velocity of p with respect to **O** and the velocity of **M** with respect to **O** (both of which are observed from **O**):

$$ {}^{O}\dot{r}_{p/M} = {}^{O}\dot{r}_{p/O} - {}^{O}\dot{r}_{M/O} \tag{1} $$

For this discussion, the vector notation used by Stevens and Lewis is used (see Figure 3 below) but other notations are equally valid. Using the equation of Coriolis (Stevens and Lewis equation 1.2-10), the velocity of p with respect to **O** observed from **O** is given by:

$$ {}^{O}\dot{r}_{p/O} = {}^{O}\dot{r}_{M/O} + {}^{M}\dot{r}_{p/M} + \omega_{M/O} \times r_{p/M} \tag{2} $$

The left-hand side term and the first right hand side term in equation (2) are the velocity terms in the right-hand side of equation (1). Combining the two equations produces the following relationship:

$$ {}^{O}\dot{r}_{p/M} = {}^{M}\dot{r}_{p/M} + \omega_{M/O} \times r_{p/M} \tag{3} $$

Equation (3) shows that the velocity of p with respect to **M** as observed from **O** does not equal the velocity of p with respect to **M** as observed from **M** in the general case. This illustrates the need to clearly specify, for derivatives of a linear position vector, the coordinate systems that define the point (this standard designates the point on the vehicle by “Of”), the origin from which the position is measured (this standard designates this by “Wrt”), and the frame in which the observation is made (“ObsFr”). An additional challenge is to achieve this specification using just the ASCII set of characters that are used to compose variable names.

Figure 3 shows how the notation used by Stevens and Lewis are mapped into the coordinate system components of the variable name schema. Within this standard, point p will be illustrative of the Of variable name component, coordinate system **M** will be illustrative of the Wrt variable name component and coordinate system **O** will be illustrative of the ObsFr variable name component.

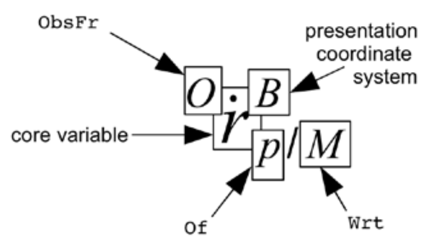


Figure 3 — Mapping Stevens and Lewis notation into variable name components

Another coordinate system that must be specified is that into which the three vector components are resolved in (this standard uses the term ‘presentation coordinate system’). This is indicated in Figure 3 as the right superscript B, which would indicate which coordinate system is used to resolve the vector into three scalar components.

In order to define position, velocity, acceleration, or higher derivative variables (both translational and rotational), it is often necessary to specify each of these various coordinate systems. The kinematic requirements to clearly define these variables are presented below.

Positions: For positions (including rotational attitudes), the variable name must specify the origin from which the position is being measured. The name also must specify the coordinate system in which the vector is being resolved.

Take, for example, the core variable name

```
position
```

This name alone is meaningless. Therefore, it is necessary to describe what the position is representing:

```
positionOfPilotEye
```

This is still ambiguous as it is necessary to specify both the point from which the pilot’s eyepoint is being measured and into which coordinate system the position vector is being resolved.

`positionOfPilotEyeWrtCm`

This indicates what point is being located relative to what reference point, and therefore a relative position vector may be defined in 3-space. However, without knowing in which coordinate system the vector is being resolved, any number of coordinate systems could be used. Thus

`bodyPositionOfPilotEyeWrtCm`

This is a complete and unambiguous variable name representing a three-dimensional position. To define the name of any of the three body coordinate system axes, we need to append the name of the appropriate axis and units of measurement:

bodyPositionOfPilotEyeWrtCm_ft_X
This defines a scalar variable representing the X-body axis offset of the eyepoint from the center of mass, measured in feet.

Attitudes: Attitude (rotational position) is the orientation of one coordinate system relative to another; therefore, two coordinate systems are required (either explicit or implied) in the variable name to define an attitude. These axis systems are specified using the 'Of' and 'Wrt' components. The presentation coordinate system is not used because attitude (either as a quaternion, Euler angles, or rotation cosine matrix) is not a vector quantity resolved into X, Y, and Z components.

If the attitude is expressed as a set of Euler angles, the aeronautical convention of yaw-pitch-roll (3-2-1) rotation sequence is the default. To specify a different rotation sequence, the sequence should be appended to the Euler angle core name, e.g., eulerAngle313 for 3-1-3 rotations. To avoid confusion, for any rotation sequence other than 3-2-1, _First, _Second, _Third should be used for angle selectors in lieu of _Roll, _Pitch, _Yaw.

For example:

eulerAngleOfIssWrtEi_rad_Pitch
This variable represents the pitch attitude (rotation about the Y axis) of the user-defined International Space Station (Iss) coordinate system relative to the Earth-centered inertial (ei) coordinate system, measured in radians. This rotation uses the default yaw-pitch-roll (3-2-1) rotation convention.

eulerAngle313OfIssWrtOrion_rad_Second
This variable represents the second rotation angle of the International Space Station (Iss) coordinate system relative to another user-defined (Orion) spacecraft coordinate system measured in radians. This variable uses yaw-roll-yaw (3-1-3) rotation convention.

eulerAngleOfImuWrtBody_rad[_Roll|_Pitch|_Yaw]
This variable represents the three Euler angles of a user-defined inertial measurement unit (Imu) coordinate system relative to the body coordinate system.

eulerAngleOfImu1WrtImu2_rad[_Roll|_Pitch|_Yaw]
This variable represents the three Euler angles of a user-defined inertial measurement unit (Imu1) coordinate system relative to an Imu2 coordinate system, using the default yaw, pitch, roll

(3-2-1) rotation convention.

Derivatives of position (translational or rotational): For variables representing derivatives of *translational* positions (velocities, accelerations and higher derivatives thereof) the observer coordinate system must be specified by the naming methodology. The observer coordinate system exists in the reference frame from which the movement (a velocity, acceleration or higher derivative) is observed (or measured). In many cases this is the same reference frame as the relative coordinate system (defined by the `Wrt` component) used to specify the position of the object being observed, but in the most general case may be a different frame. The magnitude and direction of velocity (and higher derivatives) varies with selection of the observer's coordinate system since the relative coordinate system may be moving relative to the observer's coordinate system.

For *rotational* derivatives, it is unnecessary to specify an observer's coordinate system, but both coordinate frames that describe the rotational derivatives are necessary (both `Of` and `Wrt` components).

For example:

`eiAngularRateOfIssWrtOrion_rad_s_Y`
This variable represents the angular rate of the ISS coordinate system relative to the `Orion` spacecraft coordinate system. This is the angular velocity vector is resolved to the Earth-centered inertial (`ei`) coordinate system to measure the Y component in that system.

6.3.2 New Position Variables Naming Convention

The methodology for creating and defining a position variable (linear or angular) that is consistent with the requirements of this standard are as follows.

a) Each variable name may have up to nine components.

b) With the exception of the core name, all components are optional and should only be used if required by the application. Units must be specified unless the variable is nondimensional and then the `_nd` units specification is encouraged.

The variable name components are listed immediately below. Descriptions of all the components follow in this section.

1. <*variable domain*>
2. _<*dynamic equation formulation prefix*>_
3. <*presentation coordinate system*>
4. <*core name*> — the only required component
5. `Of`<*a point for positions or coordinate system for angles, normally on the vehicle*>

   If omitted in the variable name, `Of` defaults to the Cm for translational position and the body coordinate system for rotational position.

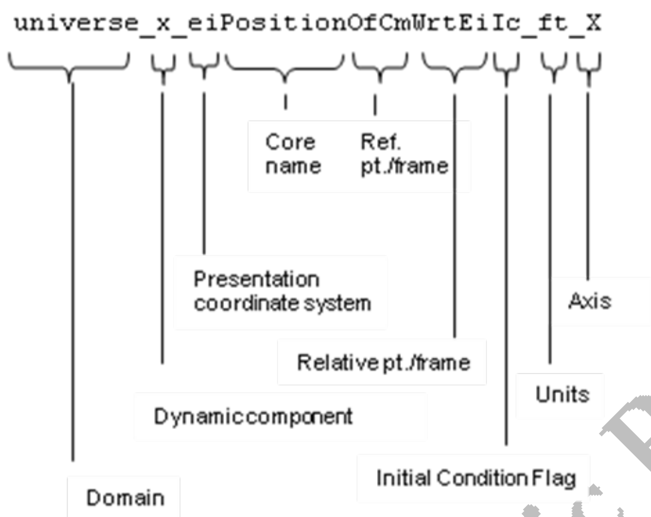
6. `Wrt`<"With respect to" *a point or coordinate system*>

   If omitted in the variable name, `Wrt` defaults to the presentation coordinate system for linear positions and to the locally level coordinate system (`ll`) for angular position.

7. `Ic` — initial condition designation
8. _*<units>*
9. _*<specific axis of the presentation coordinate system>*

Rarely are all 9 components of a name used.

For example:



6.3.3 New Velocity, Acceleration, or Higher Derivative Motion Variables Naming Convention

The methodology for creating and defining velocity and acceleration variables (or higher derivatives) consistent with the requirements of this standard are as follows:

a) Each variable name may have up to ten components.

b) With the exception of the core name, all components are optional and should only be used if required by the application. Units must be specified unless the variable is nondimensional and then the _nd units specification is encouraged.

The variable name components are listed immediately below. Descriptions of all the components follow in this section.

1. *<variable domain>*
2. _*<dynamic equation formulation prefix>*_
3. *<presentation coordinate system>*
4. *<core name>* — the only required component
5. `Of`*<a point for translation or coordinate system for rotation, normally on the vehicle>*

   If omitted, `Of` defaults to the Cm for translation derivatives and the body coordinate system (`body`) for rotational derivatives.

6. `Wrt`<"With respect to" *a point, frame or coordinate system*>

   The `Wrt` component (relative coordinate system) may be omitted; if so, the relative coordinate system defaults to the presentation coordinate system for translational variables and the locally-level coordinate (`ll`) system for rotational variables.

7. `ObsFr`<*“Observed From” coordinate system, only used for translational motion*>

   If “ObsFr” is not specified, it defaults to the same coordinate system specified by the relative coordinate system (the `Wrt` component). If the relative coordinate system is not present, `ObsFr` defaults to the presentation coordinate system.

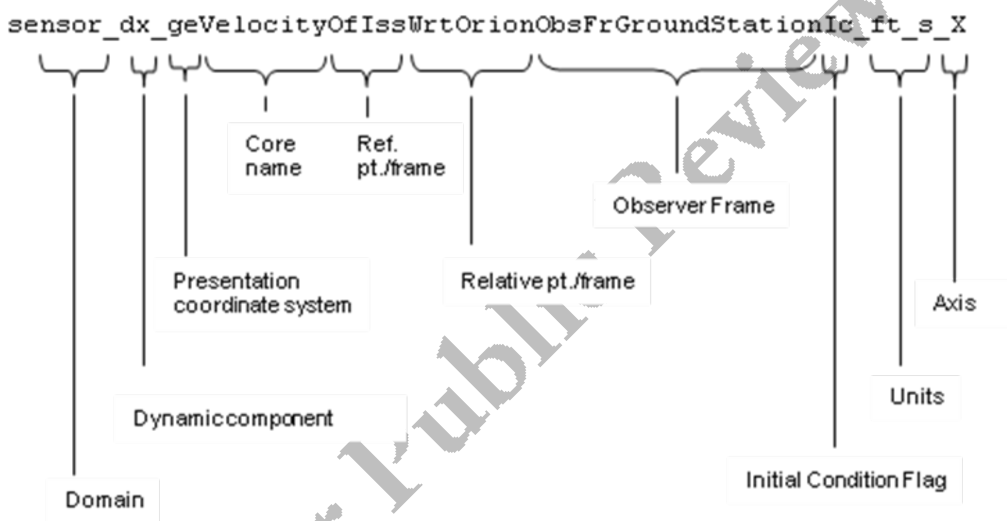
8. `Ic` — initial condition designation

9. _<*units*>

10. _<*specific axis of the presentation coordinate system*>

Rarely are all 10 components of a name used.

For example:



6.3.4 New General Variables Naming Convention

The methodology for defining variables other than positions and derivatives thereof that is consistent with the requirements of this standard are as follows.

a) Each variable name may have up to seven components.

b) With the exception of the core name, all components are optional and should only be used if required by the application. Units must be specified unless the variable is nondimensional and then the _nd units specification is encouraged.

The variable name components are listed immediately below. Descriptions of all the components follow in this section.

1. <*variable domain*>

2. _<*dynamic equation formulation prefix*>_

3. <*presentation coordinate system*>

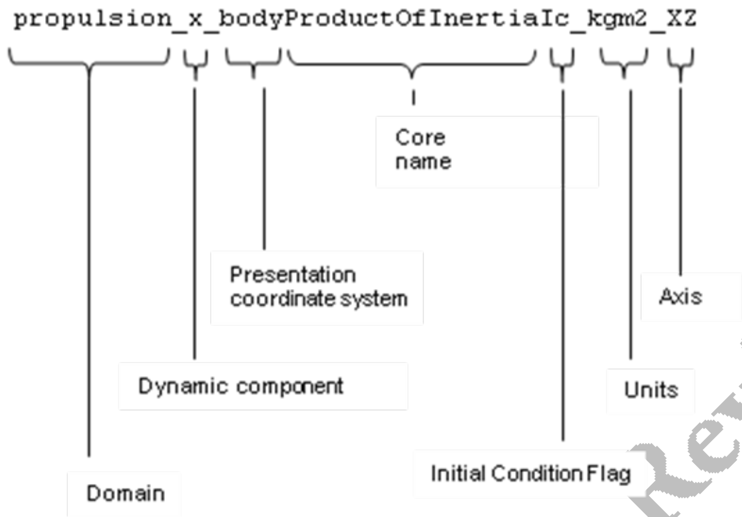
4. <*core name*> — the only required component

5. `Ic` — initial condition designation

6. _<*units*>

7. _<*specific axis of the presentation coordinate system*>

For example:



6.3.5 Adapting the Naming Convention to Hierarchical and Nested Data Representations

The naming methodology provides all the essential information about a variable in its name. This convention is concise for flat data representations (e.g., single-datum variables, arrays, common blocks). However, the convention can lead to repetition of information if applied to the members of hierarchical and nested data structures (e.g., classes, structures, records) since structure organization might parallel one or more of the variable name components. For example, a developer could create a structure to hold all of the variables in an aerodynamics model. The developer could then declare an instance of the structure with the name "aero;" the structure name would repeat information in the variable source domain component of its member variables.

An example of a "flat" variable name is:

`aero_bodyForceCoefficient_X` where "aero" is the variable domain

Prepending the name of the structure to the standard variable name could result in an expression like the one below:

`aero.aero_bodyForceCoefficient_X`

Such repetition can lead to unnecessarily long expressions. To avoid such repetition, developers may use the following guidelines to adapt the naming convention to hierarchical and nested data structures. First, when a level of a structure represents an organization of data that is equivalent to a variable name component, the developer should use the naming rules for that component to name instances of that structure level. Second, if a component of the variable name appears at a higher level or lower level, the developer should not include that component in the variable names at the current level. Using these guidelines, the example above can be changed to:

`aero.bodyForceCoefficient_X`

If the developer made a further change to represent a vector as a structure and replaced the X, Y, and Z variables for the body force coefficient with that structure, the above expression would change to:

`aero.bodyForceCoefficient.X`

To meet the intent of the guidelines, it is not necessary that the structure levels address the variable name components in the same order that the convention specifies for variable names. The intent of the naming convention is to unambiguously identify the information represented by a variable; it is not intended to shape data design. Thus, the name components can appear in a different order for a hierarchical or nested data expression. For example:

`bodyForce_lbf.aero.X`

In this example, the data design is such that all the external forces on a vehicle (expressed in body coordinates and in units of pound-force) are collected in a structure whose instance is named "bodyForce" and whose members represent each generator of force as an instance of a structure representing a vector. The variable source domain appears after the core name and units due to the chosen data design. Even so, this data expression unambiguously identifies the variable as effectively as the equivalent scalar variable name, `aero_bodyForce_lbf_X`.

6.4 Components Used to Create Variable Names

6.4.1 Variable Domain Component

This represents the domain in which the variable is calculated. In object-oriented design, it could logically be the object. The domain is normally not included if it (or the object) is the vehicle or aircraft being simulated, for example, airspeed.

In some cases the domain name component only provides background information when exchanging models. For example, in one simulation architecture the domain for `ambientPressure_N_m2` might be "`environment`" and in another architecture the domain might be "`atmosphere.`" The core component of the name is the key. For example:

`environment_ambientPressure_N_m2` in one simulation architecture is identical to
`atmosphere_ambientPressure_N_m2` in an another simulation architecture

However in some cases the domain component is critical. For example:

`aero_bodyForce_lbf_X` and `thrust_bodyForce_lbf_X` are two different variables, both are body axis forces but one comes from the propulsion system model and one from the aerodynamic model. It is this type of variable where domain must be included.

Some domain examples are presented in Table 2. The domain names presented here are not part of any standard; instead they are presented here as examples.

Table 2 — Examples of domain names

`aero`	aerodynamic models
`airLaunchedWeapon`	modeling of munitions launched into the air that have their own dynamics; includes Missile as a sub-domain
`cautionAndWarning`	caution and warning simulation
`cockpit`	input/output from/to cockpit instruments and controls
`controlLaw`	simulation of a control algorithm
`controlLoading`	models of the control system feel
`controlSurface`	simulation of an aerodynamic control effector
`controlSystem`	collective model of control laws and control effectors on a vehicle

electrical	models of the electrical system
engine (or thrust or propulsion)	thrust generation models
environment	atmospheric models (ambient properties, wind, clouds, etc.)
failureSystem	failure modeling and fault injection
fltDirect	flight director models
fuelSystem	fuel system models
gun	model of vehicle mounted guns
hydraulics	hydraulic system models
landingGear	landing gear models
massProperties	tree-based modeling of vehicle mass and moments of inertia
missile	missile models. Domain could be more specific, for example missileAim9x.
motion	motion system models and algorithms
navigationDatabase	mapping of waypoints, airports, runways, legs, procedures, and navigation transmitters (all of which are subdomains)
navigationReceiver	modeling of signal-based navigation sensors
navigationTransmitter	modeling of navigation signal generators (e.g., radios, GPS)
parachute	parachute models
propulsion	models the collection of thrust generators (engines) on a vehicle
radar	models the radar system. Domain could be more specific, for example radarApg79)
relGeom	relative state (position, velocity, and acceleration) of each vehicle to each other vehicle
sensor	models of sensors
sensorSystem	modeling the collection of sensors on a vehicle
sim	Domain encompassing control of the simulation, configuration of a simulation run, control of mathematical techniques such as integration type, etc.
vehicle	modeling of the vehicle as a cooperating system of other domain models
weaponSystem	collective model of guns and air-launched weapons on a vehicle
wheel	landing gear wheel models

`world`	world model [shape, dynamics, and reference time(s) plus navigation database and environment domains]
`universe`	domain encompassing world, vehicle, and relative geometry domains

NOTE Users may add as many domains as needed to clearly identify the variable.

Variable name examples using “aero” and “thrust” include:

a) `aero_bodyForce_lbf_X`

b) `thrust_bodyForce_lbf_X`

c) `aero_bodyForceCoefficient_X`

d) `thrust.bodyForceCoefficient_X` — this is an example of `thrust` as a structure.

e) `thrust.bodyForceCoefficient(X)`

6.4.2 Dynamic Equation Formulation Prefix Component

The dynamic equation formulation prefix is used to identify the most important dynamic variables in the simulation, the states (x) and their derivatives ($\dot{x}$), inputs (u), outputs (y), and disturbances (w) as presented in the equation below. These variables characterize the resultant dynamic response of a vehicle as shown in the equations below. In addition to these variables, the standard allows the prefix to separately designate simulation control variables (c). Simulation control variables are used to modify the behavior of the model during simulation and are not part of the vehicle model, while inputs (u) are variables that represent the inputs to the vehicle model which may include pilot control positions. Finally, in simulation or analysis where noise and environmental disturbances are modeled, the disturbances (w) are the final component in the simulation of the total system dynamics.

$$\dot{x} = f_1\{x(t), u(t), w(t)\}$$
$$y = f_2\{x(t), u(t)\}$$

The prefix shall be separated from the body of the variable by an underscore (_) and from the domain name by an underscore (or a period if preceded by a member of a structure or class). The leading underscore is not permitted if a domain name is not present.

6.4.2.1 Identification of Simulation Model States and State Derivatives

The states (x) and state derivatives (dx) are those variables that make the simulation dynamic and are the key variables in a flight simulation model. Basically, any variable that is mathematically integrated is a state derivative. The result of integration of a state derivative over a period of time is a change in the value of the corresponding state over that time. This is true for any integration in a simulation. If the user controls the changes in all the states, they control the trajectory of the simulated model. The time histories of the states and inputs are the key variables required for validation. All outputs are computed directly or indirectly from states and inputs.

The formulation of the equations of motion and the model itself determines what variables are states. This naming convention is not meant to standardize on any variable as a state, but allows the simulation engineer to explicitly identify states in the model implementation, making it easier to document and exchange the models.

Examples:

`x_bodyVelocityWrtEi_ft_s_X`	x_ prefix indicates that this variable is a state
`dx_bodyAccelerationWrtEi_ft_s2_X`	dx_ prefix indicates that this variable is a state derivative

6.4.2.2 Identification of Simulation Model Inputs

The simulation model inputs (*u*) are those variables that provide the pilot or autopilot inputs to the vehicle model. These are also called controls in many references. As with the states and state derivatives, the model inputs are key variables for validation. All model outputs are computed directly or indirectly from model states and inputs.

The formulation of the model itself determines which variables are inputs. This naming convention is not meant to standardize on any variable as an input, but allows the simulation engineer to explicitly identify them, making it easier to document models, exchange them, and verify them.

Examples:

`u_controlSurfacePos_deg_avgAileron`	u_ prefix indicates that this is a model input
`controlLaw_u_controlSurfacePos_deg_avgAileron`	same variable name with domain prefix
`controlLaw.u_controlSurfacePos_deg_avgAileron`	same variable name in a hierarchical architecture
`u_pilotControlPos_rad_long`	Another example of the longitudinal pilot input

6.4.2.3 Identification of Simulation Model Disturbances

The disturbances (*w*) are those variables that provide environmental disturbances or system noise to the simulation models.

Disturbances may be inserted into the vehicle model, environment, or equations of motion, depending upon implementation schemes. This naming convention is not meant to standardize on any variable as a disturbance, but allows the simulation engineer to explicitly identify disturbances, making it easier to document models, exchange them, and verify them.

Examples:

`w_bodyAngularRateTurbulenceWrtGe_deg_s_Yaw`	w_ prefix indicates that this variable is a disturbance
`environment_w_bodyAngularRateTurbulenceWrtGe_deg_s_Yaw`	same variable name with domain (environment) added
`environment.w_bodyAngularRateTurbulenceWrtGe_deg_s_Yaw`	same variable name in a hierarchal architecture

6.4.2.4 Identification of Simulation Model Outputs

The simulation model outputs (y) are those variables that are the outputs of the physics of the simulation models as formulated by the state equations. This is meant to assist in the specification of the state equations, mainly to help simplify model exchanges between simulations used for analysis and those used for real-time man-in-the-loop or hardware-in-the-loop simulations.

Example:

`y_leftHorizonalActuatorRamPosition_deg`	y_ prefix indicates that this variable is a model output.

6.4.2.5 Identification of Simulation Controls

The simulation controls (c) are those variables that provide the simulation operator control of the simulation [not to be confused with simulation model inputs (u)]. The simulation controls should not affect any vehicle states, state derivatives, or outputs.

The software and hardware architecture of the simulation determines what variables are simulation controls. This naming convention is not meant to standardize on any variable as a control, but allows the simulation engineer to explicitly identify simulation controls. Clear definition of simulation controls makes validation of a simulation much easier after a model is exchanged.

Examples:

`c_simDuration_s`	c_ prefix indicates that this variable is a simulation control
`c_deltaTime_s`	another example
`sim_c_deltaTime_s`	same variable name with domain added
`sim.c_deltaTime_s`	same variable name in a hierarchal architecture

6.4.3 Presentation Coordinate System Component

This is the coordinate or reference system to which the variable is referenced or in which it is measured (it is indicated by the "B" in Figure 3). Table 1 specifies the standard coordinate system abbreviations that should be used. If no coordinate system pertains to the variable or the core variable name needs no reference system to be unambiguous (e.g., Airspeed), this part of the variable name may be omitted.

6.4.3.1 Conventions Used

Earth fixed and local coordinate systems by convention use X, Y, Z, for both translation and (X, Y, Z), (Pitch, Roll, and Yaw), or (First, Second, Third) for rotation axis indices. The origin and attitude of local coordinate systems (flat Earth for example) may be user defined (such as N, E, D). Local coordinate systems are meant for runway, test range, target reference, navigational aids, etc.

6.4.3.2 Variable Name Examples

The following variable names are provided as examples.

`x_bodyAngularRate_rad_s_Roll`	These are all equivalent variable names where `body` is the coordinate system and `roll` is the

x_bodyAngularRate_rad_s.Roll x_bodyAngularRate_rad_s_X	specific axis in the body axis system, roll indicating angular motion about the longitudinal axis relative to the locally-level frame (Wrt defaults to locally-level for rotational variables). NOTE In this example the variable is designated as a state.
x_bodyVelocityWrtEi_m_s_X x_bodyVelocityWrtEi_m_s.X	These represent translational inertial velocity in the body coordinate system along the longitudinal axis (the translational variable analogous to the rotational variable above). These are all equivalent variable names.
geVelocity_m_s_Y	This represents a translational velocity with ge specified as the coordinate system and Y as the specific axis. This noninertial velocity of the CM is relative to and measured in the geocentric Earth-fixed (ge) coordinate system.
bodyTurbulenceVelocityWrtGe_ft_s_Z bodyTurbulenceVelocityWrtGe_ft_s [3] bodyTurbulenceVelocityWrtGe_ft_s.Z	These are all equivalent variable names where body is the coordinate system and Z is the specific axis in the body coordinate system, Z indicating vertical translational motion. Also illustrated as a vector and structure.
runway22VelocityOfLeftWheelWrtTd_ft_s_Z	Here runway22 is the coordinate system (user defined) and Z is the specific axis, also indicating translational motion. LeftWheel is the point on the vehicle and Td (touchdown point) is the reference point.
bodyAccelOfPilotEyeWrtEi_m_s2_Y	Here body is the coordinate system and Y is the specific axis, also indicating translational motion. Design pilot eyepoint is the point on the vehicle.
x_eiVelocity_ft_s_X	This is a case where the equations of motion are formulated such that the variable is a state, resolved in the Earth centered inertial (ei) coordinate system
eiVelocity_ft_s_X	This is a case where the equations of motion are formulated such that the variable is not a state
x_llVelocity_ft_s_X	Locally Level coordinate system
x_feVelocity_ft_s_X	Flat Earth coordinate system
bodyAngularRate_rad_s_Pitch	
bodyAngularRate_rad_s_Roll	
bodyAngularAccel_rad_s2_Yaw	

Note that the standard allows (X, Y, Z), or (Roll, Pitch, Yaw), or (First, Second, Third) as selectors for rotational positions and derivatives, since that is widely conventional. However, since the overall objective of the standard is to form a framework for clear communication between simulation facilities, the use of X, Y, Z selectors is acceptable. The appropriate core variable name shall be used to indicate whether the variable is a translational or rotational variable.

6.4.4 Core Variable Name Component

This is the most specific (hence core) name for the variable. All variable names shall include this component of the name.

Core variable name examples are as follows.

- `velocity` convention for velocities
- `angularRate` convention for angular rates
- `accel` convention for translational accelerations
- `angularAccel` convention for angular accelerations
- `pilotControlPos` conventions for pilot controls
- `pilotControlRate`
- `pilotControlAccel`
- `pilotControlForce`
- `copilotControlPos` conventions for pilot controls
- `copilotControlRate`
- `copilotControlAccel`
- `copilotControlForce`
- `controlSurfacePos` conventions for control surfaces
- `controlSurfaceRate`
- `controlSurfaceAccel`
- `controlSurfaceHingeMoment`
- `liftCoefficient`
- `dragCoefficient`
- `forceCoefficient`
- `turbulenceVelocity`
- `angleOfAttack`
- `angleOfSideslip`
- `cosineOfAngleOfSideslip`
- `thrust`

- torque

The following extended variable names are provided as examples.

- x_bodyAngularRate_rad_s_Roll
- bodyTurbulenceVelocityWrtGe_ft_s_X
- geVelocity_ft_s_Z
- geVelocity_m_s_Z
- pilotControlPos_deg_long
- pilotControlPos_deg_lat
- pilotControlRate_deg_s_pedal
- pilotControlAccel_deg_s2_long
- copilotControlPos_deg_long
- copilotControlPos_deg_lat
- copilotControlRate_deg_s_long
- copilotControlAccel_deg_s2_long
- controlSurfacePos_deg_elevator[number of surfaces]
- controlSurfaceRate_deg_s_rudder[number of surfaces]
- controlSurfaceAccel_deg_s2_aileron[number of surfaces]
- controlSurfaceHingeMoment_ftlbf_canard[number of surfaces]
- angleOfAttack_rad
- angleOfSideslip_deg
- cosineOfAngleOfSideslip
- controlSurfacePos_deg_aileron
- totalPressure_N_m2
- ambientPressure_N_m2
- totalLiftCoefficient
- aeroBodyForceCoefficient
- aeroBodyForce_lbf
- aeroBodyForce_N
- thrustBodyForce_N

6.4.5 Reference Point or Coordinate System ("Of")

This component of the name is designed to clarify positions, velocities, and accelerations and is normally omitted if the variable is not a position, velocity or acceleration. However, it may be used for any variable if desired. This component describes which point or object that is being specified. "Of" is used to specify the point or object (this is point p in Figure 2).

For those who prefer shorter variable names, the standard adopts the convention that if the point or location on the vehicle is the center of mass for translational motion variables, then the reference point may be omitted. For rotational motion, the default reference coordinate system is the body axis coordinate system.

Reference points may be defined by the user and depend on the object the variable is describing.

Examples of reference points are as follows.

- `OfCm` the center of mass is the default point, so "`OfCm`" is normally omitted in any variable name.
- `OfImu` or `OfImu1, OfImu2, OfImuLtn200,` etc.
- `OfSensor` or `OfRadar, OfFlir, OfRadarApg67,` etc.
- `OfMrc` for moment reference center
- `OfPilotEye` for the pilot eye point
- `OfRadAlt` for radar altimeter
- `OfTerrain` a normal Earth-fixed coordinate system with origin where the vehicle nadir intersects the terrain

The following variable names are provided as examples.

`bodyPositionOfImuWrtCm_m[3]`	This three-element vector locates the Imu relative to the CM in the body axis coordinate system. Note that [3] indicates (for this example) that the referenced variable is a three-element vector.
`bodyPositionWrtImu_m[3]` `bodyPositionOfCmWrtImu_m[3]`	Both of these vector names refer to the same quantity; it is the opposite of the vector above (they locate the CM relative to the Imu). In the first name "`OfCm`" is omitted since it is default.
`eulerAngleOfImuWrtBody_rad[3]`	This is the angular equivalent of the first variable above. The 3-2-1 rotation convention is implied.
`x_bodyAngularRateWrtEi_rad_s[3]`	Here element 1 would be about the X-axis (roll), element 2 would be about the Y-axis (pitch) and element 3 would be about the Z-axis (yaw). These are inertial rates since they are measured with respect to the Earth inertial (Ei) coordinate system.
`bodyVelocityWrtAir_ft_s_X`	`OfCm` is implied
`bodyVelocityOfCmWrtAir_ft_s_X`	Same meaning as above
`bodyVelocityWrtEi_ft_s_X`	Inertial velocity of the CM along the X-body axis
`bodyVelocityWrtEi_m_s_X`	Inertial velocity of the CM along the X-body axis in

	SI units
heightOfCmWrtTerrain_ft	OfCm may be omitted since it is the default
heightOfRadAltWrtTerrain_ft	
heightOfTerrainWrtWgs84_ft	Height of nadir intersection with terrain above the reference ellipsoid
bodyPositionOfPilotEyeWrtCm_ft_X	
geLongitudeRateOfImu_deg_s	
longitudeOfImuWrtGe_deg geLongitudeOfImu_deg	These are the same scalar quantity.
bodyAccelOfPilotWrtEi_ft_2[3]	Inertial acceleration vector in the body axis

6.4.6 Component Indicating Relative Reference Point or Relative Reference Coordinate System

The relative reference component is generally used in conjunction with the “reference point or location on the vehicle” component described in Section 6.4.5. It is primarily used in variables describing position, velocities, and accelerations. This component defines the reference that the motion or position is relative to. This component, preceded by “Wrt” (with respect to) in the variable name, is the equivalent of coordinate system **M** in Figure 2, as noted in Figure 3.

For position variables, Wrt refers to the reference point for linear positions. For angular positions, Wrt refers to the relative coordinate system. For derivatives of position (velocities, accelerations, etc.) Wrt is used to define relative motion of two objects.

If “Wrt” is omitted then the default points or relative coordinate systems are:

the presentation coordinate system for linear positions and translational motion. For example,

bodyPositionOfImu_m[3]. Here WrtBody is implied.

the locally level coordinate system specified for rotational variables. For example:

eulerAngleOfImu_rad[3]. Here “WrtLl” is implied.

Note: Since for translational motion the “Wrt” defaults to the presentation coordinate system the variable:

bodyVelocity_f_s_X

while a valid variable, has little usefulness because, fully enumerated is:

bodyVelocityOfCmWrtBodyObsFrBody_f_s_X

Body velocity of the Cm with respect to the body is virtually always near zero. It would only represent the movement of the Cm within the body, due to cargo shift, fuel burn, etc. It would not represent velocity of the Cm with respect to a coordinate system outside the aircraft.

Examples of reference points are as follows:

- WrtCm — this is commonly used to clarify definitions of positions within the vehicle
- WrtEi — identifies a variable that is referenced to inertial space
- WrtMrc — moment reference center

- `WrtTgt` aim point
- `WrtImpact` the desired weapon impact point
- `WrtAir` the local atmosphere, used to define air-relative (or wind-relative) motion
- `WrtMeanSL` mean sea level
- `WrtGe` the geocentric Earth-fixed coordinate system
- `WrtGround` a normal Earth-fixed coordinate system with origin where the vehicle nadir intersects the smooth surface of the Earth
- `WrtTerrain` a normal Earth-fixed coordinate system with origin where the vehicle nadir intersects the terrain

The following linear and angular position variable names are provided as examples:

bodyPositionOfImuWrtCm_m[3]	This vector locates the Imu relative to the CM in the body axis coordinate system. WrtCm may be omitted since CM is the default reference point for linear position measurements.
eulerAngleOfImu_rad[3] eulerAngleOfImuWrtLl_rad[3]	This is the angular equivalent of the first variable above. In the first variable "WrtLl" is omitted since the locally-level coordinate system is the default relative coordinate system for angular positions.
eulerAngleOfImuWrtBody_rad[3]	This is a vector representing the alignment of the IMU with respect to the aircraft body.
eulerAngleOfImu1WrtImu2_rad[3]	This is a vector representing the attitude of Imu1 relative to Imu1.
bodyPositionOfPilotEye_ft [3]	WrtBody is implied since the Wrt defaults to the presentation coordinate system. Since the Body coordinate system origin is at the Cm, this variable represents the position of the Pilot design eye with respect to the Cm (+ = eye fwd: right: below Cm)
geLongitudeOfImu_deg	WrtGe is implied (since ge is the presentation coordinate system)
geLongitude_deg	OfCm is implied when not given.
bodyPositionOfCmWrtMrc_ft[3]	
heightOfRunwayWrtMeanSL_ft	

6.4.7 Component Indicating Observer's Coordinate System (Vehicle translational motion variables only)

For variables representing derivatives of linear positions (velocities, accelerations and higher derivatives thereof), the observer's coordinate system (indicated by `ObsFr` for "Observed From") must be specified. The observer's coordinate system is in that reference frame from which the movement (a velocity, acceleration, or higher derivative) is observed or measured. In many cases this is the same reference frame as the relative coordinate system (given by `Wrt`) but in the most general case it may be a different frame. The magnitude and direction of velocity (and higher translational motion derivatives) differ depending on the motion of the observer's coordinate system. This is the coordinate system shown as the upper left superscript in the Stevens and Lewis convention shown in Figure 3 and is illustrated by coordinate system **O** in Figure 2.

It is conventional to omit the observer's coordinate system when it is the same as the reference (`Wrt`) coordinate system. As noted in Section 6.4.6, when the `Wrt` coordinate system is omitted it defaults to the presentation coordinate system for translational variables, so when both the `Wrt` (reference) and the observer's (`ObsFr`) coordinate systems are omitted, the default observer's coordinate system is the presentation coordinate system.

It is neither necessary nor appropriate to specify the observer's coordinate system for rotational motion variables as rotations are invariant with the location of the observer.

Some examples are:

`geVelocity_ft_s_X`
Velocity of the ownship center-of-mass in the geocentric Earth coordinate system (velocity along the GE X-axis). Note that the reference point (`Of`), relative coordinate system (`Wrt`) and observer's coordinate system (`ObsFr`) default to the velocity of the center of mass with respect to and observed from the geocentric Earth-fixed coordinate system since they are omitted.
`geVelocityOfCmWrtGeObsFrGe_ft_s_X`
This is the same variable as the previous one with the reference point (`OfCm`), relative coordinate system (`WrtGe`) and observer coordinate system (`ObsFrGe`) all explicitly specified (they are not required since they are the defaults).
`bodyAccelWrtEi_ft_s2_X`
Acceleration of the vehicle center of mass relative to and observed from the Earth-fixed inertial (EI) coordinate system and presented in the body axis coordinate system (acceleration along the body X-axis). Naming convention components that can be implied are omitted.
`bodyAccelOfCmWrtEiObsFrEi_ft_s2_X`
This is the same variable as the previous one with the reference point, relative coordinate system, and observer coordinate system all explicitly specified.
`bodyVelocityWrtAir_ft_s_X`
This is the air-relative velocity of the CM expressed in body coordinates; the `ObsFr` component is omitted to indicate that the observer's coordinate system is in the same frame as the steady state air mass reference frame (Air).
`bodyVelocityOfCmWrtAirObsFrAir_ft_s_X`
Same as the variable above, fully expressed
`bodyPositionOfPilotEyeWrtCm_ft_X`
The position of the pilot's eyepoint relative to the vehicle center-of-mass along the body X-axis. Note that the sign convention is clear: since the X-axis origin is at the center of mass, and is positive forward, the pilot's eyepoint position is positive when forward of the center of mass.
`bodyPositionOfPilotEyeWrtMrc_ft_X`

The position of the pilot's eyepoint relative to the moment reference center along the body X-axis. Note that the sign convention is clear: since the body X-axis origin is at the center of mass, and is positive forward, the pilot's eyepoint position is positive when forward of the MRC.	
`bodyAccelOfPilotWrtEi_ft_s2_[3]`	
This represents the inertial acceleration of the pilot, resolved into the vehicle's body axes. The `ObsFr` component is omitted, implying the motion is observed from the `Wrt` coordinate system (here, Earth Inertial).	
`bodyAccelOfPilotWrtEiObsFrEi_ft_s2_[3]`	Same as above. `ObsFr` explicitly stated.
`bodyVelocityWrtEi_ft_s_X`	Inertial velocity of the CM along the X-body axis.
`bodyVelocityOfCmWrtEiObsFrEi_ft_s_X`	Same meaning as the previous variable, fully expressed
`runway22VelocityOfLeftWheelWrtTdObsFrTd_ft_s_Z`	
This is the velocity of the wheel relative to the TD point observed from the TD coordinate system. The user must explicitly define the TD coordinate system, but logically it is in an Earth-fixed reference frame, probably with the origin at the desired touchdown point and aligned with the runway.	
`runway22VelocityOfLeftWheelWrtTd_ft_s_Z`	
This is the same variable as above, since omitting `ObsFr` implies it is the `Wrt` coordinate system.	
`velocityWrtGround_ft_s`	
This scalar variable is commonly known as groundspeed.	

6.4.8 Component Indicating Initial Variables

A convention proposed by this standard is adding "`Ic`" to the end of any variable name, before any units, to designate that the variable is an initial condition specification. This can be added to virtually any variable without an underscore separator, conceptually creating a constant, for example:

1. `x_bodyVelocityWrtEiIc_rad_s_X`
2. `grossWeightIc_N`

6.4.9 Units Suffix

The suffix is used to describe the units of the variable. The convention for the suffix is simple and is followed for all variables. When exchanging simulation models, the units of all variables must be specified and this is the mechanism to do so. This will also allow the user, the programmer, and the reader of the code to check for homogeneity of the units and is self-documenting in this respect. Therefore, units shall be included in all variables except variables that are nondimensional. If required for clarity, "nd" may be used in the units suffix to indicate a nondimensional variable. Including units has the added advantage of making this standard consistent and acceptable in countries utilizing the international system of units. For example, airspeed is equally acceptable as a standard both for the U.S. system of units and the International system of units.

The standard uses an underscore (_) to separate the numerator from the denominator an analogy to exponential notation for the specification of units. For example, the unit expression for cubic feet per second squared (for example) would be ft^3s^{-2}. Eliminating the superscripts leaves `ft3s-2`. Separating the numerator from the denominator results in `ft3_s2`, since the negative sign in the denominator exponential term is dropped.

With few exceptions, only base units are supported; it is not allowed to have, for example, milliseconds (ms). Here the proper use would be to express that variable in seconds.

Further examples are as follows:

1. `trueAirspeed_ft_s` for feet per second (ft/s)
2. `trueAirspeed_m_s` for meters per second (m/s)
3. `trueAirspeed_kt` for knots (nautical miles per hour)
4. `bodyAccelWrtEi_ft_s2_X` for feet per second squared (ft/s^2)

The suffix shall be separated from the body of the variable name by an underscore. The standard unit notations are given in Table 3; SI units and standard abbreviations are included where available.

Table 3 — Abbreviation for units-of-measure in standard variable names

Time	
second	s[a]
minute	min[e]
hour	h[e]
Length	
inch	inch
foot	ft
meter	m[a]
nautical mile	nmi
statute mile	smi
kilometer	km
centimeter	cm
millimeter	mm
astronomical unit	ua[e]

Force	
pound force	lbf
Newton	N[b]
kilogram force	kgf
Mass	
kilogram	kg[a]
pound mass	lbm
slug	slug
Solid Angle	
steradian	sr[b]
Plane Angle	
degree	deg
radian	rad[b]
revolution	rev

Temperature	
degrees Rankine	dgR
degrees Celsius	dgC[d]
degrees Fahrenheit	dgF
Kelvin	dgK[c]

Power, energy, work, heat	
energy (British thermal unit)	btu
energy (erg)	erg
energy (calorie)	Cal
energy (joule)	J[b]
power (horsepower)	Hp
power (watt)	W[b]
Electrical units	
potential (volt)	V[b]
volt, direct current	Vdc[d]
volt, alternating current	Vac[d]
current (ampere)	A[a]
frequency (hertz)	Hz[b]
inductance (henry)	H[b]
capacitance (farad)	F[b]
charge (coulomb)	C[b]
conductance (siemens)	S[b]
resistance (ohm)	ohm[d]

Other	
pressure, stress (pascal)	Pa[b]
standard gravitational acceleration unit	g
luminous intensity (candela)	cd[a]
luminous flux (lumen)	lm[b]
illuminance (lux)	lx[b]
amount of substance (mole)	mol[a]
magnetic flux density (tesla)	T[b]
magnetic flux (weber)	Wb[b]
radioactive activity (becquerel)	Bq[b]
absorbed dose (gray)	Gy[b]
dose equivalent (sievert)	Sv[b]
nautical mile per hour	kt
nondimensional	nd

Notes:

a. SI base unit (reference ISO 80000-1:2009, §6.5.2)
b. SI derived unit (reference ISO 80000-1:2009, §6.5.3)
c. SI base unit with modified abbreviation
d. SI derived unit with modified abbreviation
e. ISO recognized non-SI unit (reference ISO 80000-1:2009, §6.5.6)

6.4.10 Units-agnostic models

Some models have identical formulations whether the system of measurement is the SI system or the U.S. customary system. The units of the model's outputs depend only on the units of the values that are provided as inputs. These "units-agnostic" models can be reused in simulations with few or no conversions performed on inputs or outputs by the host simulation. To allow the exchange of units-agnostic models, the standard provides a set of abbreviations for generic units that represent the base units that differ between SI and U.S. customary system, namely length, mass, and temperature:

Unit	Abbreviation
length	`L`[a]
mass	`M`[a]
temperature	`dgT`[b]

Notes:

a. ISQ base unit. (reference ISO 80000-1:2009, §3.7)
b. ISQ base unit with modified abbreviation

The two systems of measurement use the same unit for time (second). The U.S. customary system does not define units for the base quantities of electric current, luminous intensity, and amount of substance; the SI units (see ISO 80000-1:2009) fill this omission. Therefore, generic units are not required for time, electric current, luminous intensity, or amount of substance; the SI unit for these quantities is used for variable names in unit agnostic models.

Examples of variable names using generic units:

- `bodyForce_ML_s2_Z`
- `bodyVelocityWrtGe_L_s_X`
- `thermalConductivity_ML_s3dgT`

Note that the last variable, thermal conductivity, would normally be published in SI units of W/(m-°K) [equal to kg-m/(s^3-K)] with a conversion factor to the typical English units of BTU/(hr-ft-°F), neither of which equals the English unit substitution in the variable name of slug-ft/(s^3-°R). So, a host simulation based on U.S. customary units would need to convert the published value to slug-ft/(s^3-°R) before passing the value to the model. (A unit conversion is not required in a host simulation based on SI units.) If this model were originally developed for that host simulation, the model developer would likely have placed the necessary conversions from BTU and hours (or from the published SI value) within the model; however, by formulating the model as unit agnostic, responsibility for conversion has been moved to the host simulation. The thermal conductivity example illustrates how a unit agnostic model may still require conversion of inputs or outputs by the host simulation.

6.4.11 Component Indicating Specific Axis, Coordinate Component, or Reference

The last component is the specific axis, coordinate component, or reference used within the coordinate system (coordinate systems are defined in Section 5). It may also indicate elements of vectors and arrays. It is separated from the units by an underscore (_). As can be seen in the examples, this component is appended last to keep the naming convention consistent for variables that are scalars or vectors. If the coordinate system is included in the name, the specific axis or reference should also be included.

Standard axes selector sets are

a) (X, Y, Z) for linear/translational motion,

b) (X, Y, Z), (Roll, Pitch, Yaw) or (First, Second, Third) for angular motion.

When the specific axis or reference can logically be a vector or an array, the vector or array component may be convenient for a specific implementation. When coordinate system vectors are used, a right-handed triad in order (X, Y, Z) shall be used to avoid confusion. Due to differences between 0- and 1-based array indexing in various implementation languages, use of numerical indices is discouraged.

In the following examples, `Z` would be defined as a constant of either 2 or 3 depending on the implementation language array indexing convention.

Variable name examples:

`x_bodyAngularRate_rad_s_Roll`
 	
`x_bodyAngularRate_rad_s[Roll]`
 	
`x_bodyAngularRate_rad_s.Roll`
	Here `body` is the coordinate system and roll is the specific axis in the body coordinate system, `roll` indicating angular motion. Examples show alternate scalar and vector implementations and implementation as a structure.
	
	NOTE In this example the variable is designated as a state.

`bodyTurbulenceVelocityWrtGe_ft_s_Z` (standard)
 	
`bodyTurbulenceVelocityWrtGe_ft_s[Z]`
 	
`bodyTurbulenceVelocityWrtGe_ft_s.Z`
	Here `body` is the coordinate system and `Z` is the specific axis in the body coordinate system, `Z` indicating vertical translational motion.

`geVelocity_m_s_Y`	Here `ge` is the coordinate system and `Y` is the specific axis, also indicating translational motion.
`runway22VelocityOfLeftWheelWrtTd_ft_s_Z`	where `runway22` is the coordinate system (user defined) and `Z` is the specific axis, also indicating translational motion. `LeftWheel` is the point on the vehicle and `Td` (touchdown point) is the reference point.
`bodyAccelOfPilotEyeWrtEi_m_s2_Y`	Here `body` is the coordinate system and `Y` is the specific axis, also indicating translational motion. Design pilot eyepoint location is the point on the vehicle.
`bodyProductOfInertia_slugf2_YZ`	Here, `_YZ` selects the element in the second row and third column of the inertial matrix.

6.5 Additional Discussion

Very rarely, if ever, are all 10 components of a name used. In the case of

`x_bodyAngularRate_rad_s_Roll`

the following five components were used:

1. prefix (x_) indicating that in this formulation of the equations of motion this variable is a state,
2. coordinate or reference system (body),
3. core name (AngularRate),
4. units suffix (rad_s), for radians per second, and
5. specific axis or reference (Roll).

In this case "variable source domain" was omitted because x_bodyAngularRate_rad_s_Roll is a single quantity defined by the laws of physics; there should not be separate body rates associated with aerodynamics and a propulsion system. If, however, the user wanted to have a multibody simulation, logically the "variable source domain" could be used to discriminate between different elements of the body, or, perhaps more logically, an array or structure would be used to define different elements in a multibody or flexible structure problem.

The Of, Wrt, and ObsFr were omitted because the variable is describing motion about (Of) the CM and relative to the locally-level coordinate system. Recall that Wrt defaults to the locally-level frame for rotational motion and rotational motion variables do not allow specification of an observer's (ObsFr) coordinate system.

An Ic flag is not present, indicating that this variable does not specify an initial condition.

The intent of these conventions is to provide clear communication when exchanging models, not to force the universal use of these variable names. x_bodyAngularRate_rad_s_Roll is intended to be a clear, brief, unambiguous name for the variable.

6.5.1 Discarded Conventions and Reasons

One convention considered eliminated the units suffix when the units were from a standard set, but this concept was discarded since always having the units associated with the variable name should help the developer maintain consistent units in the simulation and to reduce programming errors due to improper mixing of units. Consistent application of units in variable names should also reduce the software maintenance effort when a subsequent developer is trying to understand the code to make bug fixes, implement enhancements, or reuse the code.

6.5.2 Relationship with Markup Grammar, DAVE-ML

At present, this variable naming convention is targeted for use with the DAVE-ML XML grammar for model exchange (see Section 7). In DAVE-ML, the dynamic equation formulation prefix and the units suffix are stored as separate components (attributes or child elements) of the variable definition. Thus, including these in a variable name encoded in DAVE-ML would be redundant and a potential source of conflicting information.

The recommended practice is therefore to strip these components (the prefix and suffix) from the variable name when encoding to DAVE-ML, and reinsert them into the variable name if code or model data is generated from the DAVE-ML. Following this convention has two advantages.

1. The DAVE-ML grammar does not enforce naming rules; for those variables that do not conform to the naming convention and therefore do not have state/state derivative designation or units, DAVE-ML encourages the inclusion of this information to assist with the clear documentation of a model.
2. The convention allows XML processors to adopt the practice of automatically stripping and adding the prefix and suffix to the variable names, reducing the possibility of human error during translation.

6.6 Standard Variable Name Table Example

Using the conventions discussed above, a set of standard variable names has been created. These are presented in Annex A. An excerpt of Annex A is given in Table 4 for illustrative purposes.

Interpretation of the standard variable name annex is best given by example. Table 4 presents the standard variable defining the roll Euler angle, its axis system, and positive sign convention (positive is RWD, or right wing down). Four name examples are provided. The table includes

1. The symbol for that variable, Φ

2. The short name, `PHI` - the short name is included to accommodate standard variable definitions for legacy compilers with significant name length restrictions

3. One or more full names using the standard units conventions — generally, one full name with American convention units and one with SI units. Refer to Section 6 for a list of the standard units and their abbreviations.

NOTE: While the variable naming convention described in Section 6 encourages the use of the <variable domain> component, this Annex does not include variable domains as part of the normative standard names. This is because the variable domain is normally dependent upon the simulation architecture, and as such is immaterial to the exchange of a simulation model unless the exchange is between facilities with similar architectures.

NOTE: Any suitable units may be used. In the example for `eulerAngle_Roll` both the `_deg` for degrees and the `_rad` for radians are given. The “Full Variable Name” column does not necessarily provide all acceptable units for each variable.

4. A description of the variable, if applicable should always specify the coordinate system. Refer to Section 5 for a description of the standard coordinate systems.

5. The POSITIVE sign convention of the variable — RWD indicates that positive `eulerAngle_Roll` is right wing down. (See Section A.2.1 for a list of sign convention acronyms.)

6. Minimum value, normally only specified for angles

7. Maximum values of the variable, normally only specified for angles

In addition this example also illustrates the pitch and yaw Euler angles.

Since roll, pitch, and yaw may also conveniently be expressed as an array, the first variable name in Table 4 is the standard definition of the Euler angle array. Again, `eulerAngle_rad(3)` would be the standard array using radians as the units and is fully compliant with the standard.

Euler angles are used in virtually any air vehicle simulation. While normally the coordinate system would be included in the name, it was not included due to the universal definition of Euler angles. A more rigorous name would be `llEulerAngleOfBodyWrtLl_deg[3]` which expresses all the defaults (the variable is the Euler angles of the body with respect to the locally level [`ll`] coordinate system and is presented in [or measured in] the locally level coordinate system). Aircraft simulations typically use Euler angles defined via the 3-2-1 angle rotation sequence (yaw, pitch, roll); other rotation sequences may be used but should be explicitly identified as in `EulerAngle313`, for example.

The standard allows use of any of the standard set of units (degrees or radians in this case).

Table 4 — Standard variable name table excerpt

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Min Value	Max Value
Vehicle Positions and Angles						
$\underline{\varepsilon}$	EUL(3)	`eulerAngle_deg(3)` `eulerAngle_rad(3)`	Array of the ownship roll, pitch, and yaw Euler angles comprised of the elements defined below. LL (locally level) coordinate system.			
Φ	PHI	`eulerAngle_deg_Roll` `eulerAngle_rad_Roll`	Roll Euler Angle, LL coordinate system.	RWD	-180,-π	180, π
θ	THET	`eulerAngle_deg_Pitch` `eulerAngle_rad_Pitch`	Pitch Euler Angle, LL coordinate system	ANU	-90, -π/2	90, π/2
ψ	PSI	`eulerAngle_deg_Yaw` `eulerAngle_rad_Yaw`	Yaw Euler Angle, LL coordinate system	ANR	-180,-π	180, π

6.7 Summary

While it is recommended that this naming convention be adopted for defining future variables, the real key to a standard variable name is not the name, but the definition of the name. To exchange information between two or more organizations, the most important factor is not whether a variable is named "`airspeed`" or "`VRW`," but that there exists a precise, unambiguous definition of the variable (true, indicated, or calibrated airspeed, etc.), including units and coordinate system.

Using the standard variable name simply provides a common language and set of definitions within which to facilitate transfer of the model.

The simulation community is encouraged to propose additional standard variable names. Annex B describes the web site used to support this standard. There is an appropriate URL or email address for submitting additional names or for recommending clarification of existing names.

6.8 References

Stevens, Brian L., and Lewis, Frank L., Aircraft Control and Simulation, Second Edition. ISBN 978-0-471-37145-8, 2004, New York, J. Wiley and Sons, 2003.

International Organization for Standardization, *Quantities and units - General*, ISO 80000-1, First edition, 15 Nov. 2009.

United States of America Standards Institute: *USA Standard Code for Information Interchange,* USAS X3.4-1967, 7 July 1967.

7 Standard Simulation Data Format and XML Implementation of the Standard: DAVE-ML

7.1 Purpose

This section explains the requirements that a standard simulation data format must be able to satisfy. It includes the content of defined functions and configuration management of the content. The definition of the DAVE-ML format includes data for these components.

This document also discusses conceptually how a data table should be accessed in an executable program. The standard is implemented in XML as specified by DAVE-ML. Annex B provides links to example programs for loading and looking up data conforming to the XML standard.

7.2 Philosophy

Probably the greatest benefit of the standard to the simulation discipline is the definition of formats for the interchange of tabular data. Tabular data is used widely for nonlinear function representation of aerodynamic, engine, atmospheric, and many other model parameters. The simplified interchange of such data should improve efficiency in the simulation community.

Most simulation developers and users have addressed this issue locally. In many simulation communities, a family of tools has been built around existing local function table formats. The intent of this standard is not to replace these local standards, but rather to define a format for communication that will allow each site to develop a single format converter to and from their local format. The DAVE-ML data representation is proposed as an exchange standard.

7.3 Design Objective

The first design objective of the standard data table format was to include all relevant information about real multidimensional functions, not just the data values. In the general case of a multidimensional table, the independent variables have different numbers of breakpoints, different breakpoints, and different valid ranges, which are all relevant to consistent evaluation of the function.

An equally important design objective was to allow the table to contain information on the data source (provenance, via reference), and a confidence interval for the data. Uses of confidence intervals within a model include direct computation of output confidence levels, estimation of output confidence intervals through Monte Carlo simulations, and mathematically combining different estimates of the same parameter at the same input values. Therefore, confidence statistics should be included when updating an existing or creating a new data set. DAVE-ML allows different types of confidence intervals, not all of which can be meaningfully combined.

The data format must also be easily read by computer or human, and be as self-documenting as possible.

7.4 Standard Function Table Data — An Illustrative Example

Figure 4 presents a fairly standard three-dimensional set of aerodynamic data typical of flight test or wind tunnel results. In the example, lift coefficient is a function of angle-of-attack, Mach number, and a control surface position. More generally stated, the function output (dependent variable) CLALFA is dependent on three inputs (independent variables): `angleOfAttack_deg`, `mach`, & `controlSurfacePos_deg_avgElevator`.

The example illustrates the following characteristics:

1. The number of breakpoints may be different for each independent variable. Data is presented for a different number of angle-of-attack (`angleOfAttack_deg`) points at each combination of Mach number (`mach`) and control position (`controlSurfacePos_deg_avgElevator`). For the

first combination of Mach number and control position (`mach = 0.6`, `controlSurfacePos_deg_avgElevator = 5`) there are 17 angle-of-attack points. For the last combination of Mach number and control position (`mach = 0.8`, `controlSurfacePos_deg_avgElevator = 0`) there are 12 angle-of-attack points. There are also different numbers of Mach number points for each control position. The standard requires this to be represented as an ungridded table.

In contrast, a gridded table would require a function value be defined for every combination of a fixed set of Mach, angle-of-attack, and control position breakpoint values.

2. At some breakpoints, the values of the other independent variables are different. Again, this is a characteristic of an ungridded table.

3. The valid ranges of the independent variables are different, another ungridded table characteristic.

4. The above three differences are not consistent for all data. For example, in the sample table the `angleOfAttack_deg`, breakpoints for `mach = 0.6` and `mach = 0.7` and for `controlSurfacePos_deg_avgElevator = -5` are identical.

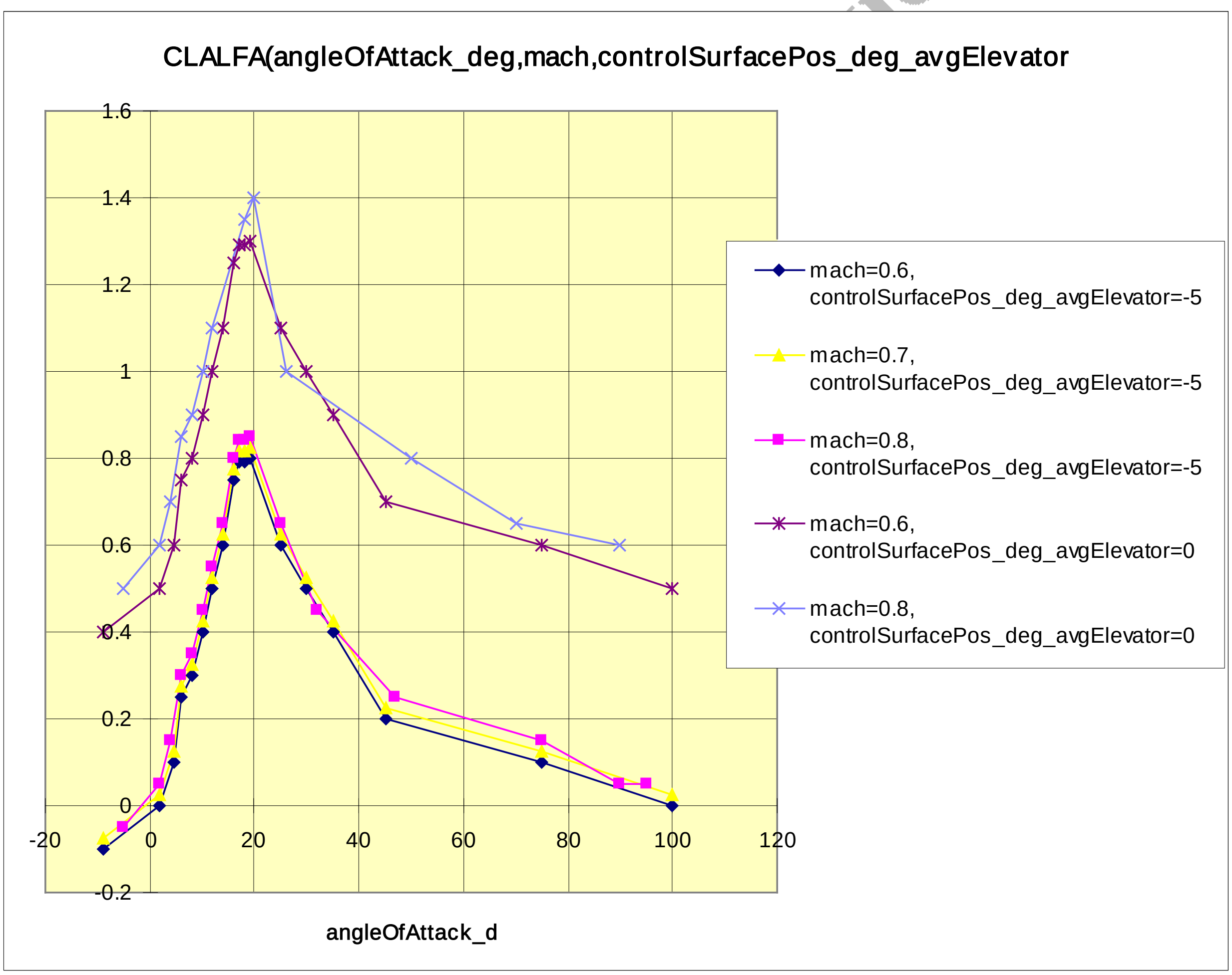


Figure 4 — An illustration of a three-dimensional function table

For function data there is other information that is of importance to the user, without which the data is not very useful. In general this information is as follows:

a) Where did the data come from? For example, what wind tunnel test or computational model?

b) How is it defined? For example, is this at a specific altitude? What is the vehicle configuration?

c) What are the engineering units of the output (the dependent variable) and the independent variables?

d) What is the sign convention of the independent and dependent variables? For example, is the control position positive trailing edge up or trailing edge down? Exactly which control surface is it?

e) Who created the table? Not where the data came from, but what person decided that this was the correct data for this table?

f) How has it been modified and for what reason?

g) How accurate is the data estimated to be? Or, mathematically what is the confidence interval of the data?

h) By what method is the data intended to be interpolated? For example, linear interpolation or cubic spline interpolation?

i) By what method is the data intended to be extrapolated when the independent variable values are outside the specified range for the breakpoint data?

The DAVE-ML grammar has data elements that contain all of the above information. It also includes the ability to automate static checks of the function data to allow spot checking of the function after it has been exchanged. An introduction and overview of DAVE-ML's seven major elements are provided next.

7.5 DAVE-ML Major Elements

The major elements of DAVE-ML are listed below in the order required by the DAVE-ML DTD. The root element of a DAVE-ML model file, *DAVEfunc*, can have several sub-elements and attributes; most attributes and sub-elements are optional. The only sub-elements a DAVE-ML file must contain are the *fileHeader* and at least one *variableDef*.

Information (breakpoints, data points, provenance, etc.) that is used by more than one major element should be defined once and then referenced in any subsequent use.

The sub-elements must appear in the following order (as required by the DTD):

fileHeader — states the source and purpose of the file. It must include the author's contact details and the file creation date, and may include a description, reference information, and modification history.

variableDef — each *variableDef* defines one of the constants or signals (variables) used in the DAVE-ML model, whether input, output, or internal. The definition includes all the attributes and sub-elements required to fully characterize the variable of interest, including a MathML definition if the variable's value is equation-based. Standard variables as defined in Section 6 and Annex A are encouraged here.

breakpointDef — defines breakpoint sets to be used in the model. The breakpoints are the coordinate values along one axis of a gridded linear function value table. One *breakpointDef* may be reused by several functions.

griddedTableDef — defines an orthogonally-gridded multidimensional table of the values of a function at the intersection of a set of specified independent inputs (breakpoints). The coordinates along each dimension are defined in separate *breakpointDef* elements.

ungriddedTableDef — defines a table of nonorthogonal values of a function, each with the values of their independent coordinates.

function — defines a function by connecting independent variables, breakpoints, and data tables to their output value.

checkData — contains one or more input/output vector pairs (and optionally a vector of internal values) for the encoded model to assist in verification and debugging of the implementation.

Annex B contains the link to the latest version of the DAVE-ML reference document, including detailed XML element references and descriptions, and examples of the data element definitions of the DAVE-ML standard.

7.6 Simple DAVE-ML Examples

The easiest way to understand the standard is through an example. A simple one dimensional relationship example, giving pitching moment coefficient as a function of angle of attack, is shown in Table 5 and Figure 5.

Table 5 — A simple one-dimensional function table

`angleOfAttack_deg`	0	18	19	20	22	23	25	27	90
`cm(angleOfAttack_deg)`	0.1	-0.1	-0.09	-0.08	-0.05	-0.05	-0.07	-0.15	-0.6

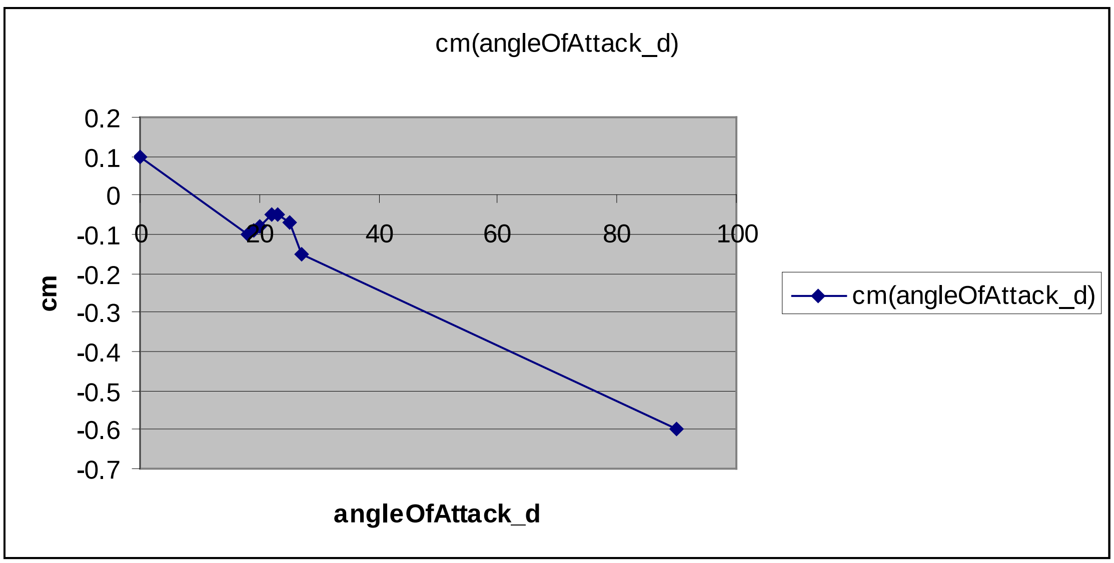


Figure 5 — A simple one-dimensional gridded function

A DAVE-ML implementation for this function could be as follows.

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<!DOCTYPE DAVEfunc PUBLIC "-//AIAA//DTD for Flight Dynamic Models - Functions
2.0//EN" "DAVEfunc.dtd">
<DAVEfunc xmlns="http://daveml.org/2010/DAVEML">

<!--            ==========================             -->
<!--============= File Header Components =============== -->
<!--            ==========================             -->
<fileHeader>

 <!-- This is an example of the file header components of the
```

```
      derivative of Cm as a function of angle of attack. It must
      define all documents that are later referenced by any function.

      Note that there is not much information in this header,
      because it is meant to be a simple example. In
      reality, probably the most important information is the
      author, the reference and the modification record, because
      these data describe where the data came from and if it has
      been changed (and how). See annex B for more complete
      examples.
 -->

 <author name="Bruce Hildreth" org="JFTI" email="bhildreth@jfti.com"/>
 <fileCreationDate date="2006-03-18"/>
 <description>
  This is made up data to use as an example of a simple gridded function.
 </description>
 <reference refID="BLHRpt1" author="Joe Smith"
      title="A Generic Aircraft Simulation Model (does not really exist)"
      accession="ISBN 1-2345-678-9" date="2004-01-01"/>

 <!-- no modifications so far, so we don't need a modificationRecord yet -->

</fileHeader>

<!--            ==================================              -->
<!--============= Variable Definition Components =============== -->
<!--            ==================================              -->


 <!-- Input variable -->

 <variableDef name="Angle of attack" varID="angleOfAttack" units="deg" >
  <isStdAIAA/> <!-- Indicates that this variable is a standard
           variable, which is why the author omitted
           description and sign convention
           and any other info. (it certainly could
           be included here)              -->
 </variableDef>

 <!-- Output (function value) -->

 <variableDef name="Pitching moment coefficient due to angle of attack"
      varID="CmAlfa" units="nondimensional" sign="+ANU">
  <description>
   The derivative of total pitching moment with respect to
   angle of attack.
 </description>
 </variableDef>

 <!--            =============================              -->
 <!--============= Breakpoint Definition Set =============== -->
 <!--            =============================              -->

 <breakpointDef bpID="angleOfAttack_bp1">
```

```
 <!--
  Note that the bpID can be any valid XML string to uniquely identify
  the breakpoints. The author here chose to use a name related to the
  independent variable that is expected to be used to look up the function.
  In fact, if this set of breakpoints were shared by many functions
  and different independent variables would be used to look up the
  function, then the bpID of "angleOfAttack_bp1" would be
  misleading and a more generic name like "AOA" would probably be
  better.
 -->

 <description>
  Angle of attack breakpoint set for CmAlfa, CdAlfa, and ClAlfa
 </description>

 <bpVals>  <!-- Always comma separated values -->
  0, 18, 19, 20, 22, 23, 25, 27, 90
 </bpVals>

</breakpointDef>

<!--            ============================               -->
<!--============= Gridded Table Definition =============== -->
<!--            ============================               -->

<griddedTableDef gtID="CmAlfa_Table1">
 <description>
  The derivative of Cm wrt fuselage AOA in degrees
 </description>

 <provenance>
  <author name="Jake Smith" org="AlCorp"/>
  <functionCreationDate date="2006-12-31"/>
  <documentRef refID="BLHRpt1" /> <!-- This points back to the Header,
                   which provides the information
                   about BLHRpt1. -->
 </provenance>

 <breakpointRefs>
  <bpRef bpID="angleOfAttack_bp1" />
 </breakpointRefs>

 <uncertainty effect="percentage">
  <normalPDF numSigmas="3">
   <bounds>12</bounds>
  </normalPDF>
  <!-- This means that the 3 sigma confidence is +-12% on the Data. -->
 </uncertainty>

 <dataTable>   <!-- Always comma separated values -->
  0.1,-0.1,-0.09, -.08, -0.05, -0.05, -0.07, -0.15, -0.6
 </dataTable>

</griddedTableDef>
```

```
<!--             ========================              -->
<!--============= Function Definition  =============== -->
<!--             ========================              -->

<!-- The function definition ties input and output variables
  with table definitions. This allows a level of abstraction such
  that the table, with its breakpoint definitions, can be reused
  by several functions (such as left and right aileron or multiple
  thruster effect tables).
-->

<function name="Cm_alpha_func">
 <description>
  Variation of pitching moment coefficient with angle of attack (example)
 </description>
 <independentVarRef varID="angleOfAttack"/>
 <dependentVarRef varID="CmAlfa"/>
 <functionDefn>
  <griddedTableRef gtID="CmAlfa_Table1"/>
 </functionDefn>
</function>

<!--             =====================              -->
<!--============= Check Data Cases  =============== -->
<!--             =====================              -->

<!-- Checkcase data provides automatic verification of the model by
  specifying the tolerance in output values for a given set of
  input values. One 'staticShot' is required per input/output
  mapping; in this case for a single input, single output model,
  we have a single input signal and a single output signal in each
  test point.
-->

<checkData>
 <staticShot name="case 1">
  <checkInputs>
   <signal>
   <varID>angleOfAttack</varID>
   <signalValue> 0.</signalValue>
   </signal>
  </checkInputs>
  <checkOutputs>
   <signal>
   <varID>CmAlfa</varID>
   <signalValue>0.01</signalValue>
   <tol>0.00001</tol>
   </signal>
  </checkOutputs>
 </staticShot>
 <staticShot name="case 2">
  <checkInputs>
   <signal>
   <varID>angleOfAttack</varID>
   <signalValue> 5.</signalValue>
```

```xml
  </signal>
 </checkInputs>
 <checkOutputs>
  <signal>
  <varID>CmAlfa</varID>
  <signalValue>0.04444</signalValue>
  <tol>0.00001</tol>
  </signal>
 </checkOutputs>
</staticShot>
<staticShot name="case 3">
 <checkInputs>
  <signal>
  <varID>angleOfAttack</varID>
  <signalValue>10.</signalValue>
  </signal>
 </checkInputs>
 <checkOutputs>
  <signal>
  <varID>CmAlfa</varID>
  <signalValue>-0.01111</signalValue>
  <tol>0.00001</tol>
  </signal>
 </checkOutputs>
</staticShot>
<staticShot name="case 4">
 <checkInputs>
  <signal>
  <varID>angleOfAttack</varID>
  <signalValue>15.</signalValue>
  </signal>
 </checkInputs>
 <checkOutputs>
  <signal>
  <varID>CmAlfa</varID>
  <signalValue>-0.06667</signalValue>
  <tol>0.00001</tol>
  </signal>
 </checkOutputs>
</staticShot>
<staticShot name="case 5">
 <checkInputs>
  <signal>
  <varID>angleOfAttack</varID>
  <signalValue>20.</signalValue>
  </signal>
 </checkInputs>
 <checkOutputs>
  <signal>
  <varID>CmAlfa</varID>
  <signalValue>-0.08</signalValue>
  <tol>0.00001</tol>
  </signal>
 </checkOutputs>
</staticShot>
<staticShot name="case 6">
 <checkInputs>
```

```
    <signal>
    <varID>angleOfAttack</varID>
    <signalValue>25.</signalValue>
    </signal>
   </checkInputs>
   <checkOutputs>
    <signal>
    <varID>CmAlfa</varID>
    <signalValue>-0.07</signalValue>
    <tol>0.00001</tol>
    </signal>
   </checkOutputs>
  </staticShot>
  <staticShot name="case 7">
   <checkInputs>
    <signal>
    <varID>angleOfAttack</varID>
    <signalValue>50.</signalValue>
    </signal>
   </checkInputs>
   <checkOutputs>
    <signal>
    <varID>CmAlfa</varID>
    <signalValue>-0.31429</signalValue>
    <tol>0.00001</tol>
    </signal>
   </checkOutputs>
  </staticShot>
 </checkData>
</DAVEfunc>
```

Although the above seems excessively long for a function with only 9 data points, most of its content involves self-documentation and checking. Therefore, as well as the function's data it includes the data's units, coordinate systems, uncertainty descriptions, and provenance. It also includes many instructional comments, and verification data for multiple simulation conditions. Also, a very large complex function would only be expanded by the additional data points. The definitions and provenance information included with the function would probably not change much.

In the minimum, the same nominal data can be represented as shown. It is also possible to completely remove all whitespace between elements for more compactness, but this greatly affects readability by humans.

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<!DOCTYPE DAVEfunc PUBLIC "-//AIAA//DTD for Flight Dynamic Models - Functions
2.0//EN" "DAVEfunc.dtd">
<DAVEfunc xmlns="http://daveml.org/2010/DAVEML">
   <fileHeader>
     <author name="Bruce Hildreth" org="SAIC"/>
     <fileCreationDate date="2006-03-18"/>
   </fileHeader>
   <variableDef name="Angle of attack" varID="angleOfAttack"
units="deg"/>
   <variableDef name="CMalpha" varID="CmAlfa" units=""/>
   <breakpointDef bpID="angleOfAttack_bp1">
     <bpVals> 0, 18, 19, 20, 22, 23, 25, 27, 90 </bpVals>
   </breakpointDef>
   <griddedTableDef gtID="CmAlfa_Table1">
```

```
      <breakpointRefs>
        <bpRef bpID="angleOfAttack_bp1"/>
      </breakpointRefs>
      <dataTable> 0.1,-0.1,-0.09, -.08, -0.05, -0.05, -0.07, -0.15, -0.6
</dataTable>
   </griddedTableDef>
   <function name="Cm_alpha_func">
      <independentVarRef varID="angleOfAttack"/>
      <dependentVarRef varID="CmAlfa"/>
      <functionDefn>
        <griddedTableRef gtID="CmAlfa_Table1"/>
      </functionDefn>
   </function>
</DAVEfunc>
```

The other principal means of model representation in DAVE-ML is through Math-ML elements, which are used to specify calculations.

For example:

totalThrust_N= engine1Thrust_N + engine2Thrust_N + engine3Thrust_N

This equation, which is part of the model being exchanged, may be encoded in DAVE-ML and exchanged as data as shown below.

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<!DOCTYPE DAVEfunc PUBLIC "-//AIAA//DTD for Flight Dynamic Models - Functions
2.0//EN" "DAVEfunc.dtd">
<DAVEfunc xmlns="http://daveml.org/2010/DAVEML">
 <fileHeader>
  <author name="Dan Newman" org="Quantitative Aeronautics"/>
  <creationDate date="2009-11-10"/>
  <description>
   Simple MathML example : total thrust is the sum of three inputs.
  </description>
 </fileHeader>
 <variableDef name="Engine #1 thrust" varID="engine1Thrust" units="N"/>
 <variableDef name="Engine #2 thrust" varID="engine2Thrust" units="N"/>
 <variableDef name="Engine #3 thrust" varID="engine3Thrust" units="N"/>
 <variableDef name="Total thrust" varID="totalThrust" units="N" >
  <calculation>
      <math>
       <apply>
        <plus/>
            <ci>engine1Thrust</ci>
            <ci>engine2Thrust</ci>
            <ci>engine3Thrust</ci>
       </apply>
      </math>
  </calculation>
 </isOutput>
 </variableDef>
</DAVEfunc>
```


7.7 Summary

The DAVE-ML implementation of the standard enables nearly effortless transfer of simulation aerodynamics models between simulation facilities or architectures. Inclusion of Math-ML elements allows the formulation of algebraic equations, such as aerodynamic, propulsion, inertial, landing gear, or control system models, to be included as data in the model. DAVE-ML is also suitable for use or transfer of tabular functions and algebraic equations for any type of data, not just simulation models.

Although the previous paragraphs provide an overview of the concepts implemented in DAVE-ML, refer to the link provided in Annex B for access to the normative authority for this standard. It includes much more detail and examples on how to easily build a DAVE-ML compliant simulation and includes tools that facilitate use of DAVE-ML based models in many applications.

8 Future Work

The AIAA Modeling and Simulation Technical Committee plans to continue its efforts in facilitation of the exchange of simulations and models throughout the user community. Comments and suggestions on this expansion are welcomed on the simulation standards discussion group. Visit http://www.daveml.org for submittal information. The following sections describe the two tasks of primary interest.

8.1 Time History Information

The immediate task that is being pursued is the transfer of validation data between facilities. This is for the purpose of sending time response validation data when a model is exchanged.

The approach being taken is to adopt a flight test data standard. This has the advantage of using an existing standard and facilitating the use of flight test data to validate a simulation. Lockheed Martin has an existing internal standard that they have released for use by the community. It is implemented in hierarchal data format (HDF) and has been adopted by the JSF community and other programs. It is the Modeling and Simulation Technical Committee's intent to adopt this for the transfer of simulation validation data. Some work will be required to define the data elements that are required for the validation of a simulation. This is expected to be a subset of the data elements that comprise flight test data.

8.2 Dynamic Element Specification

The addition of the specification of dynamics (e.g., continuous and discrete states) is being considered to expand the scope of the standard. This expansion would allow more of the domain of a flight vehicle model (flight controls as a good example) to be exchanged in a nonproprietary, facility-neutral way.

9 Conclusion

This is a standard for the purpose of facilitating the exchange of simulation models between users. This purpose cannot be emphasized enough. It is not meant to enforce any standard simulation architecture. DAVE-ML provides the mechanism for exchange of the modeling data and equations; the standard variables and coordinate systems provide a common language to facilitate effective communication. The standard is also valuable for documenting a model, since the names and coordinate system definitions are clearly documented for the user.

A model can be DAVE-ML compliant without using any standard names or coordinate systems, but the exchange of such a model between users will be more difficult since clear definitions will have to be exchanged also.

It is the earnest desire of the authors of this standard that the user community will employ the current standard for aerodynamic models, continue to suggest improvements to the standard, and develop tools to enhance the standard. `http://www.daveml.org` contains information on how to be part of this effort and/or submit change or improvement recommendations.

Annex A

Standard Variable Names (Normative)

Standard Variable Names (Normative)

A.1 General

The standard variable naming convention is described in detail in Section 6. The table in this annex contains a set of standard simulation variables that are independent of the particular vehicle type being simulated. Use of these standard variables provides a "standard language" which will facilitate the communication of the information required to exchange simulation models. These variables are tailored towards aircraft simulation and to a lesser extent, spacecraft. Visit `http://DaveML.org` to suggest additional variables or changes to the existing list.

A.2 Table Explanation

Interpretation of the standard variable name table is best given by example. In general the table has 7 columns. These are described below using the `eulerAngle_Roll` as an example:

1. The symbol for that variable, Φ
2. The short name, PHI
3. One or more full names using the standard units conventions — generally, one full name with American convention units and one with SI units. Refer to section 6 for a list of the standard units and their abbreviations.

   NOTE: While the variable naming convention described in Section 6 encourages the use of the <variable domain> component, this Annex does not include variable domains as part of the normative standard names. This is because the variable domain is normally dependent upon the simulation architecture, and as such is immaterial to the exchange of a simulation model unless the exchange is between facilities with similar architectures.

   NOTE: Any suitable units may be used. In the example for `eulerAngle_Roll` both the `_deg` for degrees and the `_rad` for radians are given. The "Full Variable Name" column does not necessarily provide all acceptable units for each variable.

4. A description of the variable, if applicable should always specify the coordinate system. Refer to section 5 for a description of the standard coordinate systems.
5. The POSITIVE sign convention of the variable — RWD indicates that positive `eulerAngle_Roll` is right wing down. (See section A.2.1 for a list of sign convention acronyms)
6. Minimum value, normally only specified for angles
7. Maximum values of the variable, normally only specified for angles

This example also illustrates the pitch and yaw Euler angles.

Some variables may be used to represent variables referenced to more than one coordinate system. In this case the coordinate system is specified as `xx` and any coordinate system reference (refer to the body of this standard) may be substituted for the `xx`. For example, `xxVelocity_ft_s_Y` may represent:

a) `eiVelocity_ft_s_Y` for the velocity along the Y axis of the ei coordinate system - Earth centered Inertial (also known as geocentric inertial) coordinate system

b) `geVelocity_ft_s_Y` for the velocity along the Y axis of the geocentric Earth (ge) coordinate system. Also referred to as the Earth Centered Earth Fixed (ECEF coordinate system).

c) `voVelocity_ft_s_Y` for the vo coordinate system (Vehicle carried, Orbit defined coordinate system)

Roll, pitch and yaw may also conveniently be expressed as an array. Again, `eulerAngle_rad[3]`[1] would be the standard array using radians as the units and is fully compliant with the standard.

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Min Value	Max Value
$\underline{\varepsilon}$	EUL[3]	eulerAngle_deg[3] eulerAngle_rad[3]	Array of the roll, pitch, and yaw Euler angles comprised of the elements defined below. LL (locally level) coordinate system.			
Φ	PHI	eulerAngle_deg_Roll eulerAngle_rad_Roll	Roll Euler Angle, LL coordinate system.	RWD	-180,-π	180, π
θ	THET	eulerAngle_deg_Pitch eulerAngle_rad_Pitch	Pitch Euler Angle, LL coordinate system	ANU	-90, -π/2	90, π/2
Ψ	PSI	eulerAngle_deg_Yaw EulerAngle_rad_Yaw	Yaw Euler Angle, LL coordinate system	ANR	-180,-π	180, π

The variable name table below does not specify which variables are states, state derivatives, inputs, disturbances, simulation controls or initial conditions. These specifications may be added to any appropriate variable. Refer to Section 4.2 in the body of this standard for use of dynamic equation prefixes and section 6.4.8 for initial condition specification.

[1] A number or pair of numbers between square brackets represents the number of elements in an array or matrix respectively.

A.2.1 Annex A Acronyms

Positive Sign Convention Acrpnyms

The following acronyms may appear as values for the “positive sign convention” of variables defined in the variable name tables.

+X	in the positive direction of the presentation coordinate system’s X-axis
+Y	in the positive direction of the presentation coordinate system’s Y-axis.
+Z	in the positive direction of the presentation coordinate system’s Z-axis
ABV	positive above
AFT	positive aft
AH	positive above horizon
ANR	positive aircraft nose right
ANU	positive aircraft nose up
BH	positive below horizon
BLO	positive below
CCFN	positive counterclockwise from north
COMP	positive compressed
CWFN	positive clockwise from north
DEC	decrease
DN or Down	positive down
E or East	positive East
FWD	positive forward
INC	positive increase
LED	positive leading edge down
LT or Left	positive left
MAC	percent mean aerodynamic chord
N or North	positive North
NSC	no sign convention (variable is always positive)
OUT	positive outward
POS	always positive
RT or Right	positive right
RTCL	positive right of centerline
RWD	positive right wing down
TED	positive trailing edge down

TEL	positive trailing edge left
TER	positive trailing edge right
TEU	positive trailing edge up
UP	positive up
WOW	weight on wheels

Control Surface and Position Acronyms

LEF	leading edge flap
TEF	trailed edge flap

A.3 Standard Variable Name Tables

Table A.1 — Vehicle Positions and Angles

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
ε	EUL	eulerAngle_deg[3] eulerAngle_rad[3]	Array of the roll, pitch, and yaw Euler angles defined below. LL (locally level) coordinate system.				
Φ	PHI	eulerAngle_deg_Roll eulerAngle_rad_Roll	Roll Euler Angle, LL coordinate system.	RWD		-180, $-\pi$	180, π
θ	THET	eulerAngle_deg_Pitch eulerAngle_rad_Pitch	Pitch Euler Angle, LL coordinate system	ANU		-90, $-\pi/2$	90, $\pi/2$
ψ	PSI	eulerAngle_deg_Yaw eulerAngle_rad_Yaw	Yaw Euler Angle, LL coordinate system	ANR		-180, $-\pi$	180, π
sin Φ	SPHI	sinEulerAngle_Roll	Sine Of Euler Roll Angle	RWD		-1.0	1.0
cos Φ	CPHI	cosEulerAngle_Roll	Cosine Of Euler Roll Angle	RWD		-1.0	1.0
sin θ	STHT	sinEulerAngle_Pitch	Sine Of Euler Pitch Angle	ANU		-1.0	1.0
cos θ	CTHT	cosEulerAngle_Pitch	Cosine Of Euler Pitch Angle	ANU		0.0	1.0
sin ψ	SPSI	sinEulerAngle_Yaw	Sine Of Euler Yaw Angle	ANR		-1.0	1.0
cos ψ	CPSI	cosEulerAngle_Yaw	Cosine Of Euler Yaw Angle	ANR		-1.0	1.0
$\mathbf{T}_{FE/B}$	T	feToBodyT[3,3]	The FE to Body transformation matrix composed of the elements defined below				
$T_{FE/B}[1,1]$	T11	feToBodyT11	CTHT*CPSI (FE To B) coordinate transformation element				
$T_{FE/B}[2,1]$	T21	feToBodyT21	SPHI*STHT*CPSI - CPHI*SPSI (FE To B) coordinate transformation element				

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
$T_{FE/B}[3,1]$	T31	`feToBodyT31`	CPHI*STHT*CPSI + SPHI*SPSI (FE to B) coordinate transformation element				
$T_{FE/B}[1,2]$	T12	`feToBodyT12`	CTHT*SPSI (FE to B) coordinate transformation element				
$T_{FE/B}[2,2]$	T22	`feToBodyT22`	SPHI*STHT*SPSI + CPHI*CPSI (FE to B) coordinate transformation element				
$T_{FE/B}[3,2]$	T32	`feToBodyT32`	CPHI*STHT*SPSI - SPHI*CPSI (FE to B) coordinate transformation element				
$T_{FE/B}[1,3]$	T13	`feToBodyT13`	-STHT (FE to B) coordinate transformation element				
$T_{FE/B}[2,3]$	T23	`feToBodyT23`	SPHI*CTHT (FE to B) coordinate transformation element				
$T_{FE/B}[3,3]$	T33	`feToBodyT33`	CPHI*CTHT (FE to B) coordinate transformation element				
γ	GAMV	`flightPathAngle_rad` `flightPathAngle_deg`	Flight Path Angle Above Horizon	ANU		$-\pi/2$ -90	$\pi/2$ 90
χ	GAMH	`flightPathAzimuth_rad` `flightPathAzimuth_deg`	Flight Path Angle In Horizon Plane, from North	CWFN		$-\pi$ -180	π 180
h	ALT	`altitudeMsl_ft` `altitudeMsl_m`	Geometric altitude of vehicle altimeter above Mean Sea Level	UP			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value

λ	XLON	`geLongitude_rad`
		`geLongitude_deg`
		Note The coordinate system may be deleted if Ge coordinate system, resulting in
		`longitude_rad`
		`longitude_deg`
			Longitude of Vehicle
			Cm with respect to the ge (geocentric Earth) coordinate system.
				WEST			

φ	XLAT	`geLatitude_rad`
		`geLatitude_deg`
		Note The coordinate system may be deleted if Ge coordinate system, resulting in
		`latitude_rad`
		`latitude_deg`
			Geodetic Latitude of Vehicle
			Cm with respect to the ge (geocentric Earth) coordinate system.
				NORTH			

	XLONIMU	`geLongitudeOfImu_rad`
		`geLongitudeOfImu_deg`
		Note The coordinate system may be deleted if Ge coordinate system, resulting in
		`longitudeOfImu_rad`
		`longitudeOfImu_deg`
			Longitude of Vehicle
			Imu with respect to the ge coordinate system. This variable does not include any Imu sensor errors.
				West			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value

	XLATIMU	`gelatitudeOfImu_rad`
		`gelatitudeOfImu_deg`
		
		Note The coordinate system may be deleted if Ge coordinate system, resulting in
		`latitudeOfImu_rad`
		`latitudeOfImu_deg`
			Geodetic Latitude of Vehicle
			Imu with respect to the Gecoordinate system. This variable does not include any Imu sensor errors.
				NORTH			

		`geSensedLongitudeOfImu_rad`
		`eSensedLongitudeOfImu_deg`
		
		Note The coordinate system may be deleted if Ge coordinate system, resulting in
		`sensedLongitudeOfImu_rad`
		`sensedLongitudeOfImu_deg`
			Longitude of Vehicle
			Imu with respect to the Ge coordinate system. This variable includes any Imu sensor errors.
				West			

		`geSensedLatitudeOfImuWrtZzz_rad`
		`geSensedLatitudeOfImuWrtZzz_deg`
		
		Note The coordinate system may be deleted if Ge coordinate system, resulting in
		`sensedLatitudeOfImu_rad`
		`sensedLatitudeOfImu_deg`
			Geodetic Latitude of Vehicle
			Imu with respect to the Ge coordinate system. This variable includes any Imu sensor errors.
				NORTH			

	HGT_RWY	`runwayHeightWrtMsl_ft` `runwayHeightWrtMsl_m`	Height Of Runway w.r.t. mean Sea Level	Above			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value

		General Definition
		`xxPositionOfYyyWrtZzz_ft[3]`
		`xxPositionOfYyyWrtZzz_m[3]`
		For Example:
		`xxPosition_ft[3]`
		is the same as
		`xxPositionOfCmWrtxx_ft[3]`
			General Definition for Linear and Angular Positions: Refer to section 6 of this standard for complete guidance on the naming of variables.
			Vector of positions of Yyy with respect to Zzz (a user defined reference point or coordinate system origin) in the xx coordinate system. The lengths of xx, Yyy, Zzz are not restricted to 2 and 3 characters respectively.
			The coordinate system xx must always be defined. If the OfYyy is not defined the definition defaults to the vehicle Cm for linear positions and the body coordinate system for angular positions. If the WrtZzz is not defined the reference point defaults to the origin of the xx coordinate system for linear position and the locally level (Ll) coordinate system for angular position.
			Comprised of the three components as defined below.				

		`xxPositionOfYyyWrtZzz_ft_X`
		`xxPositionOfYyyWrtZzz_m_X`
		or
		`xxPosition_ft_X`
			X position of Yyy with respect to Zzz (a user defined reference point) in the xx coordinate system.
			Defaults to the Cm and origin of the xx coordinate system.
				(Yyy –Zzz)			

		`xxPositionOfYyyWrtZzz_ft_Y`
		`xxPositionOfYyyWrtZzz_m_Y`
		or
		`xxPosition_ft_Y`
			Y position of Yyy with respect to Zzz (a user defined reference point) in the xx coordinate system.
			Defaults to th Cm and origin of the xx coordinate system.
				(Yyy –Zzz)			

		`xxPositionOfYyyWrtZzz_ft_Z`
		`xxPositionOfYyyWrtZzz_m_Z`
		or
		`xxPosition_ft_Z`
			Z position of Yyy with respect to Zzz (a user defined reference point) in the xx coordinate system.
			Defaults to the CG and origin of the xx coordinate system.
				(Yyy –Zzz)			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
		fePosition_ft [3]	Vector of positions of the CM in the flat Earth coordinate system. Comprised of the three components as defined below.				
	XCG	fePosition_ft_X	X or North position of the CM in the flat Earth coordinate system				
	YCG	fePosition_ft_Y	Y or East position of the CM in the flat Earth coordinate system				
	ZCG	fePosition_ft_Z	Z or Down position of the CM in the flat Earth coordinate system	minus equals above the ground			
		xxPositionOfMrcWrtZzz_ft_X xxPositionOfMrcWrtZzz_m_X	X position of the moment reference center (Mrc) with respect to Zzz in the xx coordinate system.				
		xxPositionOfMrcWrtZzz_ft_Y xxPositionOfMrcWrtZzz_m_Y	Y position of the moment reference center (Mrc) with respect to Zzz in the xx coordinate system.				
		xxPositionOfMrcWrtZzz_ft_Z xxPositionOfMrcWrtZzz_m_Z	Z position of the moment reference center (Mrc) with respect to Zzz in the xx coordinate system.				
	REF [3]	bodyPositionOfMrc_ft [3]	Vector of positions of the aerodynamic moment reference center in the body coordinate system. Since the origin of the body coordinate system is the Cm, this vector is the positions of the Mrc with respect to the Cm Comprised of the three components as defined below.				
	XREF	bodyPositionOfMrc_ft_X	X position of the Mrc in the body coordinate system	Mrc in front of the origin (Cm)			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
	YREF	`bodyPositionOfMrc_ft_Y`	Y position of the Mrc in the body coordinate system	Mrc out the right wing with respect to the origin (Cm)			
	ZREF	`bodyPositionOfMrc_ft_Z`	Z position of the Mrc in the body coordinate system	Mrc below the origin (Cm)			
	PLT2CG[3]	`bodyPositionOfPilotEyeWrtCm_f[3]` `bodyPositionOfPilotEyeWrtCm_ft[3]`	Vector of positions of the pilot's eye with respect to the Cm in the body coordinate system. Comprised of the three components as defined below.				
	XPLT2CG	`bodyPositionOfPilotEyeWrtCm_ft_X` `bodyPositionOfPilotEyeWrtCm_ft_X`	X position of pilot eye point w.r.t. Cm, in the body coordinate system	Eye FWD of Cm			
	YPLT2CG	`bodyPositionOfPilotEyeWrtCm_ft_Y` `bodyPositionOfPilotEyeWrtCm_ft_Y`	Y position of pilot eye point w.r.t. Cm, in the body coordinate system	Eye Right of the Cm			
	ZPLT2CG	`bodyPositionOfPilotEyeWrtCm_ft_Z` `bodyPositionOfPilotEyeWrtCm_ft_Z`	Z position of pilot eye point w.r.t. Cm, in the body coordinate system	Eye below Cm			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
		EXAMPLES					
		runway22Position_ft[3] indicates position of the Cm (default) with respect to the origin of the Runway22 coordinate system (default), in the runway22 coordinate system. A more complete and clear name would be: runway22PositionOfCmWrtRunway22_ft[3] runway22PositionOfFwdLeftMainWheelWrtTd_ft[3] indicates position of the forward left main wheel with respect to the touchdown point in the Runway 22 coordinate system NOTE All coordinate systems are user defined	Vector of positions of the vehicle Cm relative to the Runway 22 (a user defined coordinate system) touchdown reference point. Comprised of the three components as defined below.				
	XCGTD	runway22PositionOfCmWrtTd_ft_X runway22PositionOfCmWrtTd_m_X	Cm X-position w.r.t. runway touchdown point in the specified (Runway22) coordinate system.	Cm Down the runway from the reference point			
	YCGTD	runway22PositionOfCmWrtTd_ft_Y runway22PositionOfCmWrtTd_m_Y	Cm Y-position w.r.t. runway touchdown point in the specified (Runway22) coordinate system.	Cm to the right of the reference point			
	ZCGTD	runway22PositionOfCmWrtTd_ft_Z runway22PositionOfCmWrtTd_m_Z	Cm Z-position w.r.t. runway touchdown point in the specified (Runway22) coordinate system. (This variable is normally negative.)	Cm below the TD point			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
	RE	`smoothEarthRadius_ft` `smoothEarthRadius_m`	Geocentric radius of Earth (center to smooth surface), round Earth model or oblate spheroid at the nadir of the aircraft.				

	RALT	`heightOfCmWrtTerrain_ft`
		`heightOfCmWrtTerrain_m`
		or
		`heightWrtTerrain_ft`
		`heightWrtTerrain_m`
			Height of the aircraft Cm above the terrain	NSC			

	HTERRAIN	`heightOfTerrainWrtGround_ft` `heightOfTerrainWrtGround_m`	Height of the terrain at the nadir of the aircraft Cm. It is the terrain height above the smooth surface of the Earth, regardless of whether a flat, round or oblate spheroid model is used.				

Table A.2 — Vehicle velocities and angular rates

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
$V_{T_{XX}}$	VTxx	`totalSpeedWrtXx_ft_s` `totalSpeedWrtXx_m_s`	Total Velocity with respect to and observed from Xx where Xx is the coordinate system as defined in the body of this standard.	NSC			
V_K	VG	`groundSpeed_ft_s` `groundSpeed_m_s`	Vehicle speed along the ground.	NSC			
M_N	XMACH	`mach`	Mach number of the aircraft	NSC			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value

$\dot{h}_{xx}$	ALTDxx	`xxAltitudeRate_ft_s`
		`xxAltitudeRate_m_s`
		default coordinate system is locally level and -Z axis
			Altitude time rate of change in xx coordinate system.	DN			

	XLOND	`xxLongitudeRate_rad_s`
		`xxLongitudeRate_deg_s`
		Default is Ge coordinate system
			Longitude Rate Of Change in xx coordinate system.	WEST			

	XLATD	`xxlatitudeRate_rad_s`
		`xxlatitudeRate_deg_s`
		Default is Ge coordinate system
			Geodetic Latitude Rate of Change in xx coordinate system.	NORTH			

		General Definition-Translational Velocities
		`xxVelocityOfYyyWrtZzzObsFrWww_ft_s [3]`
		`xxVelocityOfYyyWrtZzzObsFrWww_m_s [3]`
			<u>General Definition for Translational Motion</u>: Refer to section 6 of this standard for complete guidance on the naming of variables.
			General expression for vector of velocities presented (or measured) in the xx coordinate system. Yyy indicates the reference point on the vehicle and the `OfYyy` may be omitted if it is the Cm. Zzz represents the coordinate system that the vehicle is moving with respect to and `WrtZzz` may be omitted if it is the xx coordinate system. `ObsFrWww` represents the coordinate system from which the vehicle motion is observed. The `ObsFrWww` may be omitted if it is the Zzz coordinate system (see section 6.3.3 for more detail)
			Therefore `eiVelocity_ft_s_X` is the velocity of the vehicle Cm along the X axis of the `ei` coordinate system, measured with respect to the ei coordinate system and observed from the ei coordinate system and is the default expression for `eiVelocityOfCmWrtEiObsFrEi_ft_s_X`.				

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
		General Definition-Angular Velocities xxAnggularRateOfYyyWrtZzz_rad_s_[3] xxAnggularRateOfYyyWrtZzz_deg_s_[3]	**General Definition for Rotational Motion**: Refer to section 6 of this standard for complete guidance on the naming of variables. General expression for angular velocities presented in the xx coordinate system. Yyy indicates the reference coordinate system on the vehicle and the OfYyy may be omitted if it is the body coordinate system. Zzz represents the coordinate system that the vehicle is moving with respect to and from which the vehicle motion is observed. The WrtZzz may be omitted if it is the locally level (Ll) coordinate system. (see section 6.3.3 for more detail) Therefore eiAngularRate_rad_s_Roll is the angular rate of the body axis of the vehicle with respect to the locally level coordinate system and presented (or measured) in the Earth centered inertial (ei) coordinate system and is the default expression for eiAngularRateOfBodyWrtLl_rad_s_Roll				
Ω	OM	bodyAngularRate_rad_s[3] bodyAngularRate_deg_s[3]	Vector of body coordinate angular rates of the ownship body coordinate system with respect to the locally level (Ll) coordinate system. Comprised of the three components as defined below. Angular motion is always with respect to the Ll coordinate system unless otherwise specified.				
p	P	bodyAngularRate_rad_s_Roll bodyAngularRate_deg_s_Roll	Vehicle roll velocity, body coordinate system	RWD			
q	Q	bodyAngularRate_rad_s_Pitch bodyAngularRate_deg_s_Pitch	Vehicle pitch velocity, body coordinate system	ANU			
r	R	bodyAngularRate_rad_s_Yaw bodyAngularRate_deg_s_Yaw	Vehicle yaw velocity, body coordinate system	ANR			
Ω_B	OMB	bodyAngularRateWrtEi_rad_s[3] bodyAngularRateWrtEi_deg_s[3]	Vector of body coordinate angular rates with respect to the Earth centered inertial (Ei) coordinate system. Comprised of the three components as defined below.				

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
p_B	PB	`bodyAngularRateWrtEi_rad_s_Roll` `bodyAngularRateWrtEi_deg_s_Roll`	Vehicle roll velocity, body coordinate system	RWD			
q_B	QB	`bodyAngularRateWrtEi_rad_s_Pitch` `bodyAngularRateWrtEi_deg_s_Pitch`	Vehicle pitch velocity, body coordinate system	ANU			
r_B	RB	`bodyAngularRateWrtEi_rad_s_Yaw` `bodyAngularRateWrtEi_deg_s_Yaw`	Vehicle yaw velocity, body coordinate system	ANR			
p_{vf}	PS	`saAngularRateOfBodyWrtEi_rad_s_Roll` `saAngularRateOfBodyWrtEi_deg_s_Roll`	Body coordinate system Roll rate about the X axis in the sa coordinate system, also know as stability axis roll rate.	RWD			
r_{vf}	RS	`saAngularRateOfBodyWrtEi_rad_s_yaw` `saAngularRateOfBodyWrtEi_deg_s_yaw`	Body coordinate system Yaw rate about the Z axis in the sa coordinate system, also known as the Stability Axis yaw rate	ANR			
$\underline{\dot{\varepsilon}}$	EULD	`eulerAngleRate_deg_s[3]` `eulerAngleRate_rad_s[3]`	Array of the roll, pitch, and yaw Euler angle rates defined below. LL (locally level) coordinate system				
$\dot{\phi}$	PHID	`eulerAngleRate_rad_s_Roll`	Euler roll rate, LL coordinate system	RWD			
$\dot{\theta}$	THETD	`eulerAngleRate_rad_s_Pitch`	Euler pitch rate, LL coordinate system	ANU			
$\dot{\psi}$	PSID	`eulerAngleRate_rad_s_Yaw`	Euler yaw rate, LL coordinate system	ANR			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
$\underline{V}$	VEL [3]	bodyVelocityWrtAir_ft_s[3] bodyVelocityWrtAir_m_s[3] can also be expressed as: bodyVelocityOfCmWrtAir_ft_s[3]	Vector of body coordinate velocities of the Cm with respect to the instantaneous wind comprised of the three components as defined below. This is the conventional body coordinate system airspeed vector.				
u	U	bodyVelocityWrtAir_ft_s_X bodyVelocityWrtAir_m_s_X	X-velocity Body coordinate system.	FWD			
v	V	bodyVelocityWrtAir_ft_s_Y bodyVelocityWrtAir_m_s_Y	Y-velocity Body coordinate system	RT			
w	W	bodyVelocityWrtAir_ft_s_Z bodyVelocityWrtAir_m_s_Z	Z-velocity Body coordinate system	DN			
$\underline{V}_B$	VELB[3]	bodyVelocityWrtEi_ft_s[3] bodyVelocityWrtEi_m_s[3] can also be expressed as: bodyVelocityOfCmWrtEi_ft_s[3]	Vector of body coordinate inertial velocities of the Cm comprised of the three components as defined below.				
u_B	UB	bodyVelocityWrtEi_ft_s_X bodyVelocityWrtEi_m_s_X	X-velocity Body coordinate system.	FWD			
v_B	VB	bodyVelocityWrtEi_ft_s_Y bodyVelocityWrtEi_m_s_Y	Y-velocity Body coordinate system	RT			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
w_B	WB	bodyVelocityWrtEi_ft_s_Z bodyVelocityWrtEi_m_s_Z	Z-velocity Body coordinate system	DN			
$\underline{V}_E$	VELE[3]	bodyVelocityWrtGe_ft_s[3] bodyVelocityWrtGe_m_s[3] can also be expressed as: bodyVelocityOfCmWrtGe_ft_s[3]	Vector of body coordinate Cm velocities with respect to the geocentric Earth (Ge) coordinate system. Comprised of the three components as defined below.				
u_E	UE	bodyVelocityWrtGe_ft_s_X bodyVelocityWrtGe_m_s_X	X-velocity Body coordinate system.	FWD			
v_E	VE	bodyVelocityWrtGe_ft_s_Y bodyVelocityWrtGe_m_s_Y	Y-velocity Body coordinate system	RT			
w_E	WE	bodyVelocityWrtGe_ft_s_Z bodyVelocityWrtGe_m_s_Z	Z-velocity Body coordinate system	DN			
$\underline{V}_{FE}$	VELFE	feVelocity_ft_s[3] feVelocity_m_s[3]	Vector of Flat Earth (FE) coordinate translational velocities of the Cm comprised of the three components as defined below.				
V_N	VNFE	feVelocity_ft_s_X feVelocity_m_s_X	Northward Velocity Over Flat Earth (FE) coordinate system [flat, non-rotating Earth]	NORTH			
V_E	VEFE	feVelocity_ft_s_Y feVelocity_m_s_Y	Eastward Velocity Over Flat Earth (FE) coordinate system [flat, non-rotating Earth]	EAST			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
V_D	VDFE	`feVelocity_ft_s_Z` `feVelocity_m_s_Z`	Downward Velocity Toward Earth Ctr,.(FE) coordinate system [flat, non-rotating Earth]	DN			
$\underline{V}_E$		`geVelocity_ft_s [3]` `geVelocity_m_s [3]`	Vector of Geocentric Earth (Ge) coordinate translational velocities of the Cm comprised of the three components as defined below.				
$\mathbf{V_{X_E}}$	VXGE	`geVelocity_ft_s_X` `geVelocity_m_s_X`	X axis velocity over the Earth in the geocentric Earth (GE) coordinate system in ft/sec	+X			
$\mathbf{V_{Y_E}}$	VYGE	`geVelocity_ft_s_Y` `geVelocity_m_s_Y`	Y axis velocity over the Earth in the geocentric Earth (GE) coordinate system in ft/sec	+Y			
$\mathbf{V_{Z_E}}$	VZGE	`geVelocity_ft_s_Z` `geVelocity_m_s_Z`	Y axis velocity over the Earth in the geocentric Earth (GE) coordinate system in ft/sec	+Z			
			OTHER EXAMPLES				
$\mathbf{V_{Xge}}$	VXGE	`geVelocity_km_s_X`	X axis velocity of the vehicle Cm is the geocentric (ge) coordinate system in kilometers/sec	+X			
		`runway22Velocity_ft_s_Z`	Z axis velocity of the Cm in the user defined “runway22” coordinate system in ft/s	DN			

Table A.3 — Vehicle linear and angular accelerations

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
		General Definition-Translational Accelerations xxAccelOfYyyWrtZzzObsFrWww_ft_s2 [3] xxAccelOfYyyWrtZzzObsFrWww_m_s2 [3]	**General Definition for Translational Motion**: Refer to section 6 of this standard for complete guidance on the naming of variables. General expression for vector of accelerations presented (or measured) in the xx coordinate system. Yyy indicates the reference point on the vehicle and the OfYyy may be omitted if it is the Cm. Zzz represents the coordinate system that the vehicle is moving with respect to and WrtZzz may be omitted if it is the xx coordinate system. ObsFrWww represents the coordinate system from which the vehicle motion is observed. The ObsFrWww may be omitted if it is the Zzz coordinate system (see section 6.3.3 for more detail) Therefore eiVelocity_ft_s2_X is the acceleration of the vehicle Cm along the X axis of the ei coordinate system, measured with respect to the ei coordinate system and observed from the ei coordinate system and is the default expression for eiVelocityOfCmWrtEiObsFrEi_ft_s2_X.				
		General Definition-Angular Accelerations xxAnggularAccelOfYyyWrtZzz_rad_s2_[3] xxAnggularAccelOfYyyWrtZzz_deg_s2_[3]	**General Definition for Rotational Motion**: Refer to section 6 of this standard for complete guidance on the naming of variables. General expression for angular accelerations presented in the xx coordinate system. Yyy indicates the reference coordinate system on the vehicle and the OfYyy may be omitted if it is the body coordinate system. Zzz represents the coordinate system that the vehicle is moving with respect to and from which the vehicle motion is observed. The WrtZzz may be omitted if it is the locally level (Ll) coordinate system. (see section 6.3.3 for more detail) Therefore eiAngularAccel_rad_s2_Roll is the angular acceleration of the body axis of the vehicle with respect to the locally level coordinate system and presented (or measured) in the Earth centered inertial (ei) coordinate system and is the default expression for eiAngularAccelOfBodyWrtLl_rad_s2_Roll				
$\underline{\dot{\omega}}$	OMBD	bodyAngularAccel_rad_s2[3] bodyAngularAccel_deg_s2[3]	Vector of body coordinate angular accelerations of the ownship body axis coordinate system with respect to the Locally level (Ll) coordinate system (Note: WrtLl is the default and is therefore omitted), comprised of the three body axis components as defined below.				

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
$\dot{p}$	PBD	bodyAngularAccel_rad_s2_Roll bodyAngularAccel_deg_s2_Roll	Aircraft Roll Acceleration, Body coordinate system	RWD			
$\dot{q}$	QBD	bodyAngularAccel_rad_s2_Pitch bodyAngularAccel_deg_s2_Pitch	Aircraft Pitch Acceleration, Body coordinate system	ANU			
$\dot{r}$	RBD	bodyAngularAccel_rad_s2_Yaw bodyAngularAccel_deg_s2_Yaw	Aircraft Yaw Acceleration, Body coordinate system	ANR			
$\underline{\dot{\omega}}_B$	OMBDE	bodyAngularAccelWrtEi_rad_s2[3] bodyAngularAccelWrtEi_deg_s2[3]	Vector of body coordinate angular accelerations with respect to the Earth-centered inertial coordinate system, comprised of the three body axis components as defined below.				
$\dot{p}_B$	PBDE	bodyAngularAccelWrtEi_rad_s2_Roll bodyAngularAccelWrtEi_deg_s2_Roll	Aircraft Roll Acceleration, Body coordinate system	RWD			
$\dot{q}_B$	QBDE	bodyAngularAccelWrtEi_rad_s2_Pitch bodyAngularAccelErtEi_deg_s2_Pitch	Aircraft Pitch Acceleration, Body coordinate system	ANU			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
$\dot{r}_B$	RBDE	bodyAngularAccelWrtEi_rad_s2_Yaw bodyAngularAccelWrtEi_deg_s2_Yaw	Aircraft Yaw Acceleration, Body coordinate system	ANR			
$\underline{\dot{V}}_B$		bodyAccelWrtEi_ft_s2[3] bodyAccelWrtEi_m_s2[3]	Vector of accelerations of the Cm of the aircraft with respect to and observed from the Ei coordinate system (Earth-centered inertial) in the body coordinate system. This variable includes the gravitation vector. Comprised of the three components as defined below.				
$\dot{u}_B$	UBD	bodyAccelWrtEi_ft_s2_X bodyAccelWrtEi_m_s2_X	Longitudinal acceleration (along the X-body coordinate)	FWD			
$\dot{v}_B$	VBD	bodyAccelWrtEi_ft_s2_Y bodyAccelWrtEi_m_s2_Y	Right Sideward Acceleration, Body coordinate	RT			
$\dot{w}_B$	WBD	bodyAccelWrtEi_ft_s2_Z bodyAccelWrtEi_m_s2_Z	Downward Acceleration, Body coordinate	DNDN			
$\underline{\dot{V}}$		bodyAccelWrtAir_ft_s2[3] bodyAccelWrtAir_m_s2[3]	Vector of body coordinate accelerations of the Cm with respect to the mean air mass and comprised of the three components as defined below. This variable includes the gravitation vector. Comprised of the three components as defined below.				
$\dot{u}$		bodyAccelWrtAir_ft_s2_X bodyAccelWrtAir_m_s2_X	Longitudinal acceleration (along the X-body coordinate)	FWD			
$\dot{v}$		bodyAccelWrtAir_ft_s2_Y bodyAccelWrtAir_m_s2_Y	Right Sideward Acceleration, along the Y Body coordinate	RT			
$\dot{w}$		bodyAccelWrtAir_ft_s2_Z bodyAccelWrtAir_m_s2_Z	Downward Acceleration, along the Z Body coordinate	DNDN			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
$\dot{\underline{V}}_E$		bodyAccelWrtGe_ft_s2[3] bodyAccelWrtGe_m_s2[3]	Vector of body coordinate Cm velocities with respect to the geocentric Earth (Ge) coordinate system. Comprised of the three components as defined below. This variable includes the gravitation vector. Comprised of the three components as defined below.				
$\dot{u}_E$		bodyAccelWrtGe_ft_s2_X bodyAccelWrtGe_m_s2_X	Longitudinal acceleration (along the X-body coordinate)	FWD			
$\dot{v}_E$		bodyAccelWrtGe_ft_s2_Y bodyAccelWrtGe_m_s2_Y	Right Sideward Acceleration, along the Y Body coordinate	RT			
$\dot{w}_E$		bodyAccelWrtGe_ft_s2_Z bodyAccelWrtGe_m_s2_Z	Downward Acceleration, along the Z Body coordinate	DN			
		totalAccelWrtEi_ft_s2	Magnitude of the inertial acceleration vector	NSC			
	VTDxx	totalVelocityRateWrtXx_ft_s2 totalVelocityRateWrtXx_m_s2	Rate of change of speed with respect to and observed from Xx, where xx is the coordinate system as defined in the body of this standard. Total velocity (speed) rate of change is not the same as total acceleration (magnitude of the acceleration vector). For example, a velocity vector that only undergoes a direction change shows zero change in speed (magnitude) but still shows a positive total acceleration due to its direction change.	INC			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
		xxAccel_ft_s2 [3] xxAccel_m_s2 [3]	General form for the vector of aircraft Cm translational acceleration with respect to and observed from the specified (xx) coordinate system comprised of the three components as defined below.				
		xxAccel_ft_s2_X xxAccel_m_s2_X	X-axis acceleration in xx coordinate system	+X			
		xxAccel_ft_s2_Y xxAccel_m_s2_Y	Y-axis acceleration in xx coordinate system	+Y			
		xxAccel_ft_s2_Z xxAccel_m_s2_Z	Z-axis acceleration in xx coordinate system	+Z			
		bodyAccelOfImuWrtEi_ft_s2[3] bodyAccelOfImuWrtEi_m_s2[3]	Vector of true inertial accelerations at the inertial measurement unit (Imu) including the effects of the gravitation vector. This variable assumes a perfect Imu. Comprised of the three body coordinate system components as defined below.				
	AX	bodyAccelOfImuWrtEi_ft_s2_X bodyAccelOfImuWrtEi_m_s2_X	X Acceleration Of aircraft Cm (body coordinate) Includes the gravitation vector.	FWD			
	AY	bodyAccelOfImuWrtEi_ft_s2_Y bodyAccelOfImuWrtEi_m_s2_Y	Y Acceleration Of aircraft Cm (body coordinate) Includes the gravitation vector.	RT			
	AZ	bodyAccelOfImuWrtEi_ft_s2_Z bodyAccelOfImuWrtEi_m_s2_Z	Z Acceleration Of aircraft Cm (body coordinate) Includes the gravitation vector.	DN			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
		bodySensedAccelOfImuWrtEi_ft_s2[3] bodySensedAccelOfImuWrtEi_m_s2[3]	Vector of sensed inertial accelerations at the inertial measurement unit (Imu) including the effects of the gravitation vector. This variable includes any senor scale, bias and noise. Comprised of the three body coordinate system components as defined below.				
		bodySensedAccelOfImuWrtEi_ft_s2_X bodySensedAccelOfImuWrtEi_m_s2_X	X Acceleration Of aircraft Cm (body coordinate) Includes the gravitation vector.	FWD			
		bodySensedAccelOfImuWrtEi_ft_s2_Y bodySensedAccelOfImuWrtEi_m_s2_Y	Y Acceleration Of aircraft Cm (body coordinate) Includes the gravitation vector.	RT			
		bodySensedAccelOfImuWrtEi_ft_s2_Z bodySensedAccelOfImuWrtEi_m_s2_Z	Z Acceleration Of aircraft Cm (body coordinate) Includes the gravitation vector.	DN			
		bodyAccelOfPilotWrtEi_ft_s2[3] bodyAccelOfPilotWrtEi_m_s2[3]	Vector of inertial accelerations at the pilot reference point, in the body coordinate system, comprised of the three components as defined below.				
	AXP	bodyAccelOfPilotWrtEi_ft_s2_X bodyAccelOfPilotWrtEi_m_s2_X	X Acceleration Of Pilot reference point (body coordinate)	FWD			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
	AYP	bodyAccelOfPilotWrtEift_s2_Y bodyAccelOfPilotWrtEi_m_s2_Y	Y Acceleration Of Pilot reference point(body coordinate)	RT			
	AZP	bodyAccelOfPilotWrtEi_ft_s2_Z bodyAccelOfPilotWrtEi_m_s2_Z	Z Acceleration Of Pilot reference point(body coordinate)	DN			
	GVBODY [3]	bodyLocalGravitation_ft_s2[3] bodyLocalGravitation_m_s2[3]	Local gravitation vector in the body coordinate system.				
	GVBODYX	bodyLocalGravitation_ft_s2_X bodyLocalGravitation_ft_s2_X	X axis component	FWD			
	GVBODYY	bodyLocalGravitation_ft_s2_Y bodyLocalGravitation_ft_s2_Y	Y axis component	RT			
	GVBODYZ	bodyLocalGravitation_ft_s2_Z bodyLocalGravitation_ft_s2_Z	Z axis component	DN			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
	GVGE [3]	geLocalGravitation_ft_s2 [3] geLocalGravitation_m_s2 [3]	Local gravitation vector in the ge (geocentric Earth) coordinate system.				
	GVGEX	geLocalGravitation_ft_s2_X geLocalGravitation_ft_s2_X	X axis component	FWD			
	GVGEY	geLocalGravitation_ft_s2_Y geLocalGravitation_ft_s2_Y	Y axis component	RT			
	GVGEZ	geLocalGravitation_ft_s2_Z geLocalGravitation_ft_s2_Z	Z axis component	DN			
	GVEI[3]	eiLocalGravitation_ft_s2 [3] eiLocalGravitation_m_s2 [3]	Local gravitation vector in the ei (Earth centered inertial) coordinate system.				
	GVEIX	eiLocalGravitation_ft_s2_X eiLocalGravitation_ft_s2_X	X axis component	FWD			
	GVEIY	eiLocalGravitation_ft_s2_Y eiLocalGravitation_ft_s2_Y	Y axis component	RT			
	GVEIZ	eiLocalGravitation_ft_s2_Z eiLocalGravitation_ft_s2_Z	Z axis component	DN			
	G	localGravity_ft_s2 localGravity_m_s2	Acceleration Due To Gravity (at the vehicle altitude), in the LI coordinate system.	DN			

Table A.4 — Vehicle air data

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
α	ALFA	angleOfAttack_deg angleOfAttack_rad	Angle Of Attack, Body coordinate	ANU		$-\pi$,-180	$+\pi$, +180
β	BETA	angleOfSideslip_deg angleOfSideslip_rad	Sideslip Angle, Body coordinate	ANL		$-\pi$,-180	$+\pi$, +180
$\dot{\alpha}$	ALFD	angleOfAttackRate_rad_s	Angle Of Attack Rate, Body coordinate	ANU			
$\dot{\beta}$	BETD	angleOfSideslipRate_rad_s	Sideslip Angle Rate	ANL			
$\sin\alpha$	SALPH	sineAngleOfAttack	Sine Of Angle Of Attack	ANU		-1.0	1.0
$\cos\alpha$	CALPH	cosineAngleOfAttack	Cosine Of Angle Of Attack	ANU		-1.0	1.0
$\sin\beta$	SBETA	sineAngleOfSideslip	Sine Of Sideslip Angle	ANL		-1.0	1.0
$\cos\beta$	CBETA	cosineAngleOfSideslip	Cosine Of Sideslip Angle	ANL		-1.0	1.0
V_{CAL}	VCAL	calibratedAirspeed_nmi_h	Calibrated Air Speed, knots	FWD			
V_{EQ}	VEQ	equivalentAirspeed_nmi_h	Equivalent Air Speed	FWD			
V_{IND}	VCAL	indicatedAirspeed_nmi_h	Calibrated Air Speed,	FWD			
V	VRW	trueAirspeed_ft_s trueAirspeed_m_s trueAirspeed_nmi_h	Vehicle Velocity relative to the local wind (true airspeed)	FWD			
$\bar{q}$	QBAR	dynamicPressure_lbf_ft2 dynamicPressure_N_m2	Dynamic Pressure	NSC			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
$\overline{q}_c$	QBARC	impactPressure_lbf_ft2 impactPressure_N_m2	Impact Pressure	NSC			
ρ	RHO	airDensity_lbm_ft3 airDensity_kg_m3	Air Density, At Altitude of the aircraft	NSC			
	DENALT	densityAltitude_ft densityAltitude_m	Density altitude				
a	SOUND	speedOfSound_ft_s speedOfSound_m_s	Velocity Of Sound At Altitude of the aircraft	NSC			
T_{TOTR}	TR	totalTempRatio totalTempRatio	Total Temperature Ratio	NSC			
P_{TOTR}	PR	totalPressureRatio totalPressureRatio	Total Pressure Ratio	NSC			
T_{AMB}	TAMB	ambientTemperature_dgC ambientTemperature_dgK	Ambient Temperature at altitude	NSC			
P_{AMB}	PAMB	ambientPressure_lbf_ft2 ambientPressure_N_m2	Ambient Pressure at altitude	NSC			
P_{AMBR}	PAMBR	ambientPressureRatio	Ratio Of ambient pressure at altitude to sea level ambient pressure	NSC			
T_{AMBR}	TAMBR	ambientTemperatureRatio	Ratio Of ambient temperature at altitude to sea level ambient temp.	NSC			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
t_T	TTOT	`totalTemp_dgC` `totalTemp_dgK`	Total Temperature at altitude	NSC			
p_T	PTOT	`totalPressure_lbf_ft2` `totalPressure_N_m2`	Total Pressure at altitude	NSC			

	TAMB	`ambientTemperatureAtAlt_dgK`
		`ambientTemperatureAtAlt_dgR`
		`ambientTemperatureAtAlt_dgC`
			Ambient temperature, at the altitude of the Cm				

	TTOT	`totalTemperatureAtAlt_dgK`
		`totalTemperatureAtAlt_dgR`
		`totalTemperatureAtAlt_dgC`
			Total temperature at the altitude of the Cm				

	ALT_SET	`instrumentAltimeterSetting_inchMercury`	Cockpit Altimeter setting (Kohlsman window)	29.92 is standard day			
	P_ALT	`pressureAltitude_ft` `pressureAltitude_m`	Pressure altitude at the Cm				
	RHO_SL	`seaLevelAirDensity_lbm_ft3`	Air density at sea level				
	TAMB_SL	`seaLevelAmbientTemp_dgK` `seaLevelAmbientTemp_dgC`	Ambient temperature at mean sea level				

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
	PAMB_SL	`seaLevelAmbientPressure_lbf_ft2` `seaLevelAmbientPressure_N_m2`	Ambient pressure at sea level				

Table A.5 — Atmospheric disturbances and turbulence

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
	WIND_SPEED	`meanAirMassSpeed_ft_s` `meanAirMassSpeed_m_s`	Total velocity of mean wind				
	WIND_DIRECTION	`meanAirMassDirection_deg`	Mean wind direction	Wind blowing FROM North			
V_w	VTWS	`totalWindSpeed_ft_s` `totalWindSpeed_m_s`	Total Wind Speed (mean wind plus turbulence)	NSC			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value

$\underline{V}_{W_{T_{ll}}}$		llTurbulenceVelocityWrtGe_ft_s[3]
		llTurbulenceVelocityWrtGe_m_s[3]
			Vector of locally level coordinate wind turbulence velocities with respect to the geocentric earth (Ge) fixed coordinate system.
			
			Comprised of the three components as defined below.
			
			Note: This vector is designed to be transformed from the GRAM 07 small wind perturbation velocities. GRAM 07 outputs the wind perturbation vector:
			
			`usmall` (+ East)
			
			`vsmall` (+ North)
			
			`wsmall` (+ UP)
			
			Therefore:
			
			`llturbulenceVelocityWrtGe_m_s_X = vsmall`
			
			`llturbulenceVelocityWrtGe_m_s_Y = usmall`
			
			`llturbulenceVelocityWrtGe_m_s_Z = -wsmall`				

$N_{W_{T_{ll}}}$	NSMALL	llTurbulenceVelocityWrtGe_ft_s_X llTurbulenceVelocityWrtGe_m_s_X	X-velocity Turb. Component	to the North			
$E_{W_{T_{ll}}}$	ESMALL	llTurbulenceVelocityWrtGe_ft_s_Y llTurbulenceVelocityWrtGe_m_s_Y	Y-velocity Turb. Component	to the East			
$D_{W_{T_{ll}}}$	DSMALL	llTurbulenceVelocityWrtGe_ft_s_Z llTurbulenceVelocityWrtGe_m_s_Z	Z-velocity Turb. Component	to downward			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
$\underline{V}_{Turb}$	VELBWT	bodyTurbulenceVelocityWrtGe_ft_s[3] bodyTurbulenceVelocityWrtGe_m_s[3]	Vector of body coordinate translational turbulence velocities comprised of the three components as defined below.				
U_{Turb}	UBTURB	bodyTurbulenceVelocityWrtGe_ft_s_X bodyTurbulenceVelocityWrtGe_m_s_X	X-velocity Turb. Component, Body coordinate	FWD (tailwind)			
V_{Turb}	VBTURB	bodyTurbulenceVelocityWrtGe_ft_s_Y bodyTurbulenceVelocityWrtGe_m_s_Y	Y-velocity Turb. Component, Body coordinate	RT			
W_{Turb}	WBTURB	bodyTurbulenceVelocityWrtGe_ft_s_Z bodyTurbulenceVelocityWrtGe_m_s_Z	Z-velocity Turb. Component, Body coordinate	DN			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
$\underline{V}_{W M_{ll}}$	VELMW	llVelocityOfMeanAirMassWrtGe_ft_s[3] llVelocityOfMeanAirMassWrtGe_m_s[3]	Vector of locally level coordinate mean wind translational velocities comprised of the three components as defined below. Note: This vector is designed to be transformed from the GRAM 07 wind model velocities. GRAM 07 outputs the mean wind velocity vector: umean (+ East) vmean (+ North) wmean (+ UP) Therefore: llVelocityOfMeanAirMassWrtGe_m_s_X = vmean llVelocityOfMeanAirMassWrtGe_m_s_Y = umean llVelocityOfMeanAirMassWrtGe_m_s_Z = -wmean				
$N_{W_{M_{ll}}}$	NMEAN	llVelocityOfMeanAirMassWrtGe_ft_s_X llVelocityOfMeanAirMassWrtGe_m_s_X	X-velocity Component, locally level coordinate system	to the North			
$E_{W_{M_{ll}}}$	EMEAN	llVelocityOfMeanAirMassWrtGe_ft_s_Y llVelocityOfMeanAirMassWrtGe_m_s_Y	Y-velocity Component, locally level coordinate system	to the East			
$D_{W_{M_{ll}}}$	DMEAN	llVelocityOfMeanAirMassWrtGe_ft_s_Z llVelocityOfMeanAirMassWrtGe_m_s_Z	Z-velocity Component, locally level coordinate system	to downward			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
$\underline{V}_{W_{M_B}}$	VELMWB	bodyVelocityOfMeanAirMassWrtGe_ft_s[3] bodyVelocityOfMeanAirMassWrtGe_m_s[3]	Vector of body coordinate system mean wind translational wind velocities comprised of the three components as defined below. Note: This vector is designed to be the GRAM 07 wind model mean velocities transformed into the body coordinate system.				
$u_{W_{M_B}}$	UMEANB	bodyVelocityOfMeanAirMassWrtGe_ft_s_X bodyVelocityOfMeanAirMassWrtGe_m_s_X	X-velocity Component, body coordinate system	FWD (tailwind)			
$v_{W_{M_B}}$	VMEANB	bodyVelocityOfMeanAirMassWrtGe_ft_s_Y bodyVelocityOfMeanAirMassWrtGe_m_s_Y	Y-velocity Component, body coordinate system	To the RT			
$w_{W_{M_B}}$	WMEANB	bodyVelocityOfMeanAirMassWrtGe_ft_s_Z bodyVelocityOfMeanAirMassWrtGe_m_s_Z	Z-velocity Component, body coordinate system	DN			
$\underline{V}_{Tw}$	VTW	bodyWindVelocityWrtGe_ft_s[3] bodyWindVelocityWrtGe_m_s[3]	Vector of the body coordinate system of net wind velocities impinging on the aircraft at the Cm. This would include mean air mass motion and any disturbances such as turbulence and shear. Comprised of the three components as defined below. Note: Winds are always with respect to and observed from an Earth-fixed reference frame. This vector is with respect to the geocentric Earth (Ge) fixed coordinate system.				

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
U_{Tw}	UBTWX	bodyWindVelocityWrtGe_ft_s_X bodyWindVelocityWrtGe_m_s_X	Net wind velocity impinging on the vehicle in the X body axis. Net wind is the mean air mass plus any turbulence, shears, or other wind disturbances.	FWD (tailwind)			
V_{Tw}	VBTWY	bodyWindVelocityWrtGe_ft_s_Y bodyWindVelocityWrtGe_m_s_Y	Net wind velocity impinging on the vehicle in the Y body axis Net wind is the mean air mass plus any turbulence, shears, or other wind disturbances.	RT			
W_{Tw}	VBTWZ	bodyWindVelocityWrtGe_ft_s_Z bodyWindVelocityWrtGe_m_s_Z	Net wind velocity impinging on the vehicle in the Z body axis Net wind is the mean air mass plus any turbulence, shears, or other wind disturbances.	DN			
		bodyAngularRateTurbulenceWrtLl_deg_s [3] bodyAngularRateTurbulenceWrtLl_rad_s [3]	Vector of angular turbulence velocities comprised of the three body coordinate system components as defined below. Note: Turbulence angular rate is always with respect to and observed from the locally level (Ll) reference frame.				
	PTURB	bodyAngularRateTurbulenceWrtLl_deg_s_Roll bodyAngularRateTurbulenceWrtLl_rad_s_Roll	Body coordinate roll turbulence	The turbulence would move the aircraft right wing down			
	QTURB	bodyAngularRateTurbulenceWrtLl_deg_s_Pitch bodyAngularRateTurbulenceWrtLl_rad_s_Pitch	Body coordinate pitch turbulence	The turbulence would move the aircraft nose up			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
	RTURB	bodyAngularRateTurbulenceWrtLl_deg_s_Yaw bodyAngularRateTurbulenceWrtLl_rad_s_Yaw	Body coordinate yaw turbulence	The turbulence would move the aircraft nose right			

Table A.6 — Vehicle physical characteristics

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
I		bodyMomentOfInertia_slugft2 [3,3] bodyMomentOfInertia_kgm2 [3,3]	Matrix of the total moments of inertia of the aircraft. This is with respect to the Cm and includes everything in or attached to the aircraft (stores, passengers, crew, fuel, etc.). It is comprised of the components below. $\begin{matrix} I_{XX} & -I_{XY} & -I_{ZX} \\ -I_{XY} & I_{YY} & -I_{YZ} \\ -I_{ZX} & -I_{YZ} & I_{ZZ} \end{matrix}$				
I_x	XIXX	bodyMomentOfInertia_slugft2_X bodyMomentOfInertia_kgm2_X	Vehicle Roll Moment Of Inertia about Cm, body coordinate system	NSC			
I_y	XIYY	bodyMomentOfInertia_slugft2_Y bodyMomentOfInertia_kgm2_Y	Vehicle Pitch Moment Of Inertia about Cm, body coordinate system	NSC			
I_z	XIZZ	bodyMomentOfInertia_slugft2_Z bodyMomentOfInertia_kgm2_Z	Vehicle Yaw Moment Of Inertia about Cm, body coordinate system	NSC			
I_{xz}	XIZX	bodyProductOfInertia_slugft2_ZX bodyProductOfInertia_kgm2_ZX	Vehicle ZX Cross Product Of Inertia about Cm, body coordinate system	NSC			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value

I_{xy}	XIXY	`bodyProductOfInertia_slugft2_XY`
		
		`bodyProductOfInertia_kgm2_XY`
			Vehicle XYy Cross Product Of Inertia about Cm, body coordinate system	NSC			

I_{yz}	XIYZ	`bodyProductOfInertia_slugft2_YZ`
		
		`bodyProductOfInertia_kgm2_YZ`
			Vehicle YZ Cross Product Of Inertia about Cm, body coordinate system	NSC			

	MrcPos	`vrsPositionOfMrc_ft[3]`
		
		`vrsPositionOfMrc_m[3]`
			Vector of the location of the moment reference center (Mrc) of the aircraft in the vehicle reference system (vrs). Comprised of the three components as defined below. This vector is used to define the fixed physical location of the moment reference center in the vehicle. Note that the vrs definition is specific to each vehicle.				

	XMrc	`vrsPositionOfMrc_ft`
		
		`vrsPositionOfMrc_m`
			X Mrc Position				

	YMrc	`vrsPositionOfMrc_ft`
		
		`vrsPositionOfMrc_m`
			Y Mrc Position				

	ZMrc	`vrsPositionOfMrc_ft`
		
		`vrsPositionOfMrc_m`
			Z Mrc position				

Δ_{cg}	DCG	`bodyPositionOfCmWrtMrc_ft [3]`	Vector of the location of the Cm with respect to the moment reference center (Mrc) of the aircraft in the body coordinate system. Comprised of the three components as defined below. This vector is used to define the location of the Cm which moves Wrt to the fixed moment reference center in the vehicle. Note that `vrsPositionOfMrc` locates the Mrc in the vehicle.				

ΔX_{cg}	DXCG	`bodyPositionOfCmWrtMrc_ft_X`
		
		`bodyPositionOfCmWrtMrc_m_X`
			X Cm position	Cm forward of the Mrc			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
ΔY_{cg}	DYCG	bodyPositionOfCmWrtMrc_ft_Y bodyPositionOfCmWrtMrc_m_Y	Y Cm position	Cm to the right (out the right wing) of the Mrc			
ΔZ_{cg}	DZCG	bodyPositionOfCmWrtMrc_ft_Z bodyPositionOfCmWrtMrc_m_Z	Z Cm position	Cm below the Mrc			
m	XMASS	totalMass_slug totalMass_kg	Total Mass Of Vehicle (including Fuel, crew, cargo, stores, passengers, etc.)	NSC			
W	WEIGHT	grossWeight_lbf grossWeight_N	Aircraft Gross Weight (mass*gravity), including all fuel, occupants, stores, etc.	NSC			
S	AREA	referenceWingArea_ft2 referenceWingArea_m2	Reference Wing Area	NSC			
b	SPAN	referenceWingSpan_ft referenceWingSpan_m	Reference Wing Span	NSC			
c	CHORD	referenceWingChord_ft referenceWingChord_m	Mean Aerodynamic Chord (reference wing chord)	NSC			
		engineMomentOfInertia_slugft2[3,3] engineMomentOfInertia_kgm2[3,3]	Matrix of the moments of inertia of the Rotating engine, for an engine with the propeller, includes the propeller and drive train. This is w.r.t. the rotational axis of the engine. For multi-engine vehicles is for one engine. It is comprised of the components below. I_{EXX} $-I_{EXY}$ $-I_{EZX}$ $-I_{EXY}$ I_{EYY} $-I_{EYZ}$ $-I_{EZX}$ $-I_{EYZ}$ I_{EZZ}				

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
I_{Ex}	IEXX	engineMomentOfInertia_slugft2_X engineMomentOfInertia_kgm2_X	Moment of inertia about the X-axis Of Rotating Eng, for an engine with the propeller, includes the propeller This is w.r.t. the rotational axis of the engine				
I_{Ey}	IEYY	engineMomentOfInertia_slugft2_Y engineMomentOfInertia_kgm2_Y	Moment of inertia about the Y-axis Of Rotating Eng, for an engine with the propeller, includes the propeller This is w.r.t. the rotational axis of the engine				
I_{Ez}	IEZZ	engineMomentOfInertia_slugft2_Z engineMomentOfInertia_kgm2_Z	Moment of inertia about the Z-axis Of Rotating Eng, for an engine with the propeller, includes the propeller This is w.r.t. the rotational axis of the engine				
I_{Exz}	IEXZ	engineProductOfInertia_slugft2_XZ engineProductOfInertia_kgm2_XZ	Product of inertia about the XZ-axis Of Rotating Eng, for an engine with the propeller, includes the propeller This is w.r.t. the rotational axis of the engine				

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value

I_{Exy}	IEXY	`engineProductOfInertia_slugft2_XY`
		
		`engineProductOfInertia_kgm2_XY`
			Product of inertia about the XY-axis Of Rotating Eng, for an engine with the propeller, includes the propeller
			
			This is w.r.t. the rotational axis of the engine				

I_{Eyz}	IEYZ	`engineProductOfInertia_slugft2_YZ`
		
		`engineProductOfInertia_kgm2_YZ`
			Product of inertia about the YZ-axis Of Rotating Eng, for an engine with the propeller, includes the propeller
			
			This is w.r.t. the rotational axis of the engine				

		`fuelInTank_lbm[number of fuel tanks]`
		
		`fuelInTank_kg[number of fuel tanks]`
			Vector of fuel weight by tank. Each aircraft tank is normally numbered and the vector should be ordered according to fuel tank number. In the absence of tank numbering the convention of port to starboard, upper to lower, then front to rear should be used.				

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value

		`fuelTankCentroid_ft[number of fuel tanks,3]`
		
		`fuelTankCentroid_m[number of fuel tanks,3]`
			Matrix used to locate the centoids of the fuel tanks. Each aircraft tank is normally numbered and the matrix should be ordered according to fuel tank number. The second component is the x, y and z moment arms from the moment reference center to the tank centroid in the structural coordinate system. In the absence of tank numbering the convention of port to starboard, upper to lower, then front to rear should be used.	Tank centroid behind, right, and below the moment reference center.			

Table A.7 — Vehicle control position

<table>
<tr><th>Symbol</th><th>Short Name</th><th>Full Variable Name</th><th>Description</th><th>Positive Sign Convention</th><th>Initial Value</th><th>Min Value</th><th>Max Value</th></tr>
<tr><td colspan="3"><code>Standard naming convention for crew control inputs</code>

<code>“Pos” indicates a position input</code>

<code>“Rate” indicates the derivative of the position input</code>

<code>“Accel” indicates the derivative of the rate</code>

<code>“Force” indicates the force input</code></td><td colspan="5">Control positions for a vehicle are often uniquely defined for that vehicle, therefore the:

Description

Positive Sign Convention

Initial Value

Min Value

Max Value

definitions may all change based on the particular vehicle.

The table below shall be used as default descriptions and values when they are not otherwise explicitly defined for the vehicle.</td></tr>
</table>

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
D_{δ_m}		pilotControlPos_deg_long pilotControlPos_rad_long	Longitudinal control position of the pilot.	AFT 0= vertical when vehicle body is level (pitch and roll attitude = 0)			
		pilotControlRate_deg_s_long pilotControlRate_rad_s_long	Rate of the pilot Longitudinal control movement.	Moving aft			
		pilotControlAccel_deg_s2_long pilotControlAccel_rad_s2_long	Acceleration of the pilot Longitudinal control movement.	Accelerating aft			
		pilotControlForce_lbf_long pilotControlForce_N_long	Longitudinal control force of the pilot.	Aft force			
The convention and examples above apply to all pilot and copilot controls defined below							
D_{δ_l}		pilotControlPos_deg_lat pilotControlPos_rad_lat	Lateral control position of the pilot.	LEFT 0= vertical when vehicle body is level (pitch and roll attitude = 0)			
D_{δ_n}		pilotControlPos_deg_avgPedal pilotControlPos_rad_avgPedal	Net Directional control position of the pilot. Normally, left pedal + right pedal.	Left Pedal in or counter clockwise twist of a sidestick			
		pilotControlPos_deg_rtPedal pilotControlPos_rad_rtPedal	Right Directional control position of the pilot.	NEGATIVE for Pedal in 0= pedal full aft			0.0

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
		pilotControlPos_deg_ltPedal pilotControlPos_rad_ltPedal	Left Directional control position of the pilot.	Pedal in. 0= pedal full aft		0.0	
D_{δ_Z}		pilotControlPos_deg_collective pilotControlPos_rad_collective	Pilot collective control position.	UP 0 = full down		0.0	
		pilotControlPos_deg_avgThrottle pilotControlPos_rad_avgThrottle	Average pilot throttle control position.	FWD 0= full aft w/o thrust reversing. Thrust reversing is negative			
		pilotControlPos_deg_throttle [number of engines] pilotControlPos_rad_throttle [number of engines]	Individual pilot throttle control positions. Order is outboard port (left) to outboard starboard.	FWD 0= full aft w/o thrust reversing. Thrust reversing is negative			
		copilotControlPos_deg_long copilotControlPos_rad_long	Longitundal control position of the copilot.	AFT 0= vertical when vehicle body is level (pitch and roll attitude = 0)			
		copilotControlPos_deg_lat copilotControlPos_rad_lat	Lateral control position of the copilot.	LEFT 0= vertical when vehicle body is level (pitch and roll attitude = 0)			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
		copilotControlPos_deg_avgPedal copilotControlPos_rad_avgPedal	Net Directional control position of the copilot. Normally, Left pedal + right pedal.	Left Pedal in or counter clockwise twist of a sidestick			
		copilotControlPos_deg_rtPedal copilotControlPos_rad_rtPedal	Right Directional control position of the copilot.	NEGATIVE for Pedal in 0= pedal full aft			0.0
		copilotControlPos_deg_ltPedal copilotControlPos_rad_ltPedal	Left Directional control position of the copilot.	Pedal in. 0= pedal full aft		0.0	
		copilotControlPos_deg_collective copilotControlPos_rad_collective	Copilot collective control position.	UP 0 = full down		0.0	
		copilotControlPos_deg_avgThrottle copilotControlPos_rad_avgThrottle	Average copilot throttle control position.	FWD 0= full aft w/o thrust reversing. Thrust reversing is negative			
		copilotControlPos_deg_throttle [number of engines] copilotControlPos_rad_throttle [number of engines]	Individual copilot throttle control positions. Order is outboard port (left) to outboard starboard.	FWD 0= full aft w/o thrust reversing. Thrust reversing is negative			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
		controlPos_deg_avgThrottle controlPos_rad_avgThrottle	Average pilot and copilot throttle control position.	FWD 0= full aft w/o thrust reversing. Thrust reversing is negative			
		controlPos_deg_avgPropellor controlPos_rad_avgPropellor	Average pilot and copilot propeller blade pitch control position.	FWD 0=flat pitch, Thrust reversing is negative			
		controlPos_deg_propellor [number of engines] controlPos_rad_propellor [number of engines]	Individual propeller blade pitch control position. Order is outboard port (left) to outboard starboard.	FWD 0=flat pitch, Thrust reversing is negative			

Standard naming convention for control surfaces "Pos" indicates a control surface position "Rate" indicates the derivative of the control surface position "Accel" indicates the derivative of the control surface rate "HingeMoment" indicates the hinge moment on the control surface (sign convention = + deflection results in + hinge moment)	Control surface positions for a vehicle are often uniquely defined for that vehicle, therefore the: Description Positive Sign Convention Initial Value Min Value Max Value definitions may all change based on the particular vehicle. **The table below shall be used as default descriptions and values when they are not otherwise explicitly defined for the vehicle.**

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
δ_{TEF_n}		controlSurfacePos_deg_TEF [number of trailing edge flap control surfaces] controlSurfacePos_rad_TEF [number of trailing edge flap control surfaces]	Vector of trailing edge flap positions, one for each surface deflected. Order is outboard port (left) to outboard starboard.	TED 0 deflection is flap retracted			
		controlSurfaceRate_deg_s_TEF [number of trailing edge flap control surfaces] controlSurfaceRate_rad_s_TEF [number of trailing edge flap control surfaces]	Vector of trailing edge flap deflection rates, one for each surface. Order is outboard port (left) to outboard starboard.	TED			
		controlSurfaceAccel_deg_s2_TEF [number of trailing edge flap control surfaces] controlSurfaceAccel_rad_s2_TEF [number of trailing edge flap control surfaces]	Vector of trailing edge flap deflection accelerations, one for each surface. Order is outboard port (left) to outboard starboard.	TED			
		controlSurfaceHingeMoment_ftlbf_TEF [number of trailing edge flap control surfaces] controlSurfaceHingeMoment_Nm_s_TEF [number of trailing edge flap control surfaces]	Vector of the hinge moments on the trailing edge flap, one for each surface. Order is outboard port (left) to outboard starboard.	+ = TEU moment (positive deflection results in positive moment)			
The convention and examples above apply to all control surface positions defined below							

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
δ_{TEF_n}		controlSurfacePos_deg_TEF [number of leading edge flap control surfaces] controlSurfacePos_rad_TEF [number of leading edge flap control surfaces]	Vector of trailing edge flap (TEF) positions, one for each surface deflected. Order is outboard port (left) to outboard starboard.	TED			
δ_{TEF}		controlSurfacePos_deg_avgTEF controlSurfacePos_rad_avgTEF	Trailing edge flap deflection (TEF). Average for all trailing edge flap surfaces.	TED 0 deflection is flap retracted			
$\delta_{\delta_{TEF}}$		controlSurfacePos_deg_diffTEF controlSurfacePos_rad_diffTEF	Differential trailing edge flap (DTEF)deflection (left deflections {+=TED} -right deflections {+=TED})	LT TED (RWD moment)			
δ_{LEF_n}		controlSurfacePos_deg_LEF [number of leading edge flap control surfaces] controlSurfacePos_rad_LEF [number of leading edge flap control surfaces]	Vector of leadng edge flap (LEF) positions, one for each surface deflected. Order is outboard port (left) to outboard starboard.	LED			
δ_{LEF}		controlSurfacePos_deg_avgLEF controlSurfacePos_rad_avgLEF	Leading edge flap/slat deflection. Average for all deflected leading edge flap/slat surfaces.	LED			
$\delta_{\delta_{LEF}}$		controlSurfacePos_deg_diffLEF controlSurfacePos_rad_diffLEF	Differential leading edge flap (LEF) deflection (left deflections-right deflections)	LT LED (RWD moment)			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
δ_{SP_n}		`controlSurfacePos_deg_spoiler [number of spoiler control surfaces]` `controlSurfacePos_rad spoiler [number of spoiler control surfaces]`	Vector of spoiler control surface positions, one for each surface deflected. Order is outboard port (left) to outboard starboard.	TEU			
δ_{SP}		`controlSurfacePos_deg_avgSpoiler` `controlSurfacePos_rad_avgSpoiler`	Spoiler deflection. Average for all deflected spoilers (sum of positions/number of surfaces)	TEU			
$\delta_{\delta_{SP}}$		`controlSurfacePos_deg_diffSpoiler` `controlSurfacePos_rad_diffSpolier`	Differential spoiler control surface position (right deflections-left deflections)	RT TEU (RWD moment)			
δ_{A_n}		`controlSurfacePos_deg_aileron [number of aileron control surfaces]` `controlSurfacePos_rad_aileron [number of aileron control surfaces]`	Vector of aileron control positions, one for each surface deflected. Order is outboard port (left) to outboard starboard.	TEU			
δ_{δ_A}		`controlSurfacePos_deg_diffAileron` `controlSurfacePos_rad_diffAileron`	Differential aileron deflection, (right deflections-left deflections)	Right aileron TEU (RWD moment)			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
$\delta_{Atab_{n,i}}$		controlSurfacePos_deg_aileronTab [number of aileron control surfaces, number of tabs] controlSurfacePos_rad_aileronTab [number of aileron control surfaces, number of tabs]	Array of aileron tab control positions (i) for each surface deflected (n). Order is outboard port to outboard starboard	TEU			
δ_{Atab}		controlSurfacePos_deg_avgAileronTab controlSurfacePos_rad_avgAileronTab	Average aileron tab deflection (sum of positions/number of surfaces)	TEU			
$\delta_{\delta_{Atab}}$		controlSurfacePos_deg_diffAileronTab controlSurfacePos_rad_diffAileronTab	Differential aileron tab deflection (right tab deflections-left tab deflections)	RT Aileron Tab TEU (RWD moment)			
δ_{R_n}		controlSurfacePos_deg_rudder [number of rudder control surfaces] controlSurfacePos_rad_rudder [number of rudder control surfaces]	Vector of rudder control positions, one for each surface deflected. Order is outboard port (left) to outboard starboard.	TEL			
δ_R		controlSurfacePos_deg_avgRudder controlSurfacePos_rad_avgRudder	Average rudder deflection (sum of positions/number of surfaces)	TEL			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
δ_{δ_R}		`controlSurfacePos_deg_diffRudder` `controlSurfacePos_rad_diffRudder`	Differential rudder deflection (right deflections-left deflections)	RT Rudder TEL (ANR moment)			
$\delta_{Rtab_{n,i}}$		`controlSurfacePos_deg_rudderTab [number of rudder control surfaces, number of tabs]` `controlSurfacePos_rad_rudderTab [number of rudder control surfaces, number of tabs]`	Array of rudder tab control positions (i) for each surface deflected (n). Order of tabs is upper to lower.	TEL			
δ_{Rtab}		`controlSurfacePos_deg_avgRudderTab` `controlSurfacePos_rad_avgRudderTab`	Average rudder tab deflection (sum of positions/number of surfaces)	RT Rudder Tab TEL (ANR moment)			
$\delta_{\delta_{Rtab}}$		`controlSurfacePos_deg_diffRudderTab` `controlSurfacePos_rad_diffRudderTab`	Differential rudder tab deflection (right deflections-left deflections)	RT Rudder Tab TEL (ANR moment)			
δ_{E_n}		`controlSurfacePos_deg_elevator [number of elevator control surfaces]` `controlSurfacePos_rad_elevator [number of elevator control surfaces]`	Vector of elevator (or stabilizer/stabilator) control positions, one for each surface deflected. Order is outboard port (left) to outboard starboard.	TEU			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
δ_E		controlSurfacePos_deg_avgElevator controlSurfacePos_rad_avgElevator	Average elevator (or stabilizer/stabilator) deflection) (sum of positions/number of surfaces)	TEU			
δ_{δ_E}		controlSurfacePos_deg_diffElevator controlSurfacePos_rad_diffElevator	Differential elevator deflection (right deflections-left deflections)	Right control TEU (RWD moment)			
$\delta_{Etab_{n,i}}$		controlSurfacePos_deg_elevatorTab [number of elevator tab control surfaces, number of tabs] controlSurfacePos_rad_elevatorTab [number of elevator tab control surfaces, number of tabs]	Array of elevator (or stabilizer/stabilator) tab positions (i) for each surface (n). Order is outboard port (left) to outboard starboard per control surface.	TEU			
δ_{Etab}		controlSurfacePos_deg_avgElevatorTab controlSurfacePos_rad_avgElevatorTab	Average elevator (or stabilizer/stabilator) tab control surface positions (sum of positions/number of surfaces)	TEU			
$\delta_{\delta_{Etab}}$		controlSurfacePos_deg_diffElevatorTab controlSurfacePos_rad_diffElevatorTab	Average differential elevator (or stabilizer/stabilator) tab deflection (right deflections-left deflections)	Right control TEU (RWD moment)			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value

δ_{C_n}		`controlSurfacePos_deg_canard [number of canard control surfaces]`
		
		`controlSurfacePos_rad_canard [number of canard control surfaces]`
			Vector of canard control positions, one for each surface. Order is outboard port (left) to outboard starboard.	TED		0.0	

δ_{C}		`controlSurfacePos_deg_avgCanard`
		
		`controlSurfacePos_rad_avgCanard`
			Average canard position (sum of positions/number of surfaces)	TED		0.0	

$\delta_{\delta C}$		`controlSurfacePos_deg_diffCanard`
		
		`controlSurfacePos_rad_diffCanard`
			Average differential canard deflection (LEFT deflections-RIGHT deflections)	LEFT control TED
				
				(RWD moment)			

$\delta_{Ctab_{n,i}}$		`controlSurfacePos_deg_canardTab [number of canard tab control surfaces, number of tabs]`
		
		`controlSurfacePos_rad_canardTab [number of canard tab control surfaces, number of tabs]`
			Array of canard tab positions (i) for each surface (n). Order is outboard port (left) to outboard starboard per control surface.	TED			

δ_{Ctab}		`controlSurfacePos_deg_avgCanardTab`
		
		`controlSurfacePos_rad_avgCanardTab`
			Average canard tab deflection (sum of positions/number of surfaces)	TED			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
$\delta_{\delta Ctab}$		controlSurfacePos_deg_diffCanardTab controlSurfacePos_rad_diffCanardTab	Average differential canard tab deflection (LEFT deflections-RIGHT deflections)	LEFT control TED (RWD moment)			
δ_{SB}		controlSurfacePos_deg_speedbrake controlSurfacePos_rad_speedbrake	Speedbrake deflection	Extended			
δ_{LGn}		landingGearPosition [number of landing gear struts]	Vector of landing gear positions, one for each strut. Order is outboard port (left) to outboard starboard.	0= up and locked 1= full extension with no weight on wheels		0.0	
		landingGearWeightOnWheels_lbf [number of landing gear struts] landingGearWeightOnWheels_N [number of landing gear struts]	Vector of landing gear weight on wheels, one for each strut. Order is outboard port (left) to outboard starboard.				
		landingGearWheelSpeed_rad_s [number of landing gear struts, number of trucks, number of wheels per truck]	Array of landing gear wheel speeds by strut, one for each strut. Order of struts is outboard port (left) strut, to outboard starboard. Order of trucks is front to rear. Order of wheels on each truck is port to starboard.				

Table A.8 — Vehicle aerodynamic characteristics

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
C_L	CL	`totalCoefficientOfLift`	Coefficient Of Lift, Total, includes effects of stores	UP			
C_D	CD	`totalCoefficientOfDrag`	Coefficient Of Drag, Total, includes effects of stores	AFT			
		`aeroBodyForceCoefficient[3]`	Vector of total aerodynamic force coefficients in the body coordinate system, comprised of the three components as defined below.				
C_X	CX	`aeroBodyForceCoefficient_X`	X-body Force Coefficient due to aerodynamic loads, includes stores (Body coordinate)	FWD			
C_Y	CY	`aeroBodyForceCoefficient_Y`	Y-body Force Coefficient due to aerodynamic loads, includes stores (Body coordinate)	RT			
C_Z	CZ	`aeroBodyForceCoefficient_Z`	Z-body Force Coefficient due to aerodynamic loads, includes stores (Body coordinate)	DN			
		`aeroBodyForce_lbf [3]` `aeroBodyForce_N [3]`	Vector of total aerodynamic forces in the body coordinate system, including stores. Comprised of the three components as defined below.				
F_{AX}	FAX	`aeroBodyForce_lbf_X` `aeroBodyForce_N_X`	Total X-body Force due to aerodynamic loads, includes stores (Body coordinate)	FWD			
F_{AY}	FAY	`aeroBodyForce_lbf_Y` `aeroBodyForce_N_Y`	Total Y-body Force due to aerodynamic loads, includes stores (Body coordinate)	RT			
F_{AZ}	FAZ	`aeroBodyForce_lbf_Z` `aeroBodyForce_N_Z`	Total Z-body Force due to aerodynamic loads, includes stores (Body coordinate)	DN			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
		`thrustBodyForce_lbf [3]` `thrustBodyForce_N [3]`	Vector of total net propulsion system forces in the body coordinate system (includes installation losses, inlet efficiency and propeller efficiency). Comprised of the three components as defined below.				
F_{EX}	FEX	`thrustBodyForce_lbf_X` `thrustBodyForce_N_X`	Total net engine thrust Force, X-body axis	FWD			
F_{EY}	FEY	`thrustBodyForce_lbf_Y` `thrustBodyForce_N_Y`	Total net engine thrust Force , Y-body axis	RT			
F_{EZ}	FEZ	`thrustBodyForce_lbf_Z` `thrustBodyForce_N_Z`	Total net engine thrust Force, Z-body axis	DN			
		`gearBodyForce_lbf  [3]` `gearBodyForce_N [3]`	Vector of total landing gear ground reaction forces in the body coordinate system. Does NOT include aerodynamic forces on the landing gear that are included in `aeroBodyForce` defined above. Comprised of the three components as defined below.				
F_{GX}	FGX	`gearBodyForce_lbf_X` `gearBodyForce_N_X`	Total landing gear ground reaction force, X-body axis	FWD			
F_{GY}	FGY	`gearBodyForce_lbf_Y` `gearBodyForce_N_ Y`	Total landing gear ground reaction force, Y-body axis	RT			
F_{GZ}	FGZ	`gearBodyForce_lbf_Z` `gearBodyForce_N_Z`	Total landing gear ground reaction force, Z-body axis	DN			
		`totalBodyForce_lbf [3]` `totalBodyForce_N [3]`	Vector of total forces in the body coordinate system. Includes all forces exerted upon the aircraft. Comprised of the three components as defined below.				
F_{xTOT}	FX	`totalBodyForce_lbf_X` `totalBodyForce_N_X`	Total Forces On a/c, X-body axis	FWD			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
F_{yTOT}	FY	`totalBodyForce_lbf_Y` `totalBodyForce_N_Y`	Total Forces On a/c, Y-body axis	RT			
F_{zTOT}	FZ	`totalBodyForce_lbf_Z` `totalBodyForce_N_Z`	Total Forces On a/c, Z-body axis	DN			
		`aeroBodyMomentCoefficient [3]`	Vector of total aerodynamic moment coefficients in the body coordinate system, including stores. Comprised of the three components as defined below.				
C_l	CLL	`aeroBodyMomentCoefficient_Roll`	Total Aerodynamic Rolling Moment Coefficient including stores. Moment about the X-body axis	RWD			
C_m	CLM	`aeroBodyMomentCoefficient_Pitch`	Total Aerodynamic Pitching Moment Coefficient, including stores. Moment about the Y-body axis	ANU			
C_n	CLN	`aeroBodyMomentCoefficient_Yaw`	Total Aerodynamic yawing Moment Coefficient, including stores. Moment about the Z-body axis	ANR			
		`aeroBodyMoment_ftlbf [3]` `aeroBodyMoment_Nm [3]`	Vector of total aerodynamic moments in the body coordinate system, including stores. Referenced to the moment reference center. Comprised of the three components as defined below.				
L_A	TAL	`aeroBodyMoment_ftlbf_Roll` `aeroBodyMoment_Nm_Roll`	Total Aerodynamic Rolling moment (including attached stores), about the X-body axis	RWD			
M_A	TAM	`aeroBodyMoment_ftlbf_Pitch` `aeroBodyMoment_Nm_Pitch`	Total Aerodynamic pitching moment (including attached stores), about the Y-body axis	ANU			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
N_A	TAN	aeroBodyMoment_ftlbf_Yaw aeroBodyMoment_Nm_Yaw	Total Aerodynamic yawing moment (including attached stores), about the Z-body axis	ANR			
		thrustBodyMoment_ftlbf [3] thrustBodyMoment_Nm [3]	Vector of total net propulsion system moments in the body coordinate system (includes installation losses, inlet efficiency and propeller efficiency). Referenced to the moment reference center. Comprised of the three components as defined below.				
L_E	TEL	thrustBodyMoment_ftlbf_Roll thrustBodyMoment_Nm_Roll	Total Engine Rolling Moment, about the X-body axis	RWD			
M_E	TEM	thrustBodyMoment_ftlbf_Pitch thrustBodyMoment_Nm_Pitch	Total Engine pitching Moment, about the Y-body axis	ANU			
N_E	TEN	thrustBodyMoment_ftlbf_Yaw thrustBodyMoment_Nm_Yaw	Total Engine yawing Moment, about the X-body axis	ANR			
		landingGearBodyMoment_ftlbf [3] landingGearBodyMoment_Nm [3]	Vector of total landing gear ground reaction moments in the body coordinate system. Referenced to the moment reference center. Does NOT include aerodynamic moments on the landing gear that are included in `aeroBodyMoment` defined above. Comprised of the three components as defined below.				
L_G	TGL	landingGearBodyMoment_ftlbf_Roll landingGearBodyMoment_Nm_Roll	Total Landing Gear Rolling Moment, about the X-body axis	RWD			
M_G	TGM	landingGearBodyMoment_ftlbf_Pitch landingGearBodyMoment_Nm_Pitch	Total Landing gear Pitch Moment, about the Y-body axis	ANU			

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
N_G	TGN	`landingGearBodyMoment_ftlbf_Yaw` `landingGearBodyMoment_Nm_Yaw`	Total Landing Gear Yawing Moment, about the Z-body axis	ANR			
		`totalBodyMoment_ftlbf [3]` `totalBodyMoment_Nm [3]`	Vector of total moments in the body coordinate system. Referenced to the moment reference center. Includes all moments exerted upon the aircraft. Comprised of the three components as defined below.				
L_{TOT}	TTL	`totalBodyMoment_ftlbf_Roll` `totalBodyMoment_Nm_Roll`	Total Rolling Moment, about the X-body axis	RWD			
M_{TOT}	TTM	`totalBodyMoment_ftlbf_Pitch` `totalBodyMoment_Nm_Pitch`	Total Pitching Moment, about the Y-body axis	ANU			
N_{TOT}	TTN	`totalBodyMoment_ftlbf_Yaw` `totalBodyMoment_Nm_Yaw`	Total Yawing Moment, about the Z-body axis	ANR			

Table A.9 — Simulation control parameters

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
	TIME	`simDuration_s`	Time Since Start Of Operate Mode	NSC			
		`deltaTime_s[number of different integration step sizes]`	Vector of Integration step sizes				
		`simDate`	Date simulated. Date at the start of the simulation is used. (Not the date the simulation run was made) Type yyyy-mm-dd				

Symbol	Short Name	Full Variable Name	Description	Positive Sign Convention	Initial Value	Min Value	Max Value
		`simTime`	Simulated time of day based on 24 hours Zulu. Type hh:mm:ss.ss				
		`productionDate`	Date the simulation run was made (Not the simulated date [simDate]) Type yyyy-mm-dd				

References

GRAM 07.

Justus, C.G., and Leslie, F. W.: "The NASA MSFC Earth Global Reference Atmospheric Model—2007 Version" NASA TM-2008-215581.

For symbols:

ISO 1151-1 : 1988

ISO 1151-2 : 1985

ISO 1151-4 : 1994(E)

ISO 1151-5 : 1987

Not all symbols presented above are defined by ISO. This document attempts to make them consistent where similar.

For Time and Dates:

ISO 8601:2000

Annex B

DAVE-ML Website (Informative)

The official DAVE-ML site is http://daveml.org/. This link contains all DAVE-ML documentation and links and information on DAVE-ML tools and applications. Additional information is available at http://www.aiaa.org/