Aerospace Toolbox

User's Guide

R2011b

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Aerospace Toolbox User's Guide

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Getting Started

Product Overview

The Aerospace Toolbox product extends the MATLAB® technical computing environment by providing reference standards, environment models, and aerodynamic coefficient importing for performing advanced aerospace analysis to develop and evaluate your designs. The toolbox provides the following to enable you to visualize flight data in a three-dimensional environment and reconstruct behavioral anomalies in flight-test results:

- Aero.Animation, Aero.Body, Aero.Camera, and Aero.Geometry objects and associated methods
- An interface to the FlightGear flight simulator
- An interface to the Simulink® 3D Animation™ software

To ensure design consistency, the Aerospace Toolbox software provides utilities for unit conversions, coordinate transformations, and quaternion math, as well as standards-based environmental models for the atmosphere, gravity, and magnetic fields. You can import aerodynamic coefficients directly from the U.S. Air Force Digital Data Compendium (DATCOM) to carry out preliminary control design and vehicle performance analysis.

The toolbox provides you with the following main features:

- Provides standards-based environmental models for atmosphere, gravity, and magnetic fields.
- Converts units and transforms coordinate systems and spatial representations.
- Implements predefined utilities for aerospace parameter calculations, time calculations, and quaternion math.
- Imports aerodynamic coefficients directly from DATCOM.
- Interfaces to the FlightGear flight simulator, enabling visualization of vehicle dynamics in a three-dimensional environment.

The Aerospace Toolbox functions can be used in applications such as aircraft technology, telemetry data reduction, flight control analysis, navigation analysis, visualization for flight simulation, and environmental modeling, and can help you perform the following tasks:

- Analyze, initialize, and visualize a broad range of large aerospace system architectures, including aircraft, missiles, spacecraft (probes, satellites, manned and unmanned), and propulsion systems (engines and rockets), while reducing development time.
- Support and define new requirements for aerospace systems.
- Perform complex calculations and analyze data to optimize and implement your designs.
- Test the performance of flight tests.

The Aerospace Toolbox software maintains and updates the algorithms, tables, and standard environmental models, eliminating the need to provide internal maintenance and verification of the models and reducing the cost of internal software maintenance.

Related Products

The Aerospace Toolbox software requires the MATLAB software.

In addition to Aerospace Toolbox, the Aerospace product family includes the Aerospace Blockset product. The toolbox provides static data analysis capabilities, while blockset provides an environment for dynamic modeling and vehicle component modeling and simulation. The Aerospace Blockset™ software uses part of the functionality of the toolbox as an engine. Use these products together to model aerospace systems in the MATLAB and Simulink® environments.

Other related products are listed in the Aerospace Toolbox product page at the MathWorks Web site. They include toolboxes and blocksets that extend the capabilities of the MATLAB and Simulink products. These products will enhance your use of the toolbox in various applications.

For more information about any MathWorks® software products, see either

- The online documentation for that product if it is installed
- The MathWorks Web site at `www.mathworks.com`

Getting Online Help

In this section...

Exploring the Toolbox

A list of the toolbox functions is available to you by typing

```
help aero
```

You can view the code for any function by typing

```
type function_name
```

Using the MATLAB Help System for Documentation and Demos

The MATLAB Help browser allows you to access the documentation and demo models for all the MATLAB and Simulink based products that you have installed. The online Help includes an online search system.

Consult the Help for Using MATLAB section of the MATLAB Desktop Tools and Development Environment documentation for more information about the MATLAB Help system.

2

Using Aerospace Toolbox

Defining Coordinate Systems

In this section...

Fundamental Coordinate System Concepts

Coordinate systems allow you to keep track of an aircraft or spacecraft's position and orientation in space. The Aerospace Toolbox coordinate systems are based on these underlying concepts from geodesy, astronomy, and physics.

Definitions

The Aerospace Toolbox software uses *right-handed* (RH) Cartesian coordinate systems. The *right-hand rule* establishes the *x*-*y*-*z* sequence of coordinate axes.

An *inertial frame* is a nonaccelerating motion reference frame. Loosely speaking, acceleration is defined with respect to the distant cosmos. In an inertial frame, Newton's second law (force = mass X acceleration) holds.

Strictly defined, an inertial frame is a member of the set of all frames not accelerating relative to one another. A *noninertial frame* is any frame accelerating relative to an inertial frame. Its acceleration, in general, includes both translational and rotational components, resulting in *pseudoforces* (*pseudogravity*, as well as *Coriolis* and *centrifugal forces*).

The toolbox models the Earth's shape (the *geoid*) as an oblate spheroid, a special type of ellipsoid with two longer axes equal (defining the *equatorial plane*) and a third, slightly shorter (*geopolar*) axis of symmetry. The equator is the intersection of the equatorial plane and the Earth's surface. The geographic poles are the intersection of the Earth's surface and the geopolar axis. In general, the Earth's geopolar and rotation axes are not identical.

Latitudes parallel the equator. Longitudes parallel the geopolar axis. The *zero longitude* or *prime meridian* passes through Greenwich, England.

Approximations

The Aerospace Toolbox software makes three standard approximations in defining coordinate systems relative to the Earth.

- The Earth's surface or geoid is an oblate spheroid, defined by its longer equatorial and shorter geopolar axes. In reality, the Earth is slightly deformed with respect to the standard geoid.
- The Earth's rotation axis and equatorial plane are perpendicular, so that the rotation and geopolar axes are identical. In reality, these axes are slightly misaligned, and the equatorial plane wobbles as the Earth rotates. This effect is negligible in most applications.
- The only noninertial effect in Earth-fixed coordinates is due to the Earth's rotation about its axis. This is a *rotating*, *geocentric* system. The toolbox ignores the Earth's motion around the Sun, the Sun's motion in the Galaxy, and the Galaxy's motion through cosmos. In most applications, only the Earth's rotation matters.

  This approximation must be changed for spacecraft sent into deep space, i.e., outside the Earth-Moon system, and a heliocentric system is preferred.

Motion with Respect to Other Planets

The Aerospace Toolbox software uses the standard WGS-84 geoid to model the Earth. You can change the equatorial axis length, the flattening, and the rotation rate.

You can represent the motion of spacecraft with respect to any celestial body that is well approximated by an oblate spheroid by changing the spheroid size, flattening, and rotation rate. If the celestial body is rotating westward (retrogradely), make the rotation rate negative.

Coordinate Systems for Modeling

Modeling aircraft and spacecraft is simplest if you use a coordinate system fixed in the body itself. In the case of aircraft, the forward direction is modified by the presence of wind, and the craft's motion through the air is not the same as its motion relative to the ground.

Body Coordinates

The noninertial body coordinate system is fixed in both origin and orientation to the moving craft. The craft is assumed to be rigid.

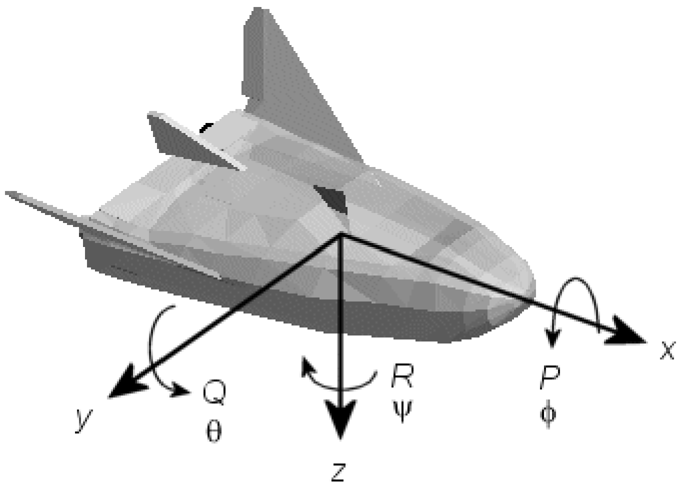
The orientation of the body coordinate axes is fixed in the shape of body.

- The *x*-axis points through the nose of the craft.
- The *y*-axis points to the right of the *x*-axis (facing in the pilot's direction of view), perpendicular to the *x*-axis.
- The *z*-axis points down through the bottom of the craft, perpendicular to the *x*-*y* plane and satisfying the RH rule.

Translational Degrees of Freedom. Translations are defined by moving along these axes by distances *x*, *y*, and *z* from the origin.

Rotational Degrees of Freedom. Rotations are defined by the Euler angles *P*, *Q*, *R* or Φ, Θ, Ψ. They are

- *P* or Φ: Roll about the *x*-axis
- *Q* or Θ: Pitch about the *y*-axis
- *R* or Ψ: Yaw about the *z*-axis



Wind Coordinates

The noninertial wind coordinate system has its origin fixed in the rigid aircraft. The coordinate system orientation is defined relative to the craft's velocity V.

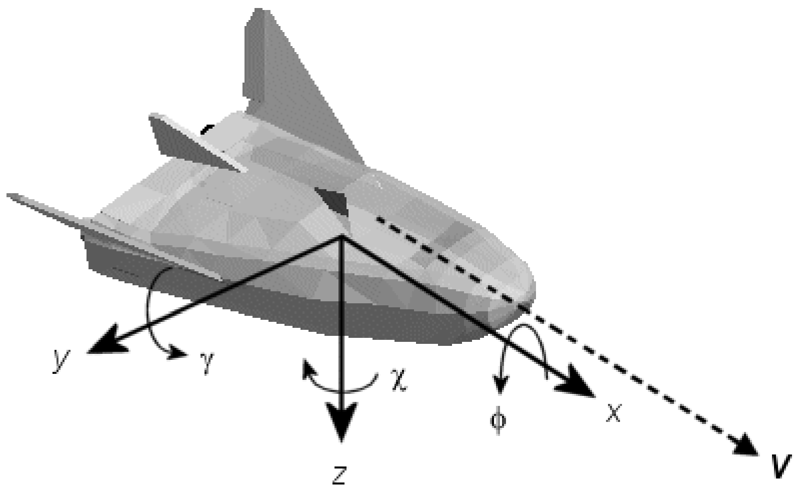
The orientation of the wind coordinate axes is fixed by the velocity V.

- The x-axis points in the direction of V.
- The y-axis points to the right of the x-axis (facing in the direction of V), perpendicular to the x-axis.
- The z-axis points perpendicular to the x-y plane in whatever way needed to satisfy the RH rule with respect to the x- and y-axes.

Translational Degrees of Freedom. Translations are defined by moving along these axes by distances x, y, and z from the origin.

Rotational Degrees of Freedom. Rotations are defined by the Euler angles Φ, γ, χ. They are

- Φ: Bank angle about the *x*-axis
- γ: Flight path about the *y*-axis
- χ: Heading angle about the *z*-axis



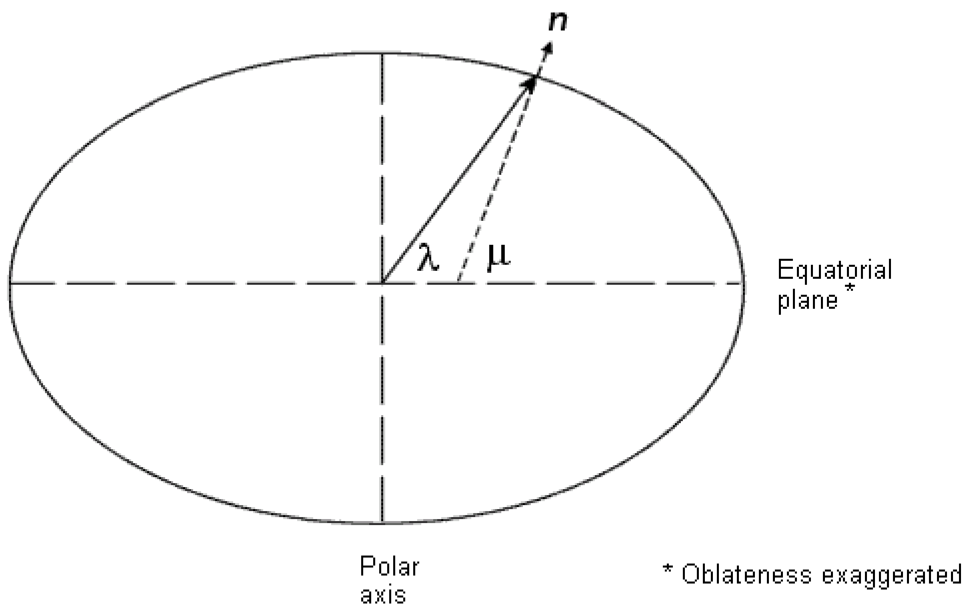
Coordinate Systems for Navigation

Modeling aerospace trajectories requires positioning and orienting the aircraft or spacecraft with respect to the rotating Earth. Navigation coordinates are defined with respect to the center and surface of the Earth.

Geocentric and Geodetic Latitudes

The *geocentric latitude* λ on the Earth's surface is defined by the angle subtended by the radius vector from the Earth's center to the surface point with the equatorial plane.

The *geodetic latitude* μ on the Earth's surface is defined by the angle subtended by the surface normal vector *n* and the equatorial plane.

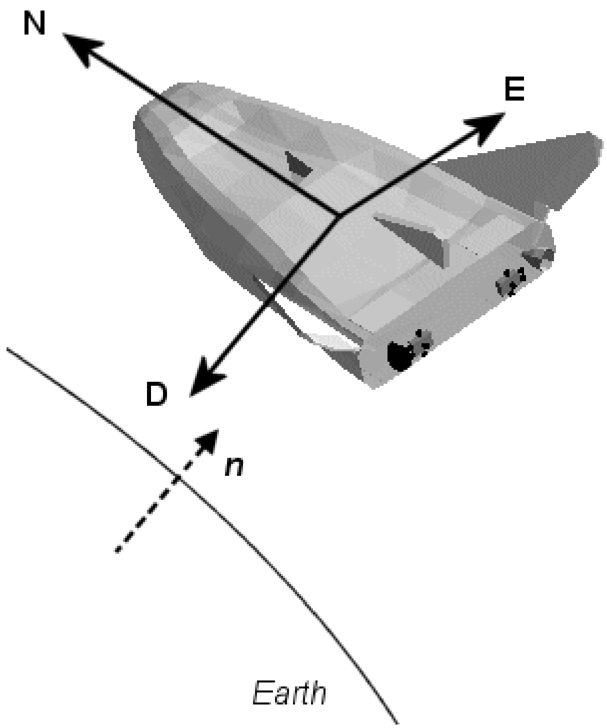


NED Coordinates

The north-east-down (NED) system is a noninertial system with its origin fixed at the aircraft or spacecraft's center of gravity. Its axes are oriented along the geodetic directions defined by the Earth's surface.

- The x-axis points north parallel to the geoid surface, in the polar direction.
- The y-axis points east parallel to the geoid surface, along a latitude curve.
- The z-axis points downward, toward the Earth's surface, antiparallel to the surface's outward normal n.

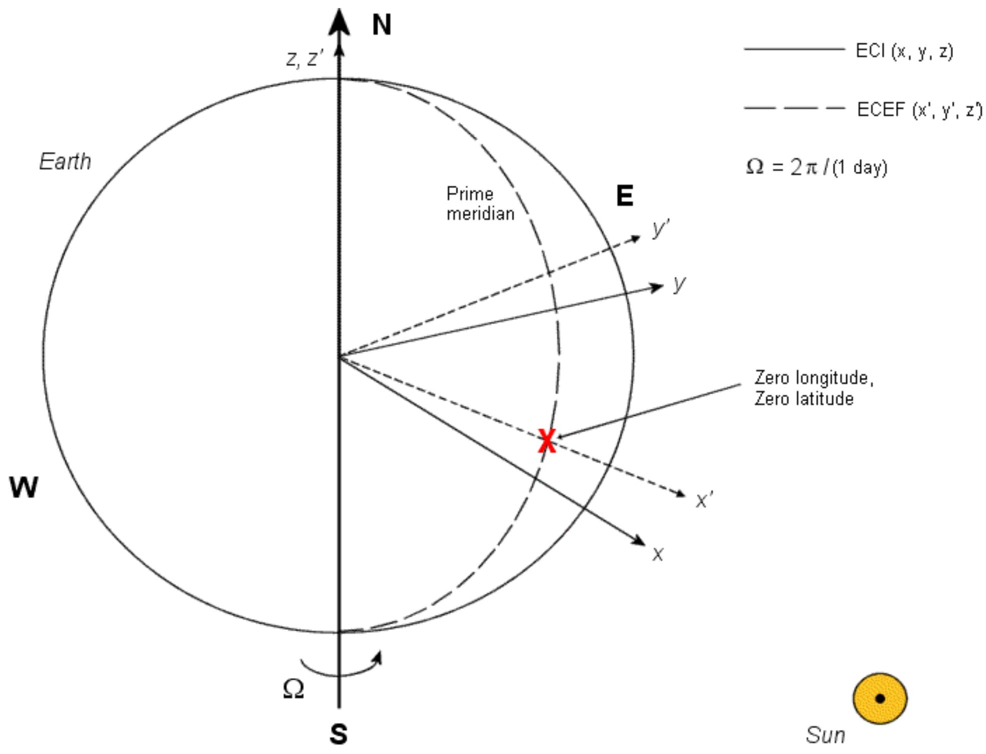
  Flying at a constant altitude means flying at a constant z above the Earth's surface.



ECI Coordinates

The Earth-centered inertial (ECI) system is a mixed inertial system. It is oriented with respect to the Sun. Its origin is fixed at the center of the Earth.

- The *z*-axis points northward along the Earth's rotation axis.
- The *x*-axis points outward in the Earth's equatorial plane exactly at the Sun. (This rule ignores the Sun's oblique angle to the equator, which varies with season. The actual Sun always remains in the *x*-*z* plane.)
- The *y*-axis points into the eastward quadrant, perpendicular to the *x*-*z* plane so as to satisfy the RH rule.



Earth-Centered Coordinates

ECEF Coordinates

The Earth-center, Earth-fixed (ECEF) system is a noninertial system that rotates with the Earth. Its origin is fixed at the center of the Earth.

- The *z*-axis points northward along the Earth's rotation axis.
- The *x*-axis points outward along the intersection of the Earth's equatorial plane and prime meridian.
- The *y*-axis points into the eastward quadrant, perpendicular to the *x*-*z* plane so as to satisfy the RH rule.

Coordinate Systems for Display

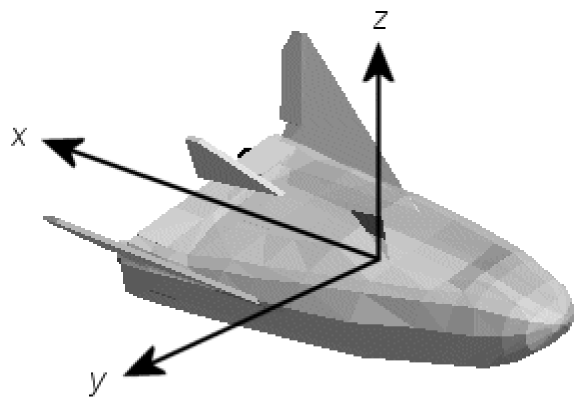
The Aerospace Toolbox software lets you use FlightGear coordinates for rendering motion.

FlightGear is an open-source, third-party flight simulator with an interface supported by the Aerospace Toolbox product.

- "Working with the Flight Simulator Interface" on page 2-53 discusses the toolbox interface to FlightGear.
- See the FlightGear documentation at www.flightgear.org for complete information about this flight simulator.

The FlightGear coordinates form a special body-fixed system, rotated from the standard body coordinate system about the *y*-axis by -180 degrees:

- The *x*-axis is positive toward the back of the vehicle.
- The *y*-axis is positive toward the right of the vehicle.
- The *z*-axis is positive upward, e.g., wheels typically have the lowest *z* values.



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

Mapping Toolbox User's Guide, The MathWorks, Inc., Natick, Massachusetts. `www.mathworks.com/access/helpdesk/help/toolbox/map/`.

Rogers, R. M., *Applied Mathematics in Integrated Navigation Systems*, AIAA, Reston, Virginia, 2000.

Stevens, B. L., and F. L. Lewis, *Aircraft Control and Simulation*, 2nd ed., Wiley-Interscience, New York, 2003.

Thomson, W. T., *Introduction to Space Dynamics*, John Wiley & Sons, New York, 1961/Dover Publications, Mineola, New York, 1986.

World Geodetic System 1984 (WGS 84), `http://earth-info.nga.mil/GandG/wgs84`.

Defining Aerospace Units

The Aerospace Toolbox functions support standard measurement systems. The Unit Conversion functions provide means for converting common measurement units from one system to another, such as converting velocity from feet per second to meters per second and vice versa.

The unit conversion functions support all units listed in this table.

Quantity	MKS (SI)	English
Acceleration	meters/second^2 (m/s^2), kilometers/second^2 (km/s^2), (kilometers/hour)/second (km/h-s), g-unit (*g*)	inches/second^2 (in/s^2), feet/second^2 (ft/s^2), (miles/hour)/second (mph/s), g-unit (*g*)
Angle	radian (rad), degree (deg), revolution	radian (rad), degree (deg), revolution
Angular acceleration	radians/second^2 (rad/s^2), degrees/second^2 (deg/s^2)	radians/second^2 (rad/s^2), degrees/second^2 (deg/s^2)
Angular velocity	radians/second (rad/s), degrees/second (deg/s), revolutions/minute (rpm), revolutions/second (rps)	radians/second (rad/s), degrees/second (deg/s), revolutions/minute (rpm), revolutions/second (rps)
Density	kilogram/meter^3 (kg/m^3)	pound mass/foot^3 (lbm/ft^3), slug/foot^3 (slug/ft^3), pound mass/inch^3 (lbm/in^3)
Force	newton (N)	pound (lb)
Inertia	kilogram-meter^2 (kg-m^2)	slug-foot^2 (slug-ft^2)
Length	meter (m)	inch (in), foot (ft), mile (mi), nautical mile (nm)
Mass	kilogram (kg)	slug (slug), pound mass (lbm)

Quantity	MKS (SI)	English
Pressure	pascal (Pa)	pound/inch^2 (psi), pound/foot^2 (psf), atmosphere (atm)
Temperature	kelvin (K), degrees Celsius (^oC)	degrees Fahrenheit (^oF), degrees Rankine (^oR)
Torque	newton-meter (N-m)	pound-feet (lb-ft)
Velocity	meters/second (m/s), kilometers/second (km/s), kilometers/hour (km/h)	inches/second (in/sec), feet/second (ft/sec), feet/minute (ft/min), miles/hour (mph), knots

Importing Digital DATCOM Data

In this section...

Overview

The Aerospace Toolbox product enables bringing United States Air Force (USAF) Digital DATCOM files into the MATLAB environment by using the `datcomimport` function. For more information, see the `datcomimport` function reference page. This section explains how to import data from a USAF Digital DATCOM file.

The example used in the following topics is available as an Aerospace Toolbox demo. You can run the demo either by entering `astimportddatcom` in the MATLAB Command Window or by finding the demo entry (Importing from USAF Digital DATCOM Files) in the MATLAB Online Help and clicking **Run in the Command Window** on its demo page.

Example of a USAF Digital DATCOM File

The following is a sample input file for USAF Digital DATCOM for a wing-body-horizontal tail-vertical tail configuration running over five alphas, two Mach numbers, and two altitudes and calculating static and dynamic derivatives. You can also view this file by entering `type astdatcom.in` in the MATLAB Command Window.

```
$FLTCON NMACH=2.0,MACH(1)=0.1,0.2$
$FLTCON NALT=2.0,ALT(1)=5000.0,8000.0$
$FLTCON NALPHA=5.,ALSCHD(1)=-2.0,0.0,2.0,
 ALSCHD(4)=4.0,8.0,LOOP=2.0$
$OPTINS SREF=225.8,CBARR=5.75,BLREF=41.15$
```

```
 $SYNTHS XCG=7.08,ZCG=0.0,XW=6.1,ZW=-1.4,ALIW=1.1,XH=20.2,
   ZH=0.4,ALIH=0.0,XV=21.3,ZV=0.0,VERTUP=.TRUE.$
 $BODY NX=10.0,
   X(1)=-4.9,0.0,3.0,6.1,9.1,13.3,20.2,23.5,25.9,
   R(1)=0.0,1.0,1.75,2.6,2.6,2.6,2.0,1.0,0.0$
 $WGPLNF CHRDTP=4.0,SSPNE=18.7,SSPN=20.6,CHRDR=7.2,SAVSI=0.0,CHSTAT=0.25,
   TWISTA=-1.1,SSPNDD=0.0,DHDADI=3.0,DHDADO=3.0,TYPE=1.0$
NACA-W-6-64A412
 $HTPLNF CHRDTP=2.3,SSPNE=5.7,SSPN=6.625,CHRDR=0.25,SAVSI=11.0,
   CHSTAT=1.0,TWISTA=0.0,TYPE=1.0$
NACA-H-4-0012
 $VTPLNF CHRDTP=2.7,SSPNE=5.0,SSPN=5.2,CHRDR=5.3,SAVSI=31.3,
   CHSTAT=0.25,TWISTA=0.0,TYPE=1.0$
NACA-V-4-0012
CASEID SKYHOGG BODY-WING-HORIZONTAL TAIL-VERTICAL TAIL CONFIG
DAMP
NEXT CASE
```

The output file generated by USAF Digital DATCOM for the same wing-body-horizontal tail-vertical tail configuration running over five alphas, two Mach numbers, and two altitudes can be viewed by entering `type astdatcom.out` in the MATLAB Command Window.

Importing Data from DATCOM Files

Use the `datcomimport` function to bring the Digital DATCOM data into the MATLAB environment.

```
alldata = datcomimport('astdatcom.out', true, 0);
```

Examining Imported DATCOM Data

The `datcomimport` function creates a cell array of structures containing the data from the Digital DATCOM output file.

```
data = alldata{1}
data =

        case: 'SKYHOGG BODY-WING-HORIZONTAL TAIL-VERTICAL TAIL CONFIG'
        mach: [0.1000 0.2000]
         alt: [5000 8000]
```

```
      alpha: [-2 0 2 4 8]
      nmach: 2
       nalt: 2
     nalpha: 5
      rnnub: []
     hypers: 0
       loop: 2
       sref: 225.8000
       cbar: 5.7500
      blref: 41.1500
        dim: 'ft'
      deriv: 'deg'
     stmach: 0.6000
     tsmach: 1.4000
       save: 0
      stype: []
       trim: 0
       damp: 1
      build: 1
       part: 0
    highsym: 0
    highasy: 0
    highcon: 0
       tjet: 0
     hypeff: 0
         lb: 0
        pwr: 0
       grnd: 0
      wsspn: 18.7000
      hsspn: 5.7000
     ndelta: 0
      delta: []
     deltal: []
     deltar: []
        ngh: 0
     grndht: []
     config: [1x1 struct]
         cd: [5x2x2 double]
         cl: [5x2x2 double]
         cm: [5x2x2 double]
```

```
cn: [5x2x2 double]
ca: [5x2x2 double]
xcp: [5x2x2 double]
cla: [5x2x2 double]
cma: [5x2x2 double]
cyb: [5x2x2 double]
cnb: [5x2x2 double]
clb: [5x2x2 double]
qqinf: [5x2x2 double]
eps: [5x2x2 double]
depsdalp: [5x2x2 double]
clq: [5x2x2 double]
cmq: [5x2x2 double]
clad: [5x2x2 double]
cmad: [5x2x2 double]
clp: [5x2x2 double]
cyp: [5x2x2 double]
cnp: [5x2x2 double]
cnr: [5x2x2 double]
clr: [5x2x2 double]
```

Filling in Missing DATCOM Data

By default, missing data points are set to 99999 and data points are set to NaN where no DATCOM methods exist or where the method is not applicable.

It can be seen in the Digital DATCOM output file and examining the imported data that $C_{Y\beta}$, $C_{n\beta}$, C_{lq}, and C_{mq} have data only in the first alpha value. Here are the imported data values.

```
data.cyb
ans(:,:,1) =

  1.0e+004 *

   -0.0000   -0.0000
    9.9999    9.9999
    9.9999    9.9999
    9.9999    9.9999
    9.9999    9.9999
```

```
ans(:,:,2) =

  1.0e+004 *

   -0.0000   -0.0000
    9.9999    9.9999
    9.9999    9.9999
    9.9999    9.9999
    9.9999    9.9999

data.cnb
ans(:,:,1) =

  1.0e+004 *

    0.0000    0.0000
    9.9999    9.9999
    9.9999    9.9999
    9.9999    9.9999
    9.9999    9.9999


ans(:,:,2) =

  1.0e+004 *

    0.0000    0.0000
    9.9999    9.9999
    9.9999    9.9999
    9.9999    9.9999
    9.9999    9.9999

data.clq
ans(:,:,1) =

  1.0e+004 *

    0.0000    0.0000
```

```
    9.9999    9.9999
    9.9999    9.9999
    9.9999    9.9999
    9.9999    9.9999


ans(:,:,2) =

  1.0e+004 *

    0.0000    0.0000
    9.9999    9.9999
    9.9999    9.9999
    9.9999    9.9999
    9.9999    9.9999

data.cmq
ans(:,:,1) =

  1.0e+004 *

   -0.0000   -0.0000
    9.9999    9.9999
    9.9999    9.9999
    9.9999    9.9999
    9.9999    9.9999


ans(:,:,2) =

  1.0e+004 *

   -0.0000   -0.0000
    9.9999    9.9999
    9.9999    9.9999
    9.9999    9.9999
    9.9999    9.9999
```

The missing data points will be filled with the values for the first alpha, since these data points are meant to be used for all alpha values.

```
aerotab = {'cyb' 'cnb' 'clq' 'cmq'};

for k = 1:length(aerotab)
    for m = 1:data.nmach
        for h = 1:data.nalt
            data.(aerotab{k})(:,m,h) = data.(aerotab{k})(1,m,h);
        end
    end
end
```

Here are the updated imported data values.

```
data.cyb
ans(:,:,1) =

   -0.0035   -0.0035
   -0.0035   -0.0035
   -0.0035   -0.0035
   -0.0035   -0.0035
   -0.0035   -0.0035


ans(:,:,2) =

   -0.0035   -0.0035
   -0.0035   -0.0035
   -0.0035   -0.0035
   -0.0035   -0.0035
   -0.0035   -0.0035

data.cnb
ans(:,:,1) =

  1.0e-003 *

    0.9142    0.8781
    0.9142    0.8781
    0.9142    0.8781
    0.9142    0.8781
    0.9142    0.8781
```

```
ans(:,:,2) =

  1.0e-003 *

    0.9190    0.8829
    0.9190    0.8829
    0.9190    0.8829
    0.9190    0.8829
    0.9190    0.8829

data.clq
ans(:,:,1) =

    0.0974    0.0984
    0.0974    0.0984
    0.0974    0.0984
    0.0974    0.0984
    0.0974    0.0984


ans(:,:,2) =

    0.0974    0.0984
    0.0974    0.0984
    0.0974    0.0984
    0.0974    0.0984
    0.0974    0.0984

data.cmq
ans(:,:,1) =

   -0.0892   -0.0899
   -0.0892   -0.0899
   -0.0892   -0.0899
   -0.0892   -0.0899
   -0.0892   -0.0899
```

```
ans(:,:,2) =

   -0.0892   -0.0899
   -0.0892   -0.0899
   -0.0892   -0.0899
   -0.0892   -0.0899
   -0.0892   -0.0899
```

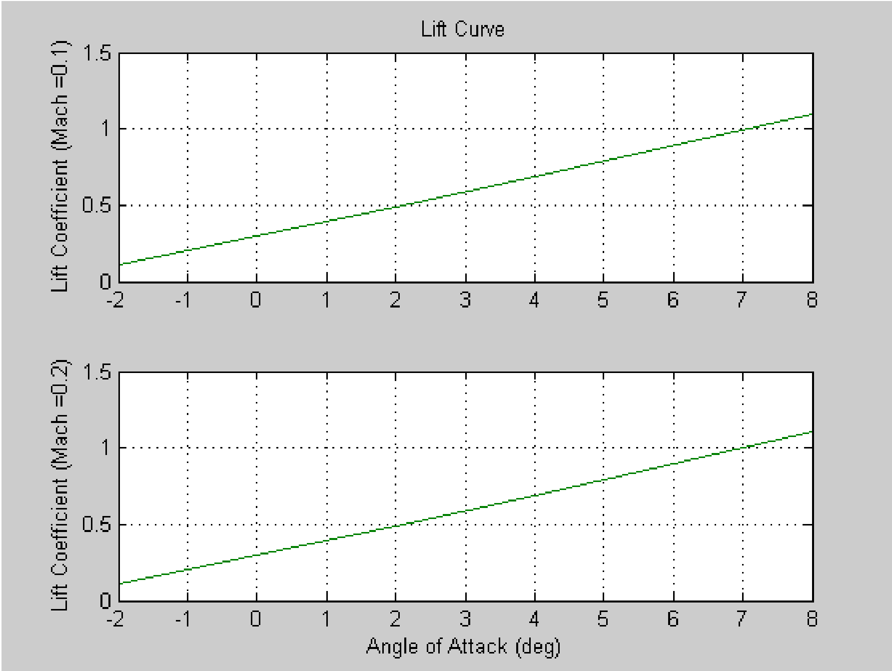
Plotting Aerodynamic Coefficients

You can now plot the aerodynamic coefficients:

- "Plotting Lift Curve Moments" on page 2-22
- "Plotting Drag Polar Moments" on page 2-23
- "Plotting Pitching Moments" on page 2-24

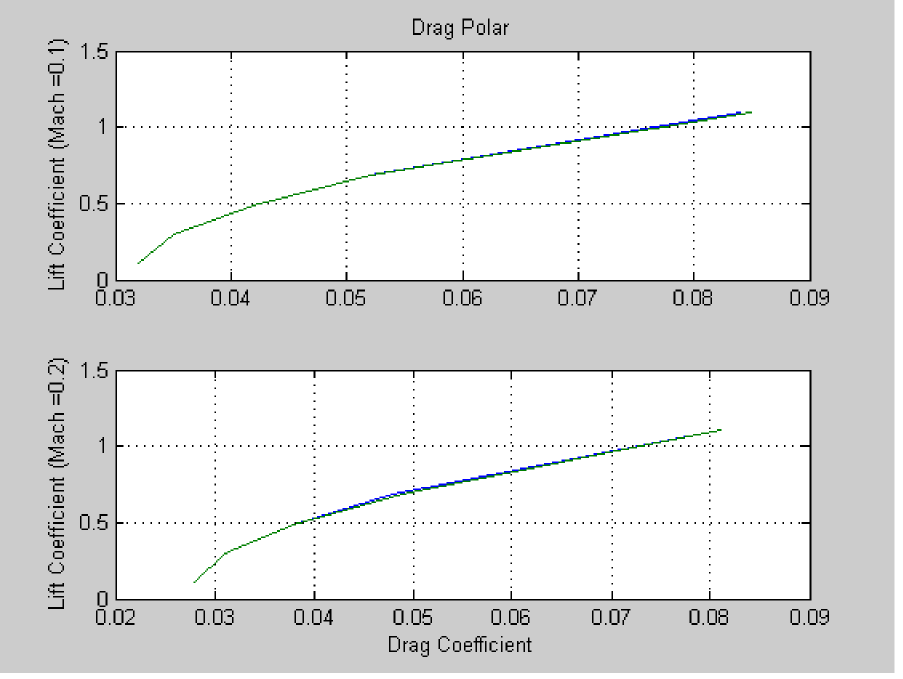
Plotting Lift Curve Moments

```
h1 = figure;
figtitle = {'Lift Curve' ''};
for k=1:2
    subplot(2,1,k)
    plot(data.alpha,permute(data.cl(:,k,:),[1 3 2]))
    grid
    ylabel(['Lift Coefficient (Mach =' num2str(data.mach(k)) ')'])
    title(figtitle{k});
end
xlabel('Angle of Attack (deg)')
```



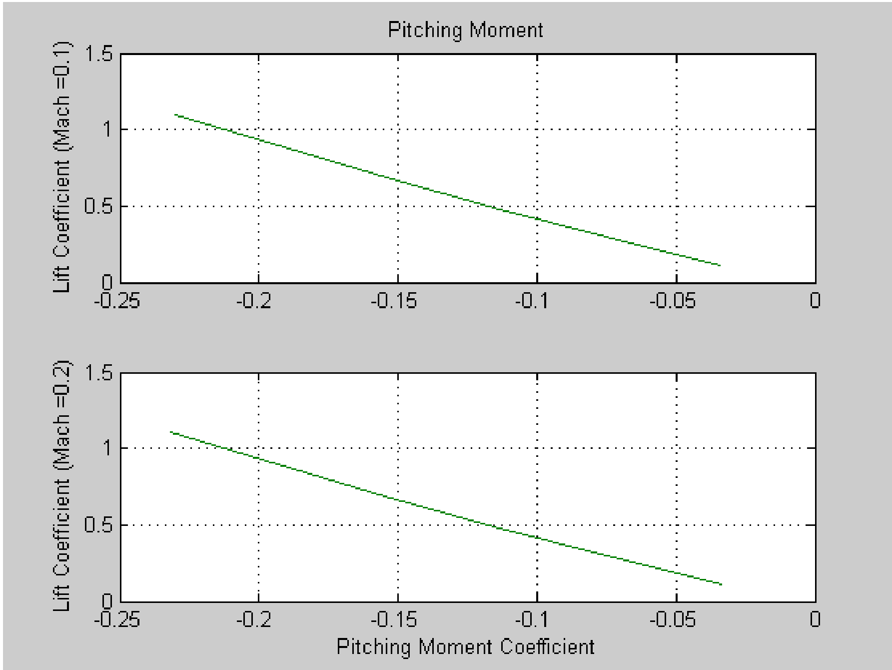
Plotting Drag Polar Moments

```
h2 = figure;
figtitle = {'Drag Polar' ''};
for k=1:2
    subplot(2,1,k)
    plot(permute(data.cd(:,k,:),[1 3 2]),permute(data.cl(:,k,:),[1 3 2]))
    grid
    ylabel(['Lift Coefficient (Mach =' num2str(data.mach(k)) ')'])
    title(figtitle{k})
end
xlabel('Drag Coefficient')
```



Plotting Pitching Moments

```
h3 = figure;
figtitle = {'Pitching Moment' ''};
for k=1:2
    subplot(2,1,k)
    plot(permute(data.cm(:,k,:),[1 3 2]),permute(data.cl(:,k,:),[1 3 2]))
    grid
    ylabel(['Lift Coefficient (Mach =' num2str(data.mach(k)) ')'])
    title(figtitle{k})
end
xlabel('Pitching Moment Coefficient')
```


Pitching Moment
Lift Coefficient (Mach =0.1)
1.5
1
0.5
0
-0.25
-0.2
-0.15
-0.1
-0.05
0
Lift Coefficient (Mach =0.2)
1.5
1
0.5
0
-0.25
-0.2
-0.15
-0.1
-0.05
0
Pitching Moment Coefficient

3-D Flight Data Playback

In this section...

Aerospace Toolbox Animation Objects

To visualize flight data in the Aerospace Toolbox environment, you can use the following animation objects and their associated methods. These animation objects use the MATLAB time series object, `timeseries` to visualize flight data.

- `Aero.Animation` — You can use this animation object to visualize flight data without any other tool or toolbox. The following objects support this object.
  - `Aero.Body`
  - `Aero.Camera`
  - `Aero.Geometry`
- `Aero.VirtualRealityAnimation` — You can use this animation object to visualize flight data with the Simulink 3D Animation product. The following objects support this object.
  - `Aero.Node`
  - `Aero.Viewpoint`
- `Aero.FlightGearAnimation`

  You can use this animation object to visualize flight data with the FlightGear simulator.

Using Aero.Animation Objects

The toolbox interface to animation objects uses the Handle Graphics® product. The demo, Overlaying Simulated and Actual Flight Data (`astmlanim`), visually compares simulated and actual flight trajectory data. It does this by creating animation objects, creating bodies for those objects, and loading the flight trajectory data. This section describes what happens when the demo runs.

1. Create and configure an animation object.
   a. Configure the animation object.
   b. Create and load bodies for that object.
2. Load recorded data for flight trajectories.
3. Display body geometries in a figure window.
4. Play back flight trajectories using the animation object.
5. Manipulate the camera.
6. Manipulate bodies, as follows:
   a. Move and reposition bodies.
   b. Create a transparency in the first body.
   c. Change the color of the second body.
   d. Turn off the landing gear of the second body.

Running the Demo

1. Start the MATLAB software.
2. Run the demo either by entering `astmlanim` in the MATLAB Command Window or by finding the demo entry (Overlaying Simulated and Actual Flight Data) in the MATLAB Online Help and clicking **Run in the Command Window** on its demo page.

   While running, the demo performs several steps by issuing a series of commands, as explained below.

Creating and Configuring an Animation Object

This series of commands creates an animation object and configures the object.

1 Create an animation object.

```
h = Aero.Animation;
```

2 Configure the animation object to set the number of frames per second (`FramesPerSecond`) property. This controls the rate at which frames are displayed in the figure window.

```
h.FramesPerSecond = 10;
```

3 Configure the animation object to set the seconds of animation data per second time scaling (`TimeScaling`) property.

```
h.TimeScaling = 5;
```

The combination of `FramesPerSecond` and `TimeScaling` property determine the time step of the simulation. The settings in this demo result in a time step of approximately 0.5 s.

4 Create and load bodies for the animation object. The demo will use these bodies to work with and display the simulated and actual flight trajectories. The first body is orange; it represents simulated data. The second body is blue; it represents the actual flight data.

```
idx1 = h.createBody('pa24-250_orange.ac','Ac3d');
idx2 = h.createBody('pa24-250_blue.ac','Ac3d');
```

Both bodies are AC3D format files. AC3D is one of several file formats that the animation objects support. FlightGear uses the same file format. The animation object reads in the bodies in the AC3D format and stores them as patches in the geometry object within the animation object.

Loading Recorded Data for Flight Trajectories

This series of commands loads the recorded flight trajectory data, which is contained in files in the *`matlabroot`*`\toolbox\aero\astdemos` folder.

- `simdata` – Contains simulated flight trajectory data, which is set up as a 6DoF array.
- `fltdata` – Contains actual flight trajectory data, which is set up in a custom format. To access this custom format data, the demo needs to

set the body object **TimeSeriesSourceType** parameter to `Custom`, then specify a custom read function.

1 Load the flight trajectory data.

```
load simdata
load fltdata
```

2 Set the time series data for the two bodies.

```
h.Bodies{1}.TimeSeriesSource = simdata;
h.Bodies{2}.TimeSeriesSource = fltdata;
```

3 Identify the time series for the second body as custom.

```
h.Bodies{2}.TimeSeriesSourceType = 'Custom';
```

4 Specify the custom read function to access the data in `fltdata` for the second body. The demo provides the custom read function in *matlabroot*`\toolbox\aero\astdemos\CustomReadBodyTSData.m`.

```
h.Bodies{2}.TimeseriesReadFcn = @CustomReadBodyTSData;
```

Displaying Body Geometries in a Figure Window

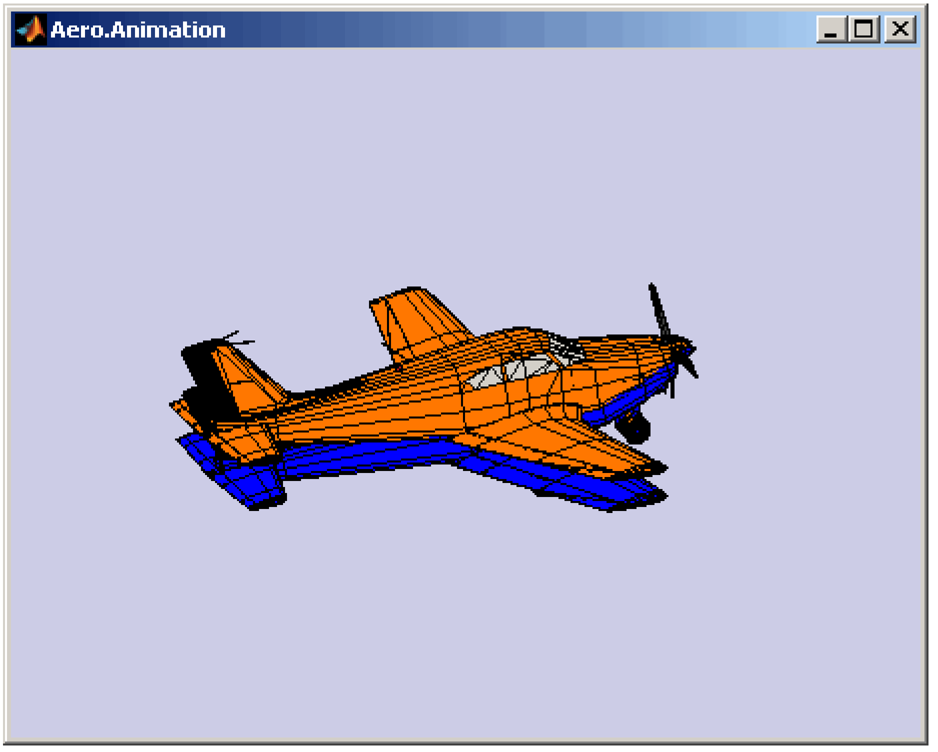
This command creates a figure object for the animation object.

```
h.show();
```

Playing Back Flight Trajectories Using the Animation Object

This command plays the animation bodies for the duration of the time series data. This illustrates the differences between the simulated and actual flight data.

```
h.play();
```



Manipulating the Camera

This command series describes how you can manipulate the camera on the two bodies, and redisplay the animation. The `PositionFcn` property of a camera object controls the camera position relative to the bodies in the animation. In the section "Playing Back Flight Trajectories Using the Animation Object" on page 2-29, the camera object uses a default value for the `PositionFcn` property. In this command series, the demo references a custom `PositionFcn` function, which uses a static position based on the position of the bodies; no dynamics are involved. The custom `PositionFcn` function is located in the *`matlabroot`*`\toolbox\aero\astdemos` folder.

1 Set the camera `PositionFcn` to the custom function `staticCameraPosition`.

```
h.Camera.PositionFcn = @staticCameraPosition;
```

2 Run the animation again.

```
h.play();
```

Manipulating Bodies

This section illustrates some of the actions you can perform on bodies.

Moving and Repositioning Bodies. This series of commands illustrates how to move and reposition bodies.

1 Set the starting time to 0.

```
t = 0;
```

2 Move the body to the starting position that is based on the time series data. Use the Aero.Animation object `Aero.Animation.updateBodies` method.

```
h.updateBodies(t);
```

3 Update the camera position using the custom `PositionFcn` function set in the previous section. Use the Aero.Animation object `Aero.Animation.updateCamera` method.

```
h.updateCamera(t);
```

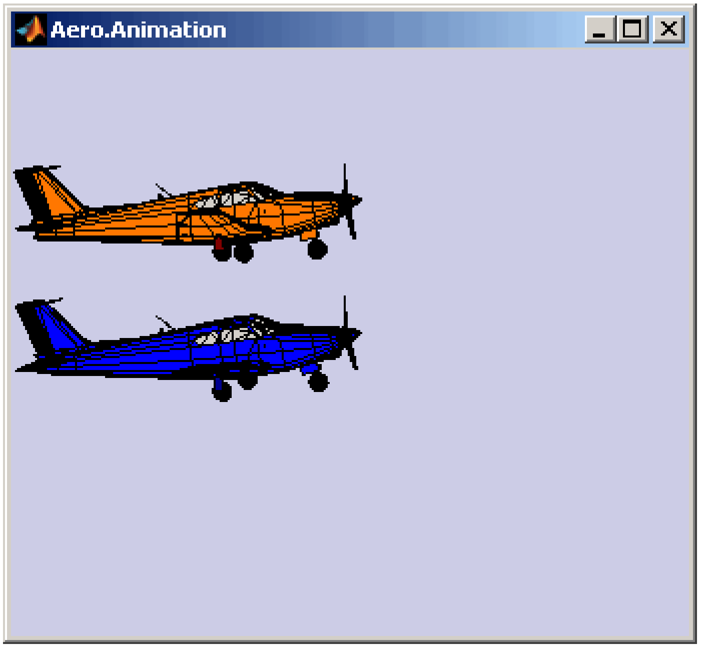
4 Reposition the bodies by first getting the current body position, then separating the bodies.

a Get the current body positions and rotations from the objects of both bodies.

```
pos1 = h.Bodies{1}.Position;
rot1 = h.Bodies{1}.Rotation;
pos2 = h.Bodies{2}.Position;
rot2 = h.Bodies{2}.Rotation;
```

b Separate and reposition the bodies by moving them to new positions.

```
h.moveBody(1,pos1 + [0 0 -3],rot1);
h.moveBody(2,pos1 + [0 0  0],rot2);
```



Creating a Transparency in the First Body. This series of commands illustrates how to create and attach a transparency to a body. The animation object stores the body geometry as patches. This example manipulates the transparency properties of these patches (see "Creating 3-D Models with Patches" in the MATLAB documentation).

Note The use of transparencies might decrease animation speed on platforms that use software OpenGL® rendering (see `opengl` in the MATLAB documentation).

---

1 Change the body patch properties. Use the Aero.Body `PatchHandles` property to get the patch handles for the first body.

```
patchHandles2 = h.Bodies{1}.PatchHandles;
```

2 Set the desired face and edge alpha values for the transparency.

```
desiredFaceTransparency = .3;
desiredEdgeTransparency = 1;
```

3 Get the current face and edge alpha data and change all values to the desired alpha values. In the figure, note the first body now has a transparency.

```
for k = 1:size(patchHandles2,1)
    tempFaceAlpha = get(patchHandles2(k),'FaceVertexAlphaData');
    tempEdgeAlpha = get(patchHandles2(k),'EdgeAlpha');
    set(patchHandles2(k),...
        'FaceVertexAlphaData',repmat(desiredFaceTransparency,size(tempFaceAlpha)));
    set(patchHandles2(k),...
        'EdgeAlpha',repmat(desiredEdgeTransparency,size(tempEdgeAlpha)));
end
```

Changing the Color of the Second Body. This series of commands illustrates how to change the color of a body. The animation object stores the body geometry as patches. This example will manipulate the `FaceVertexColorData` property of these patches.

1 Change the body patch properties. Use the Aero.Body `PatchHandles` property to get the patch handles for the first body.

```
patchHandles3 = h.Bodies{2}.PatchHandles;
```

2 Set the patch color to red.

```
desiredColor = [1 0 0];
```

3 Get the current face color and data and propagate the new patch color, red, to the face. Note the following:

- The `if` condition prevents the windows from being colored.
- The `name` property is stored in the body geometry data (`h.Bodies{2}.Geometry.FaceVertexColorData(k).name`).
- The code changes only the indices in `patchHandles3` with nonwindow counterparts in the body geometry data.

Note If you cannot access the `name` property to determine the parts of the vehicle to color, you must use an alternative way to selectively color your vehicle.

```
for k = 1:size(patchHandles3,1)
    tempFaceColor = get(patchHandles3(k),'FaceVertexCData');
    tempName = h.Bodies{2}.Geometry.FaceVertexColorData(k).name;
    if isempty(strfind(tempName,'Windshield')) &&...
       isempty(strfind(tempName,'front-windows')) &&...
       isempty(strfind(tempName,'rear-windows'))
    set(patchHandles3(k),...
        'FaceVertexCData',repmat(desiredColor,[size(tempFaceColor,1),1]));
    end
end
```

Turning Off the Landing Gear of the Second Body. This command series illustrates how to turn off the landing gear on the second body by turning off the visibility of all the vehicle parts associated with the landing gear.

Note The indices into the `patchHandles3` vector are determined from the `name` property. If you cannot access the `name` property to determine the indices, you must use an alternative way to determine the indices that correspond to the geometry parts.

```
for k = [1:8,11:14,52:57]
    set(patchHandles3(k),'Visible','off')
end
```

Using Aero.VirtualRealityAnimation Objects

The Aerospace Toolbox interface to virtual reality animation objects uses the Simulink 3D Animation software. See `Aero.VirtualRealityAnimation`, `Aero.Node`, and `Aero.Viewpoint` for details.

1 Create and configure an animation object.
   a Configure the animation object.
   b Initialize that object.
2 Enable the tracking of changes to virtual worlds.
3 Load the animation world.
4 Load time series data for simulation.
5 Set coordination information for the object.
6 Add a chase helicopter to the object.
7 Load time series data for chase helicopter simulation.
8 Set coordination information for the new object.
9 Add a new viewpoint for the helicopter.

10 Play the animation.

11 Create a new viewpoint.

12 Add a route.

13 Add another helicopter.

14 Remove bodies.

15 Revert to the original world.

Running the Demo

1 Start the MATLAB software.

2 Run the demo either by entering `astvranim` in the MATLAB Command Window or by finding the demo entry (Visualize Aircraft Takeoff via the Simulink 3D Animation product) in the MATLAB Online Help and clicking **Run in the Command Window** on its demo page.

   While running, the demo performs several steps by issuing a series of commands, as explained below.

Creating and Configuring a Virtual Reality Animation Object

This series of commands creates an animation object and configures the object.

1 Create an animation object.

```
h = Aero.VirtualRealityAnimation;
```

2 Configure the animation object to set the number of frames per second (`FramesPerSecond`) property. This controls the rate at which frames are displayed in the figure window.

```
h.FramesPerSecond = 10;
```

3 Configure the animation object to set the seconds of animation data per second time scaling (`TimeScaling`) property.

```
h.TimeScaling = 5;
```

The combination of FramesPerSecond and TimeScaling property determine the time step of the simulation. The settings in this demo result in a time step of approximately 0.5 s.

4 Specify the .wrl file for the vrworld object.

```
h.VRWorldFilename = [matlabroot,'/toolbox/aero/astdemos/asttkoff.wrl'];
```

The virtual reality animation object reads in the .wrl file.

Enabling Aero.VirtualRealityAnimation Methods to Track Changes to Virtual Worlds

Aero.VirtualRealityAnimation methods that change the current virtual reality world use a temporary .wrl file to manage those changes. To enable these methods to work in a write-protected folder such as astdemos, type the following.

1 Copy the virtual world file, asttkoff.wrl, to a temporary folder.

```
copyfile(h.VRWorldFilename,[tempdir,'asttkoff.wrl'],'f');
```

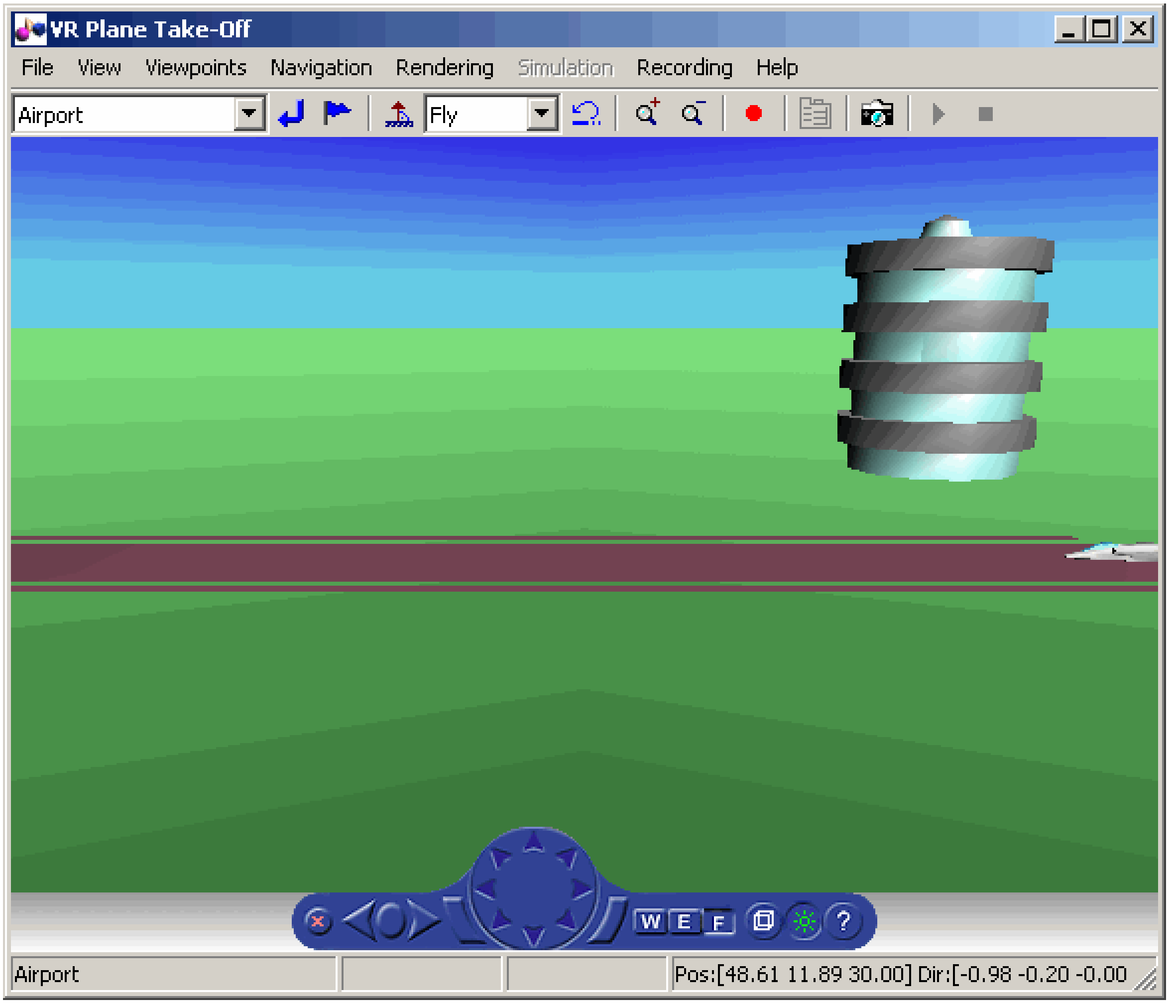
2 Set the asttkoff.wrl world filename to the copied .wrl file.

```
h.VRWorldFilename = [tempdir,'asttkoff.wrl'];
```

Loading the Animation World

Load the animation world described in the VRWorldFilename field of the animation object. When parsing the world, this method creates node objects for existing nodes with DEF names. The initialize method also opens the Simulink 3D Animation Viewer.

```
h.initialize();
```



Displaying Figures

While working with this demo, you can capture a view of a scene with the `takeVRCapture` tool. This tool is specific to the `astvranim` demo. To display the initial scene, type

```
takeVRCapture(h.VRFigure);
```

A MATLAB figure window displays with the initial scene.

Loading Time Series Data for Simulation

To prepare for simulation, set the simulation time series data. `takeoffData.mat` contains logged simulated data that you can use to set the time series data. `takeoffData` is set up as the Simulink structure`'StructureWithTime'`, which is a default data format.

1 Load the `takeoffData`.

```
load takeoffData
```

2 Set the time series data for the node.

```
h.Nodes{7}.TimeseriesSource = takeoffData;
h.Nodes{7}.TimeseriesSourceType = 'StructureWithTime';
```

Aligning the Position and Rotation Data with Surrounding Virtual World Objects

The virtual reality animation object expects positions and rotations in aerospace body coordinates. If the input data coordinate system is different, as is the case in this demo, you must create a coordinate transformation function to correctly line up the position and rotation data with the surrounding objects in the virtual world. This code should set the coordinate transformation function for the virtual reality animation. The custom transfer function for this demo is *`matlabroot`*`/toolbox/aero/astdemos/vranimCustomTransform.m`. In this demo, if the input translation coordinates are `[x1,y1,z1]`, the custom transform function must adjust them as:

```
[X,Y,Z] = -[y1,x1,z1]
```

To run this custom transformation function, type:

```
h.Nodes{7}.CoordTransformFcn = @vranimCustomTransform;
```

Viewing the Nodes in a Virtual Reality Animation Object

While working with this demo, you can view all the nodes currently in the virtual reality animation object with the `nodeInfo` method.

```
h.nodeInfo;
```

This method displays the nodes currently in your demo:

```
Node Information
1 _v1
2 Lighthouse
3 _v3
4 Terminal
5 Block
6 _V2
7 Plane
8 Camera1
```

Adding a Chase Helicopter

As part of the demo, add a chase helicopter node to your demo. Use the `addNode` method to add another node to the virtual reality animation object.

Note By default, each time you add or remove a node, or when you call the `saveas` method, a message shows the current `.wrl` file location. To disable this message, set the `'ShowSaveWarning'` property in the virtual reality animation object. You can disable this message before adding the chase helicopter.

---

1 Disable the message.

```
h.ShowSaveWarning = false;
```

2 Add the chase helicopter node.

```
h.addNode('Lynx',[matlabroot,'/toolbox/aero/astdemos/chaseHelicopter.wrl']);
```

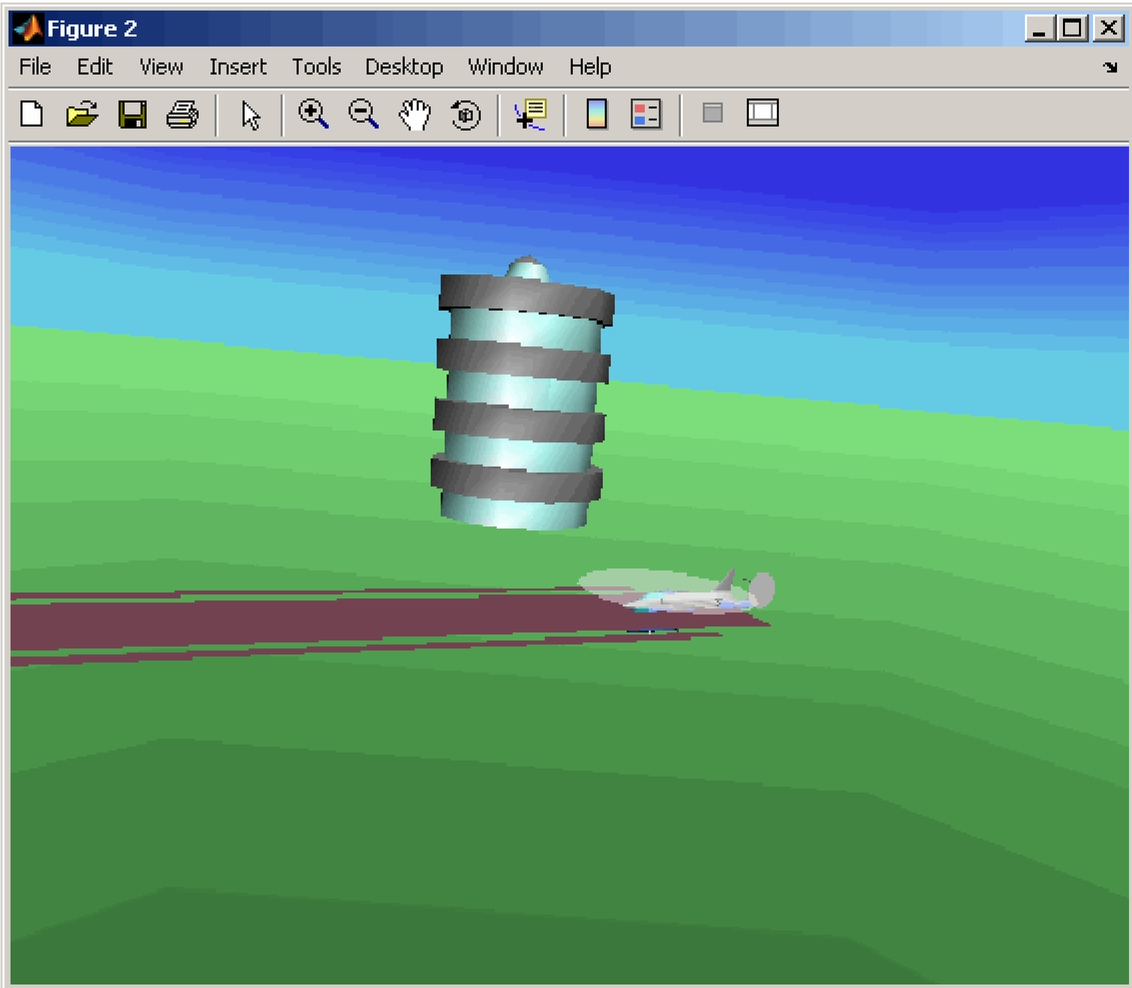
The helicopter appears in the Simulink 3D Animation Viewer.

3 Move the camera angle of the virtual reality figure to view the aircraft and newly added helicopter.

```
set(h.VRFigure,'CameraDirection',[0.45 0 -1]);
```

4 View the scene with the chase helicopter.

```
takeVRCapture(h.VRFigure);
```



Loading Time Series Data for Simulation

To prepare to simulate the chase helicopter, set the simulation time series data. `chaseData.mat` contains logged simulated data that you can use to set the time series data. `chaseData` is set up as the Simulink structure`'StructureWithTime'`, which is a default data format.

1 Load the `chaseData`.

```
load chaseData
```

2 Set the time series data for the node.

```
h.Nodes{2}.TimeseriesSource = chaseData;
```

Aligning the Chase Helicopter Position and Rotation Data with Surrounding Virtual World Objects

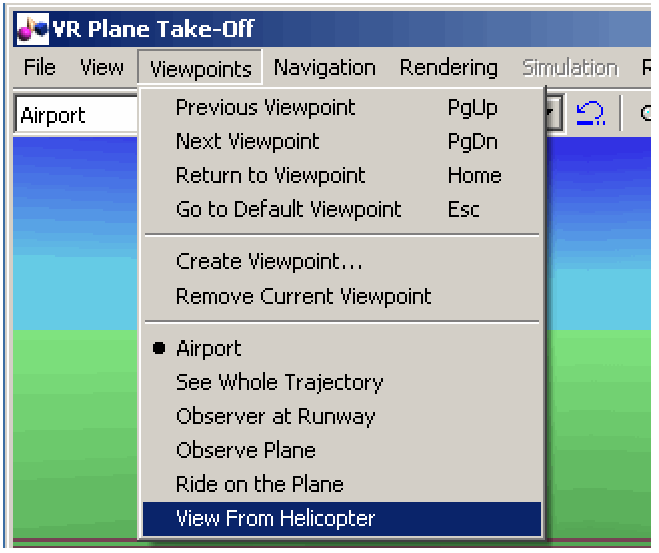
Use the custom transfer function to align the chase helicopter.

```
h.Nodes{2}.CoordTransformFcn = @vranimCustomTransform;
```

Adding a New Viewpoint

To add a viewpoint for the chase helicopter, use the `addViewpoint` method. New viewpoints appear in the **Viewpoints** menu of the Simulink 3D Animation Viewer. Type the following to add the viewpoint `View From Helicopter` to the **Viewpoints** menu.

```
h.addViewpoint(h.Nodes{2}.VRNode,'children','chaseView','View From Helicopter');
```



Playing Back the Simulation

The `play` command animates the virtual reality world for the given position and angle for the duration of the time series data. Set the orientation of the viewpoint first.

1 Set the orientation of the viewpoint via the vrnode object associated with the node object for the viewpoint.

```
setfield(h.Nodes{1}.VRNode,'orientation',[0 1 0 convang(160,'deg','rad')]);
set(h.VRFigure,'Viewpoint','View From Helicopter');
```

2 Play the animation.

```
h.play();
```

Adding a Route to the Camera1 Node

The vrworld has a `Ride on the Plane` viewpoint. To enable this viewpoint to function as intended, connect the plane position to the Camera1 node with the `addRoute` method. This method adds a VRML `ROUTE` statement.

```
h.addRoute('Plane','translation','Camera1','translation');
```

Adding Another Helicopter and Viewing All Bodies Simultaneously

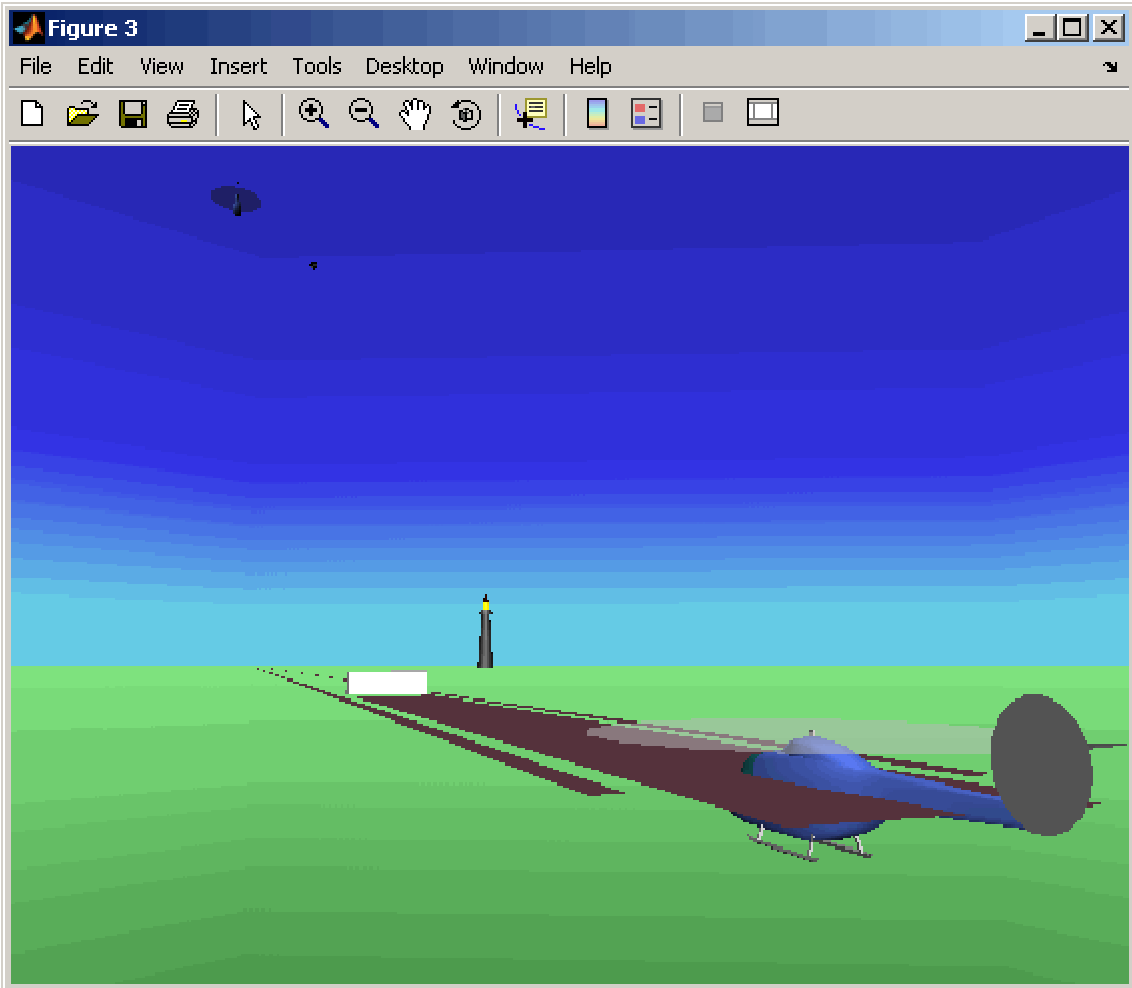
You can add another helicopter to the scene and also change the viewpoint to one that views all three bodies in the scene at once.

1 Add a new node, `Lynx1`.

```
h.addNode('Lynx1',[matlabroot,'/toolbox/aero/astdemos/chaseHelicopter.wrl']);
```

2 Change the viewpoint to one that views all three bodies.

```
set(h.VRFigure,'Viewpoint','See Whole Trajectory');
```



Removing Bodies

Use the `removeNode` method to remove the second helicopter. To obtain the name of the node to remove, use the `nodeInfo` method.

1 View all the nodes.

```
h.nodeInfo
```

```
Node Information
1 Lynx1_Inline
2 Lynx1
3 chaseView
4 Lynx_Inline
5 Lynx
6 _v1
7 Lighthouse
8 _v3
9 Terminal
10 Block
11 _V2
12 Plane
13 Camera1
```

2 Remove the `Lynx1` node.

```
h.removeNode('Lynx1');
```

3 Change the viewpoint to one that views the whole trajectory.

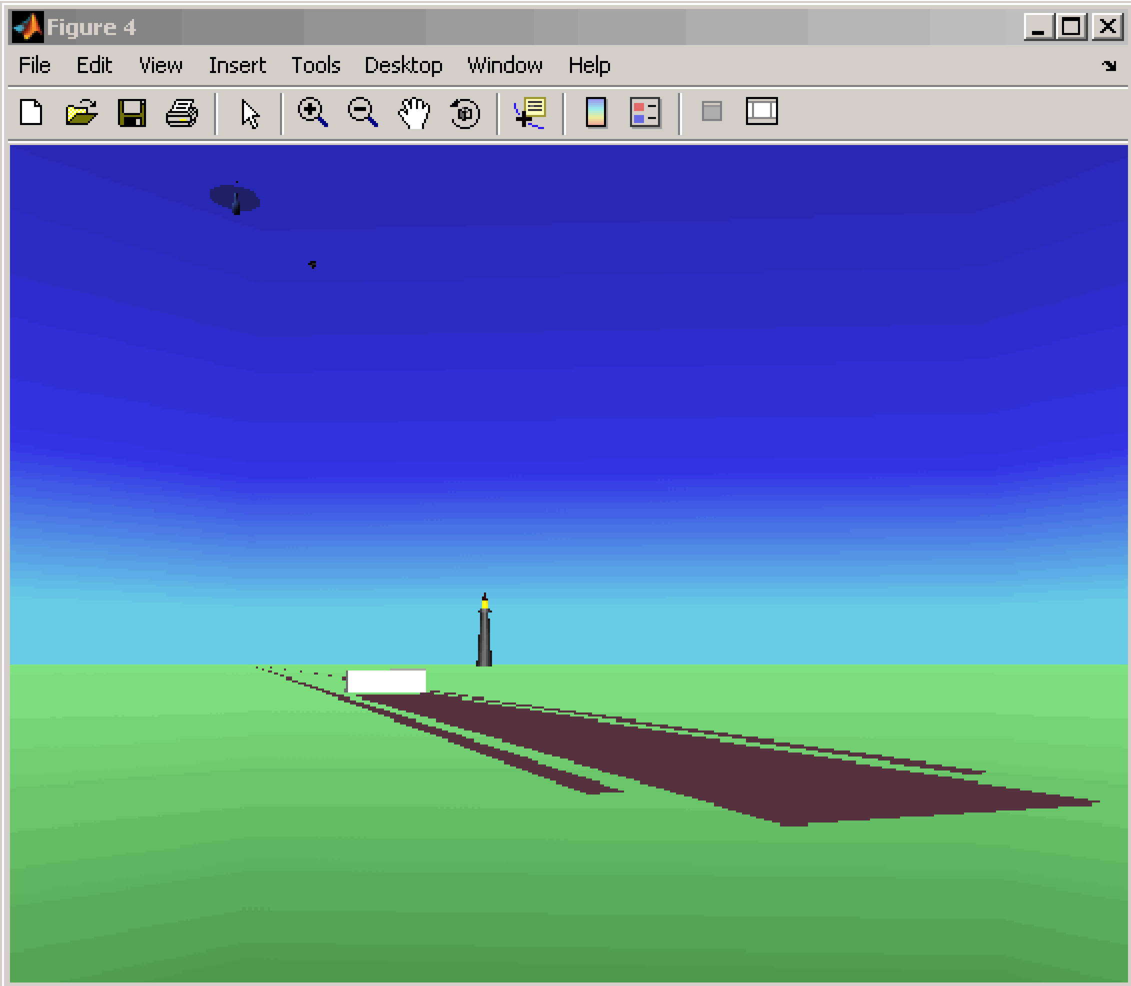
```
set(h.VRFigure,'Viewpoint','See Whole Trajectory');
```

4 Check that you have removed the node.

```
h.nodeInfo

Node Information
1 chaseView
2 Lynx_Inline
3 Lynx
4 _v1
5 Lighthouse
6 _v3
7 Terminal
8 Block
9 _V2
10 Plane
11 Camera1
```

The following figure is a view of the entire trajectory with the third body removed.



Reverting to the Original World

The original file name is stored in the `'VRWorldOldFilename'` property of the virtual reality animation object. To display the original world, set `'VRWorldFilename'` to the original name and reinitialize it.

1 Revert to the original world, 'VRWorldFilename'.

```
h.VRWorldFilename = h.VRWorldOldFilename{1};
```

2 Reinitialize the restored world.

```
h.initialize();
```

Closing and Deleting Worlds

To close and delete a world, use the `delete` method.

```
h.delete();
```

Using Aero.FlightGearAnimation Objects

The Aerospace Toolbox interface to the FlightGear flight simulator enables you to visualize flight data in a three-dimensional environment. The third-party FlightGear simulator is an open source software package available through a GNU® General Public License (GPL). This section explains how to obtain and install the third-party FlightGear flight simulator. It then explains how to play back 3-D flight data by using a FlightGear demo, provided with your Aerospace Toolbox software, as an example.

- "About the FlightGear Interface" on page 2-48
- "Configuring Your Computer for FlightGear" on page 2-49
- "Installing and Starting FlightGear" on page 2-52
- "Working with the Flight Simulator Interface" on page 2-53
- "Running the Demo" on page 2-55

About the FlightGear Interface

The FlightGear flight simulator interface included with the Aerospace Toolbox product is a unidirectional transmission link from the MATLAB software to FlightGear using FlightGear's published `net_fdm` binary data exchange protocol. Data is transmitted via UDP network packets to a running instance of FlightGear. The toolbox supports multiple standard binary distributions of FlightGear. See "Working with the Flight Simulator Interface" on page 2-53 for interface details.

FlightGear is a separate software entity neither created, owned, nor maintained by MathWorks.

- To report bugs in or request enhancements to the Aerospace Toolbox FlightGear interface, contact MathWorks Technical Support at http://www.mathworks.com/contact_TS.html.
- To report bugs or request enhancements to FlightGear itself, visit `www.flightgear.org` and use the contact page.

Obtaining FlightGear. You can obtain FlightGear from `www.flightgear.org` in the download area or by ordering CDs from FlightGear. The download area contains extensive documentation for installation and configuration. Because FlightGear is an open source project, source downloads are also available for customization and porting to custom environments.

Configuring Your Computer for FlightGear

You must have a high performance graphics card with stable drivers to use FlightGear. For more information, see the FlightGear CD distribution or the hardware requirements and documentation areas of the FlightGear Web site, `www.flightgear.org`.

MathWorks tests of FlightGear performance and stability indicate significant sensitivity to computer video cards, driver versions, and driver settings. You need OpenGL support with hardware acceleration activated. The OpenGL settings are particularly important. Without proper setup, performance can drop from about a 30 frames-per-second (fps) update rate to less than 1 fps.

Graphics Recommendations for Microsoft Windows. MathWorks recommends the following for Windows® users:

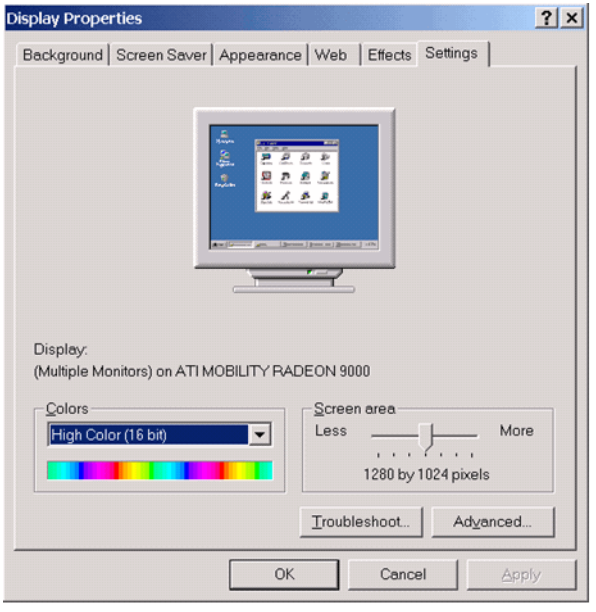
- Choose a graphics card with good OpenGL performance.
- Always use the latest tested and stable driver release for your video card. Test the driver thoroughly on a few computers before deploying to others.

  For Microsoft® Windows XP systems running on x86 (32-bit) or AMD-64/EM64T chip architectures, the graphics card operates in the unprotected kernel space known as Ring Zero. This means that glitches in the driver can cause the Windows operating system to lock or crash. Before buying a large number of computers for 3-D applications, test, with your vendor, one or two computers to find a combination of hardware, operating system, drivers, and settings that are stable for your applications.

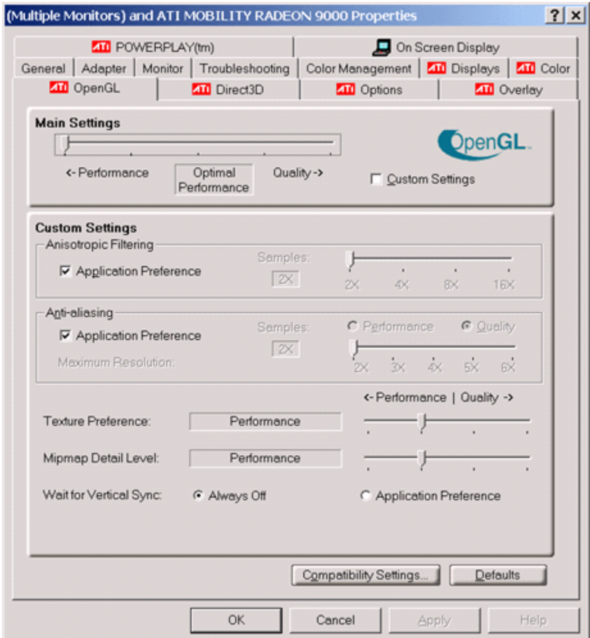
Setting Up OpenGL Graphics on Windows. For complete information on Silicon Graphics OpenGL settings, refer to the documentation at the OpenGL Web site, `www.opengl.org`.

Follow these steps to optimize your video card settings. Your driver's panes might look different.

1. Ensure that you have activated the OpenGL hardware acceleration on your video card. On Windows, access this configuration through **Start > Settings > Control Panel > Display**, which opens the following dialog box. Select the **Settings** tab.



2. Click the **Advanced** button in the lower right of the dialog box, which opens the graphics card's custom configuration dialog box, and go to the **OpenGL** tab. For an ATI Mobility Radeon 9000 video card, the **OpenGL** pane looks like this:



3 For best performance, move the **Main Settings** slider near the top of the dialog box to the **Performance** end of the slider.

4 If stability is a problem, try other screen resolutions, other color depths in the **Displays** pane, and other OpenGL acceleration modes.

Many cards perform much better at 16 bits-per-pixel color depth (also known as 65536 color mode, 16-bit color). For example, on an ATI Mobility Radeon 9000 running a given model, 30 fps are achieved in 16-bit color mode, while 2 fps are achieved in 32-bit color mode.

Setup on Linux®, Mac OS® X, and Other Platforms. FlightGear distributions are available for Linux, Mac OS X, and other UNIX® platforms from the FlightGear Web site, `www.flightgear.org`. Installation on these platforms, like Windows, requires careful configuration of graphics cards and drivers. Consult the documentation and hardware requirements sections at the FlightGear Web site.

Using MATLAB Graphics Controls to Configure Your OpenGL Settings. You can also control your OpenGL rendering from the MATLAB command line with the MATLAB Graphics `opengl` command. Consult the `opengl` command reference for more information.

Installing and Starting FlightGear

The extensive FlightGear documentation guides you through the installation in detail. Consult the documentation section of the FlightGear Web site for complete installation instructions: `www.flightgear.org`.

Keep the following points in mind:

- Generous central processor speed, system and video RAM, and virtual memory are essential for good flight simulator performance.

  MathWorks recommends a minimum of 512 megabytes of system RAM and 128 megabytes of video RAM for reasonable performance.

- Be sure to have sufficient disk space for the FlightGear download and installation.
- MathWorks recommends configuring your computer's graphics card before you install FlightGear. See the preceding section, "Configuring Your Computer for FlightGear" on page 2-49.
- Shutting down all running applications (including the MATLAB software) before installing FlightGear is recommended.
- MathWorks tests indicate that the operational stability of FlightGear is especially sensitive during startup. It is best to not move, resize, mouse over, overlap, or cover up the FlightGear window until the initial simulation scene appears after the startup splash screen fades out.
- The current releases of FlightGear are optimized for flight visualization at altitudes below 100,000 feet. FlightGear does not work well or at all with very high altitude and orbital views.

The Aerospace Toolbox product supports FlightGear on a number of platforms (`http://www.mathworks.com/products/aerotb/requirements.html`). The following table lists the properties you should be aware of before you start to use FlightGear.

FlightGear Property	Folder Description	Platforms	Typical Location
FlightGearBase-Directory	FlightGear installation folder.	Windows	C:\Program Files\FlightGear (default)
		Sun™ Solaris™ or Linux	Directory into which you installed FlightGear
		Mac®	/Applications (folder to which you dragged the FlightGear icon)
GeometryModelName	Model geometry folder	Windows	C:\Program Files\-FlightGear\data\-Aircraft\HL20 (default)
		Solaris or Linux	$FlightGearBaseDirectory/-data/Aircraft/HL20
		Mac	$FlightGearBaseDirectory/-FlightGear.app/Contents/-Resources/data/Aircraft/HL20

Working with the Flight Simulator Interface

The Aerospace Toolbox product provides a demo named Displaying Flight Trajectory Data, which shows you how you can visualize flight trajectories with FlightGear Animation object. The demo is intended to be modified depending on the particulars of your FlightGear installation. This section explains how to run this demo. Use this demo as an example to play back your own 3-D flight data with FlightGear.

You need to have FlightGear installed and configured before attempting to simulate this model. See "About the FlightGear Interface" on page 2-48.

To run the demo:

1. Import the aircraft geometry into FlightGear.

2. Run the demo. The demo performs the following steps:

   a Loads recorded trajectory data
   b Creates a time series object from trajectory data
   c Creates a FlightGearAnimation object

3. Modify the animation object properties, if needed.
4. Create a run script for launching FlightGear flight simulator.
5. Start FlightGear flight simulator.
6. Play back the flight trajectory.

The following sections describe how to perform these steps in detail.

Importing the Aircraft Geometry into FlightGear. Before running the demo, copy the aircraft geometry model into FlightGear. From the following procedures, choose the one appropriate for your platform. This section assumes that you have read "Installing and Starting FlightGear" on page 2-52.

If your platform is Windows:

1. Go to your installed FlightGear folder. Open the `data` folder, then the `Aircraft` folder: *`FlightGear`*`\data\Aircraft\`.

2. You may already have an `HL20` subfolder there, if you have previously run the Aerospace Blockset NASA HL-20 with FlightGear Interface demo. In this case, you don't have to do anything, because the geometry model is the same.

   Otherwise, copy the `HL20` folder from the *`matlabroot`*`\toolbox\aero\aerodemos\` folder to the *`FlightGear`*`\data\Aircraft\` folder. This folder contains the preconfigured geometries for the HL-20 simulation and `HL20-set.xml`. The file *`matlabroot`*`\toolbox\aero\aerodemos\HL20\models\HL20.xml` defines the geometry.

If your platform is Solaris or Linux:

1. Go to your installed FlightGear folder. Open the `data` folder, then the `Aircraft` folder: *`$FlightGearBaseDirectory`*`/data/Aircraft/`.

2 You may already have an `HL20` subfolder there, if you have previously run the Aerospace Blockset NASA HL-20 with FlightGear Interface demo. In this case, you do not have to do anything, because the geometry model is the same.

   Otherwise, copy the `HL20` folder from the *`matlabroot`*`/toolbox/aero/aerodemos/` folder to the *`$FlightGearBaseDirectory`*`/data/Aircraft/` folder. This folder contains the preconfigured geometries for the HL-20 simulation and `HL20-set.xml`. The file *`matlabroot`*`/toolbox/aero/aerodemos/HL20/models/HL20.xml` defines the geometry.

If your platform is Mac:

1 Open a terminal.

2 List the contents of the Aircraft folder. For example, type

```
ls $FlightGearBaseDirectory/data/Aircraft/
```

3 You may already have an `HL20` subfolder there, if you have previously run the Aerospace Blockset NASA HL-20 with FlightGear Interface demo. In this case, you do not have to do anything, because the geometry model is the same. Continue to "Running the Demo" on page 2-27.

   Otherwise, copy the `HL20` folder from the

```
matlabroot/toolbox/aero/aerodemos/
```

   folder to the

```
$FlightGearBaseDirectory/FlightGear.app/Contents/Resources/data/Aircraft/
```

   folder. This folder contains the preconfigured geometries for the HL-20 simulation and `HL20-set.xml`. The file *`matlabroot`*`/toolbox/aero/aerodemos/HL20/models/HL20.xml` defines the geometry.

Running the Demo

1 Start the MATLAB software.

2 Run the demo either by entering `astfganim` in the MATLAB Command Window or by finding the demo entry (Displaying Flight Trajectory Data) in the MATLAB Online Help and clicking **Run in the Command Window** on its demo page.

   While running, the demo performs several steps by issuing a series of commands, as explained below.

Loading Recorded Flight Trajectory Data. The flight trajectory data for this example is stored in a comma separated value formatted file. Using `dlmread`, the data is read from the file starting at row 1 and column 0, which skips the header information.

```
tdata = dlmread('asthl20log.csv',',',1,0);
```

Creating a Time Series Object from Trajectory Data. The time series object, `ts`, is created from the latitude, longitude, altitude, and Euler angle data along with the time array in `tdata` using the MATLAB `timeseries` command. Latitude, longitude, and Euler angles are also converted from degrees to radians using the `convang` function.

```
ts = timeseries([convang(tdata(:,[3 2]),'deg','rad') ...
        tdata(:,4) convang(tdata(:,5:7),'deg','rad')],tdata(:,1));
```

Creating a FlightGearAnimation Object. This series of commands creates a FlightGearAnimation object:

1 Open a FlightGearAnimation object.

   ```
   h = fganimation;
   ```

2 Set FlightGearAnimation object properties for the time series.

   ```
   h.TimeseriesSourceType = 'Timeseries';
   h.TimeseriesSource = ts;
   ```

3 Set FlightGearAnimation object properties relating to FlightGear. These properties include the path to the installation folder, the version number, the aircraft geometry model, and network information for the FlightGear flight simulator.

   ```
   h.FlightGearBaseDirectory = 'C:\Program Files\FlightGear20';
   ```

```
h.FlightGearVersion = '2.0';
h.GeometryModelName = 'HL20';
h.DestinationIpAddress = '127.0.0.1';
h.DestinationPort = '5502';
```

4 Set the initial conditions (location and orientation) for the FlightGear flight simulator.

```
h.AirportId = 'KSFO';
h.RunwayId = '10L';
h.InitialAltitude = 7224;
h.InitialHeading = 113;
h.OffsetDistance = 4.72;
h.OffsetAzimuth = 0;
```

5 Setting the seconds of animation data per second of wall-clock time.

```
h.TimeScaling = 5;
```

6 Checking the FlightGearAnimation object properties and their values.

```
get(h)
```

At this point, the demo stops running and returns the FlightGearAnimation object, h:

```
        TimeseriesSource: [196x1 timeseries]
    TimeseriesSourceType: 'Timeseries'
       TimeseriesReadFcn: @TimeseriesRead
             TimeScaling: 5
         FramesPerSecond: 12
       FlightGearVersion: '2.0'
          OutputFileName: 'runfg.bat'
 FlightGearBaseDirectory: 'C:\Program Files\FlightGear20'
       GeometryModelName: 'HL20'
    DestinationIpAddress: '127.0.0.1'
         DestinationPort: '5502'
               AirportId: 'KSFO'
                RunwayId: '10L'
         InitialAltitude: 7224
          InitialHeading: 113
          OffsetDistance: 4.7200
```

```
                    OffsetAzimuth: 0
```

You can now set the object properties for data playback (see "Modifying the FlightGearAnimation Object Properties" on page 2-58).

Modifying the FlightGearAnimation Object Properties. Modify the FlightGearAnimation object properties as needed. If your FlightGear installation folder is other than that in the demo (for example, `FlightGear`), modify the `FlightGearBaseDirectory` property by issuing the following command:

```
h.FlightGearBaseDirectory = 'C:\Program Files\FlightGear';
```

Similarly, if you want to use a particular file name for the run script, modify the `OutputFileName` property.

Verify the FlightGearAnimation object properties:

```
get(h)
```

You can now generate the run script (see "Generating the Run Script" on page 2-58).

Generating the Run Script. To start FlightGear with the desired initial conditions (location, date, time, weather, operating modes), it is best to create a run script by using the `GenerateRunScript` command:

```
GenerateRunScript(h)
```

By default, `GenerateRunScript` saves the run script as a text file named `runfg.bat`. You can specify a different name by modifying the `OutputFileName` property of the FlightGearAnimation object, as described in the previous step.

This file does not need to be generated each time the data is viewed, only when the desired initial conditions or FlightGear information changes.

You are now ready to start FlightGear (see "Starting the FlightGear Flight Simulator" on page 2-59).

Installing Additional FlightGear Scenery. When you install the FlightGear software, the installation provides a basic level of scenery files. The FlightGear documentation thoroughly guides you through installing scenery as part the general FlightGear installation.

If you need to install more FlightGear scenery files, see the instructions at `http://www.flightgear.org`. Those instructions describe how to install the additional scenery in a default location. MathWorks recommends that you follow those instructions.

If you must install additional scenery in a non-standard location, try setting the `FG_SCENERY` environment variable in the script output from the `GenerateRunScript` function. See the documentation at `http://www.flightgear.org` for a description of the `FG_SCENERY` variable.

Note Each time you run the `GenerateRunScript` function, it creates a new script and overwrites any edits you have added.

Starting the FlightGear Flight Simulator. To start FlightGear from the MATLAB command prompt, use the `system` command to execute the run script. Provide the name of the output file created by GenerateRunScript as the argument:

```
system('runfg.bat &');
```

FlightGear starts in a separate window.

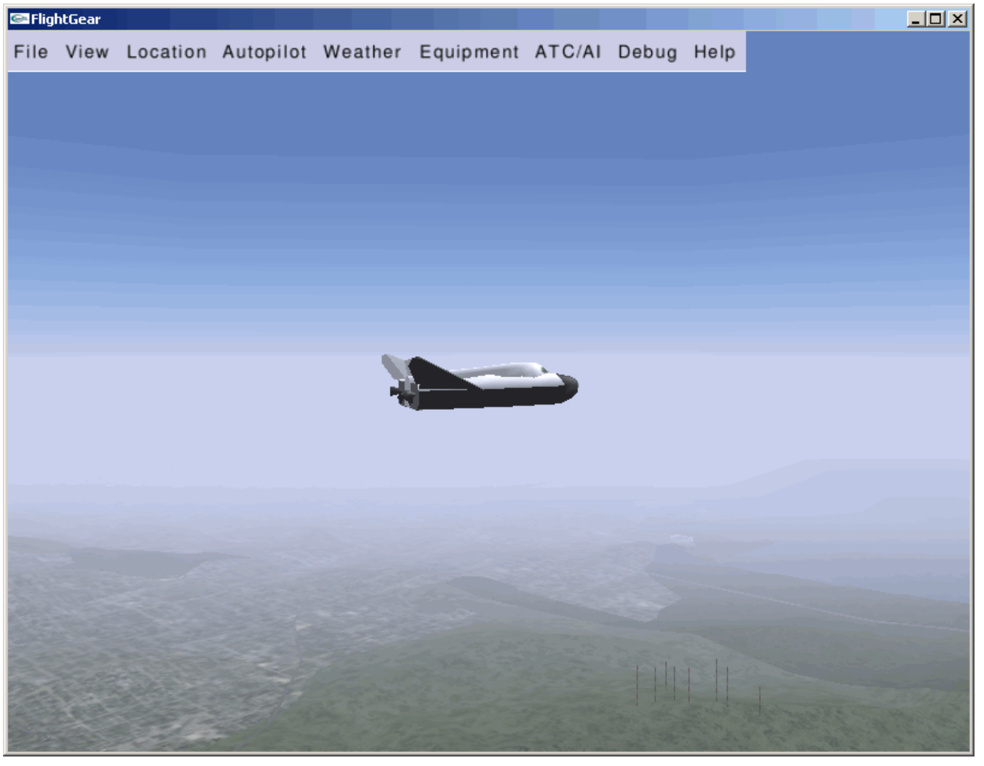
Tip With the FlightGear window in focus, press the **V** key to alternate between the different aircraft views: cockpit view, helicopter view, chase view, and so on.

You are now ready to play back data (see “Playing Back the Flight Trajectory” on page 2-60).

Playing Back the Flight Trajectory. Once FlightGear is running, the FlightGearAnimation object can start to communicate with FlightGear. To animate the flight trajectory data, use the play command:

```
play(h)
```

The following illustration shows a snapshot of flight data playback in tower view without yaw.



3

Function Reference

Animation Objects

addBody (Aero.Animation)	Add loaded body to animation object and generate its patches
Aero.Animation	Construct animation object
createBody (Aero.Animation)	Create body and its associated patches in animation
delete (Aero.Animation)	Destroy animation object
hide (Aero.Animation)	Hide animation figure
initialize (Aero.Animation)	Create animation object figure and axes and build patches for bodies
initIfNeeded (Aero.Animation)	Initialize animation graphics if needed
moveBody (Aero.Animation)	Move body in animation object
play (Aero.Animation)	Animate `Aero.Animation` object given position/angle time series
removeBody (Aero.Animation)	Remove one body from animation
show (Aero.Animation)	Show animation object figure
updateBodies (Aero.Animation)	Update bodies of animation object
updateCamera (Aero.Animation)	Update camera in animation object

Body Objects

Body (Aero.Body)	Construct body object for use with animation object
findstartstoptimes (Aero.Body)	Return start and stop times of time series data
generatePatches (Aero.Body)	Generate patches for body with loaded face, vertex, and color data
load (Aero.Body)	Get geometry data from source
move (Aero.Body)	Change animation body position and orientation
update (Aero.Body)	Change body position and orientation as function of time

Camera Objects

Camera (Aero.Camera)	Construct camera object for use with animation object
update (Aero.Camera)	Update camera position based on time and position of other Aero.Body objects

FlightGear Objects

ClearTimer (Aero.FlightGearAnimation)	Clear and delete timer for animation of FlightGear flight simulator
delete (Aero.FlightGearAnimation)	Destroy FlightGear animation object
fganimation (Aero.FlightGearAnimation)	Construct FlightGear animation object
GenerateRunScript (Aero.FlightGearAnimation)	Generate run script for FlightGear flight simulator
initialize (Aero.FlightGearAnimation)	Set up FlightGear animation object
play (Aero.FlightGearAnimation)	Animate FlightGear flight simulator using given position/angle time series
SetTimer (Aero.FlightGearAnimation)	Set name of timer for animation of FlightGear flight simulator
update (Aero.FlightGearAnimation)	Update position data to FlightGear animation object

Geometry Objects

Geometry (Aero.Geometry)	Construct 3-D geometry for use with animation object
read (Aero.Geometry)	Read geometry data using current reader

Node Objects

findstartstoptimes (Aero.Node)	Return start and stop times for time series data
move (Aero.Node)	Change node translation and rotation
Node (Aero.Node)	Create node object for use with virtual reality animation
update (Aero.Node)	Change node position and orientation versus time data

Viewpoint Objects

Viewpoint (Aero.Viewpoint)	Create viewpoint object for use in virtual reality animation

Virtual Reality Objects

addNode (Aero.VirtualRealityAnimation)	Add existing node to current virtual reality world
addRoute (Aero.VirtualRealityAnimation)	Add VRML ROUTE statement to virtual reality animation
addViewpoint (Aero.VirtualRealityAnimation)	Add viewpoint for virtual reality animation
delete (Aero.VirtualRealityAnimation)	Destroy virtual reality animation object
initialize (Aero.VirtualRealityAnimation)	Create and populate virtual reality animation object
nodeInfo (Aero.VirtualRealityAnimation)	Create list of nodes associated with virtual reality animation object
play (Aero.VirtualRealityAnimation)	Animate virtual reality world for given position and angle in time series data
removeNode (Aero.VirtualRealityAnimation)	Remove node from virtual reality animation object
removeViewpoint (Aero.VirtualRealityAnimation)	Remove viewpoint node from virtual reality animation
saveas (Aero.VirtualRealityAnimation)	Save virtual reality world associated with virtual reality animation object
updateNodes (Aero.VirtualRealityAnimation)	Change virtual reality animation node position and orientation as function of time
VirtualRealityAnimation (Aero.VirtualRealityAnimation)	Construct virtual reality animation object

Axes Transformations

angle2dcm	Create direction cosine matrix from rotation angles
angle2quat	Convert rotation angles to quaternion
dcm2alphabeta	Convert direction cosine matrix to angle of attack and sideslip angle
dcm2angle	Create rotation angles from direction cosine matrix
dcm2latlon	Convert direction cosine matrix to geodetic latitude and longitude
dcm2quat	Convert direction cosine matrix to quaternion
dcmbody2wind	Convert angle of attack and sideslip angle to direction cosine matrix
dcmecef2ned	Convert geodetic latitude and longitude to direction cosine matrix
ecef2lla	Convert Earth-centered Earth-fixed (ECEF) coordinates to geodetic coordinates
flat2lla	Estimate array of geodetic latitude, longitude, and altitude coordinates from flat Earth position
geoc2geod	Convert geocentric latitude to geodetic latitude
geod2geoc	Convert geodetic latitude to geocentric latitude
igrf11magm	Calculate Earth's magnetic field using 11th generation of International Geomagnetic Reference Field

lla2ecef	Convert geodetic coordinates to Earth-centered Earth-fixed (ECEF) coordinates
lla2flat	Estimate flat Earth position from geodetic latitude, longitude, and altitude
quat2angle	Convert quaternion to rotation angles
quat2dcm	Convert quaternion to direction cosine matrix

Environment

atmoscira	Use COSPAR International Reference Atmosphere 1986 model
atmoscoesa	Use 1976 COESA model
atmosisa	Use International Standard Atmosphere model
atmoslapse	Use Lapse Rate Atmosphere model
atmosnonstd	Use climatic data from MIL-STD-210 or MIL-HDBK-310
atmosnrlmsise00	Implement mathematical representation of 2001 United States Naval Research Laboratory Mass Spectrometer and Incoherent Scatter Radar Exosphere
atmospalt	Calculate pressure altitude based on ambient pressure
geoidegm96	Calculate geoid height as determined from EGM96 Geopotential Model
geoidheight	Calculate geoid height

gravitycentrifugal	Implement centrifugal effect of planetary gravity
gravitysphericalharmonic	Implement spherical harmonic representation of planetary gravity
gravitywgs84	Implement 1984 World Geodetic System (WGS84) representation of Earth's gravity
gravityzonal	Implement zonal harmonic representation of planetary gravity
wrldmagm	Use World Magnetic Model

File Reading

datcomimport	Bring DATCOM file into MATLAB environment

Flight Parameters

airspeed	Airspeed from velocity
alphabeta	Incidence and sideslip angles
dpressure	Compute dynamic pressure using velocity and density
geocradius	Estimate radius of ellipsoid planet at geocentric latitude
machnumber	Compute Mach number using velocity and speed of sound
rrdelta	Compute relative pressure ratio
rrsigma	Compute relative density ratio
rrtheta	Compute relative temperature ratio

Gas Dynamics

flowfanno	Fanno line flow relations
flowisentropic	Isentropic flow ratios
flownormalshock	Normal shock relations
flowprandtlmeyer	Calculate Prandtl-Meyer functions for expansion waves
flowrayleigh	Rayleigh line flow relations

Quaternion Math

quatconj	Calculate conjugate of quaternion
quatdivide	Divide quaternion by another quaternion
quatinv	Calculate inverse of quaternion
quatmod	Calculate modulus of quaternion
quatmultiply	Calculate product of two quaternions
quatnorm	Calculate norm of quaternion
quatnormalize	Normalize quaternion
quatrotate	Rotate vector by quaternion

Time

decyear	Calculate decimal year
juliandate	Calculate Julian date
leapyear	Determine leap year
mjuliandate	Calculate modified Julian date

Unit Conversion

convacc	Convert from acceleration units to desired acceleration units
convang	Convert from angle units to desired angle units
convangacc	Convert from angular acceleration units to desired angular acceleration units
convangvel	Convert from angular velocity units to desired angular velocity units
convdensity	Convert from density units to desired density units
convforce	Convert from force units to desired force units
convlength	Convert from length units to desired length units
convmass	Convert from mass units to desired mass units
convpres	Convert from pressure units to desired pressure units
convtemp	Convert from temperature units to desired temperature units
convvel	Convert from velocity units to desired velocity units

Alphabetical List

Aero.Animation.addBody

Purpose

Add loaded body to animation object and generate its patches

Syntax

```
idx = addBody(h,b)
idx = h.addBody(b)
```

Description

`idx = addBody(h,b)` and `idx = h.addBody(b)` add a loaded body, `b`, to the animation object `h` and generates its patches. `idx` is the index of the body to be added.

Input Arguments

`h`	Animation object.
`b`	Loaded body.

Output Arguments

`idx`	Index of the body to be added.

Examples

Add a second body to the list that is a pointer to the first body. This means that if you change the properties of one body, the properties of the other body change correspondingly.

```
h = Aero.Animation;
idx1 = h.createBody('pa24-250_orange.ac','Ac3d');
b = h.Bodies{1};
idx2 = h.addBody(b);
```

Purpose

Add existing node to current virtual reality world

Syntax

```
addNode(h, node_name, wrl_file)
h.addNode(node_name, wrl_file)
```

Description

`addNode(h, node_name, wrl_file)` and `h.addNode(node_name, wrl_file)` add an existing node, `node_name`, to the current virtual reality world. The `wrl_file` is the file from which the new node is taken. `addNode` adds a new node named `node_name`, which contains (or points to) the `wrl_file`. `node_name` must be unique from other node names in the same `.wrl` file. `wrl_file` must contain the node to be added. You must specify the full path for this file. The vrnode object associated with the node object must be defined using a `DEF` statement in the `.wrl` file. This method creates a node object on the world of type Transform.

When you use the `addNode` method to add a node, all the objects in the `.wrl` file will be added to the virtual reality animation object under one node. If you want to add separate nodes for the objects in the `.wrl` file, place each node in a separate `.wrl` file.

Examples

Add node to world defined in `chaseHelicopter.wrl`.

```
h = Aero.VirtualRealityAnimation;
h.VRWorldFilename = [matlabroot,'/toolbox/aero/astdemos/asttkoff.wrl'];
copyfile(h.VRWorldFilename,[tempdir,'asttkoff.wrl'],'f');
h.VRWorldFilename = [tempdir,'asttkoff.wrl'];
h.initialize();
h.addNode('Lynx',[matlabroot,'/toolbox/aero/astdemos/chaseHelicopter.wrl']);
```

See Also

`Aero.Node` | `move` | `removeNode` | `updateNodes` | `Aero.VirtualRealityAnimation`

addRoute (Aero.VirtualRealityAnimation)

Purpose

Add VRML ROUTE statement to virtual reality animation

Syntax

```
addRoute(h, nodeOut, eventOut, nodeIn, eventIn)
h.addNode(nodeOut, eventOut, nodeIn, eventIn)
```

Description

`addRoute(h, nodeOut, eventOut, nodeIn, eventIn)` and `h.addNode(nodeOut, eventOut, nodeIn, eventIn)` add a VRML ROUTE statement to the virtual reality animation, where `nodeOut` is the node from which information is routed, `eventOut` is the event (property), `nodeIn` is the node to which information is routed, and `eventIn` is the receiving event (property).

Examples

Add a ROUTE command to connect the Plane position to the Camera1 node.

```
h = Aero.VirtualRealityAnimation;
h.VRWorldFilename = [matlabroot,'/toolbox/aero/astdemos/asttkoff.wrl'];
copyfile(h.VRWorldFilename,[tempdir,'asttkoff.wrl'],'f');
h.VRWorldFilename = [tempdir,'asttkoff.wrl'];
h.initialize();
h.addNode('Lynx',[matlabroot,'/toolbox/aero/astdemos/chaseHelicopter.wrl']);
h.addRoute('Plane','translation','Camera1','translation');
```

See Also

`addViewpoint`

Purpose

Add viewpoint for virtual reality animation

Syntax

```
addViewpoint(h, parent_node, parent_field, node_name)
h.addViewpoint(parent_node, parent_field, node_name)
addViewpoint(h, parent_node, parent_field, node_name,
   description)
h.addViewpoint(parent_node, parent_field, node_name,
   description)
addViewpoint(h, parent_node, parent_field, node_name,
   description, position)
h.addViewpoint(parent_node, parent_field, node_name,
   description, position)
addViewpoint(h, parent_node, parent_field, node_name,
   description, position, orientation)
h.addViewpoint(parent_node, parent_field, node_name,
   description, position, orientation)
```

Description

`addViewpoint(h, parent_node, parent_field, node_name)` and `h.addViewpoint(parent_node, parent_field, node_name)` add a viewpoint named `node_name` whose `parent_node` is the parent node field of the vrnode object and whose `parent_field` is a valid parent field of the vrnode object to the virtual world animation object, `h`.

`addViewpoint(h, parent_node, parent_field, node_name, description)`and `h.addViewpoint(parent_node, parent_field, node_name, description)` add a viewpoint named `node_name` whose `parent_node` is the parent node field of the vrnode object and whose `parent_field` is a valid parent field of the vrnode object to the virtual world animation object, `h`. `description` is the string you want to describe the viewpoint.

`addViewpoint(h, parent_node, parent_field, node_name, description, position)` and `h.addViewpoint(parent_node, parent_field, node_name, description, position)` add a viewpoint named `node_name` whose `parent_node` is the parent node field of the vrnode object and whose `parent_field` is a valid parent field of the vrnode object to the virtual world animation object, `h`. `description` is the string you want to describe the viewpoint and position is the position of the viewpoint. Specify position using VRML coordinates (*x y z*).

addViewpoint(h, parent_node, parent_field, node_name, description, position, orientation) and h.addViewpoint(parent_node, parent_field, node_name, description, position, orientation) add a viewpoint named node_name whose parent_node is the parent node field of the vrnode object and whose parent_field is a valid parent field of the vrnode object to the virtual world animation object, h. description is the string you want to describe the viewpoint, position is the position of the viewpoint, and orientation is the orientation of the viewpoint. Specify position using VRML coordinates (*x y z*). Specify orientation in a VRML axes angle format (*x y z* Θ).

Note If you call addViewpoint with only the description argument, you must set the position and orientation of the viewpoint with the Simulink 3D Animation vrnode/setfield function. This requires you to use VRML coordinates.

Examples

Add a viewpoint named chaseView.

```
h = Aero.VirtualRealityAnimation;
h.VRWorldFilename = [matlabroot,'/toolbox/aero/astdemos/asttkoff.wrl'];
copyfile(h.VRWorldFilename,[tempdir,'asttkoff.wrl'],'f');
h.VRWorldFilename = [tempdir,'asttkoff.wrl'];
h.initialize();
h.addViewpoint(h.Nodes{2}.VRNode,'children','chaseView','View From Helicopter');
```

See Also

addRoute | removeViewpoint

Purpose

Visualize aerospace animation

Description

Use the Aero.Animation class to visualize flight data without any other tool or toolbox. You only need the Aerospace Toolbox to visualize this data.

Construction

Aero.Animation	Construct animation object

Methods

addBody	Add loaded body to animation object and generate its patches
createBody	Create body and its associated patches in animation
delete	Destroy animation object
hide	Hide animation figure
initialize	Create animation object figure and axes and build patches for bodies
initIfNeeded	Initialize animation graphics if needed
moveBody	Move body in animation object
play	Animate `Aero.Animation` object given position/angle time series
removeBody	Remove one body from animation
show	Show animation object figure
updateBodies	Update bodies of animation object
updateCamera	Update camera in animation object

Properties

Bodies	Specify name of animation object
Camera	Specify camera that animation object contains
Figure	Specify name of figure object
FigureCustomizationFcn	Specify figure customization function
FramesPerSecond	Animation rate
Name	Specify name of animation object
TCurrent	Current time
TFinal	End time
TimeScaling	Scaling time
TStart	Start time

See Also

`Aero.FlightGearAnimation` | `Aero.VirtualRealityAnimation`

How To

- “Using Aero.Animation Objects” on page 2-26

Purpose Construct animation object

Syntax

```
h = Aero.Animation
```

Description `h = Aero.Animation` constructs an animation object. The animation object is returned to `h`.

Note The `Aero.Animation` constructor does not retain the properties of previously created animation objects, even those that you have saved to a MAT-file. This means that subsequent calls to the animation object constructor always create animation objects with default properties.

Examples

```
h=Aero.Animation
```

Aero.Body

Purpose

Create body object for use with animation object

Syntax

```
h = Aero.Body
```

Description

`h = Aero.Body` constructs a body for an animation object. The animation object is returned in `h`. To use the Aero.Body object, you typically:

1. Create the animation body.
2. Configure or customize the body object.
3. Load the body.
4. Generate patches for the body (requires an axes from a figure).
5. Set time series data source.
6. Move or update the body.

By default, an Aero.Body object natively uses aircraft *x*-*y*-*z* coordinates for the body geometry and the time series data. It expects the rotation order *z*-*y*-*x* (psi, theta, phi).

Convert time series data from other coordinate systems on the fly by registering a different `CoordTransformFcn` function.

Constructor Summary

Constructor	Description
`Body`	Construct body object for use with animation object.

Method Summary

Method	Description
`findstartstoptimes`	Return start and stop times of time series data.
`generatePatches`	Generate patches for body with loaded face, vertex, and color data.
`load`	Get geometry data from source.
`move`	Change Aero.Body position and orientation.
`update`	Changes body position and orientation versus time data.

Property Summary

Property	Description	Values
`CoordTransformFcn`	Specify a function that controls the coordinate transformation.	string
`Name`	Specify name of body.	
`Position`	Specify position of body.	MATLAB array
`Rotation`	Specify rotation of body.	MATLAB array
`Geometry`	Specify geometry of body.	handle
`PatchGeneration-Fcn`	Specify patch generation function.	MATLAB array
`PatchHandles`	Specify patch handles.	MATLAB array
`ViewingTransform`	Specify viewing transform.	MATLAB array
`TimeseriesSource`	Specify time series source.	MATLAB array

Property	Description	Values
TimeseriesSource-Type	Specify the type of time series data stored in 'TimeseriesSource'. Five values are available. They are listed in the following table. The default value is 'Array6DoF'.	string
TimeseriesReadFcn	Specify time series read function.	MATLAB array

The time series data, stored in the property 'TimeseriesSource', is interpreted according to the 'TimeseriesSourceType' property, which can be one of:

'Timeseries'	MATLAB time series data with six values per time: lat lon alt phi theta psi The values are resampled.
'StructureWithTime'	Simulink struct with time (for example, Simulink root outport logging 'Structure with time'): • signals(1).values: lat lon alt • signals(2).values: phi theta psi Signals are linearly interpolated vs. time using interp1.

`'Array6DoF'`	A double-precision array in `n` rows and 7 columns for 6-DoF data: `time lat lon alt phi theta psi`. If a double-precision array of 8 or more columns is in `'TimeseriesSource'`, the first 7 columns are used as 6-DoF data.
`'Array3DoF'`	A double-precision array in `n` rows and 4 columns for 3-DoF data: `time lat alt theta`. If a double-precision array of 5 or more columns is in `'TimeseriesSource'`, the first 4 columns are used as 3-DoF data.
`'Custom'`	Position and angle data is retrieved from `'TimeseriesSource'` by the currently registered `'TimeseriesReadFcn'`.

See Also

`Aero.Geometry`

Aero.Camera

Purpose

Construct camera object for use with animation object

Syntax

```
h = Aero.Camera
```

Description

`h = Aero.Camera` constructs a camera object `h` for use with an animation object. The camera object uses the registered coordinate transform. By default, this is an aerospace body coordinate system. Axes of custom coordinate systems must be orthogonal.

By default, an `Aero.Body` object natively uses aircraft *x*-*y*-*z* coordinates for the body geometry and the time series data. Convert time series data from other coordinate systems on the fly by registering a different `CoordTransformFcn` function.

Constructor Summary

Constructor	Description
`Camera`	Construct camera object for use with animation object.

Method Summary

Method	Description
`update`	Update camera position based on time and position of other Aero.Body objects.

Property Summary

Property	Description	Values
`CoordTransformFcn`	Specify a function that controls the coordinate transformation.	MATLAB array
`PositionFcn`	Specify a function that controls the position of a camera relative to an animation body.	MATLAB array
`Position`	Specify position of camera.	MATLAB array `[-150,-50,0]`

Property	Description	Values
Offset	Specify offset of camera.	MATLAB array [-150,-50,0]
AimPoint	Specify aim point of camera.	MATLAB array [0,0,0]
UpVector	Specify up vector of camera.	MATLAB array [0,0,-1]
ViewAngle	Specify view angle of camera.	MATLAB array {3}
ViewExtent	Specify view extent of camera.	MATLAB array {[-50,50]}
xlim	Specify *x*-axis limit of camera.	MATLAB array {[-50,50]}
ylim	Specify *y*-axis limit of camera.	MATLAB array {[-50,50]}
zlim	Specify *z*-axis limit of camera.	MATLAB array {[-50,50]}
PrevTime	Specify previous time of camera.	MATLAB array {0}
UserData	Specify custom data.	MATLAB array {[]}

See Also

Aero.Geometry

Aero.FlightGearAnimation

Purpose

Construct FlightGear animation object

Syntax

```
h = Aero.FlightGearAnimation
```

Description

`h = Aero.FlightGearAnimation` constructs a FlightGear animation object. The FlightGear animation object is returned to `h`.

Constructor

Method	Description
`fganimation`	Construct FlightGear animation object.

Method Summary

Method	Description
`delete`	Destroy FlightGear animation object.
`initialize`	Set up FlightGear animation object.
`play`	Animate FlightGear flight simulator using given position/angle time series.
`update`	Update position data to FlightGear animation object.

Property Summary

Properties	Description
`TimeseriesSource`	Specify variable that contains the time series data.
`TimeseriesSource-Type`	Specify the type of time series data stored in `'TimeseriesSource'`. Five values are available. They are listed in the following table. The default value is `'Array6DoF'`.
`TimeseriesReadFcn`	Specify a function to read the time series data if `'TimeseriesSourceType'` is `'Custom'`.
`TimeScaling`	Specify the seconds of animation data per second of wall-clock time. The default ratio is `1`.

Properties	Description
FramesPerSecond	Specify the number of frames per second used to animate the 'TimeseriesSource'. The default value is 12 frames per second.
FlightGearVersion	Select your FlightGear software version: '0.9.3', '0.9.8', '0.9.9', '0.9.10', '1.0', '1.9.1', or '2.0'. The default version is '2.0'.
OutputFileName	Specify the name of the output file. The file name is the name of the command you will use to start FlightGear with these initial parameters. The default value is 'runfg.bat'.
FlightGearBase-Directory	Specify the name of your FlightGear installation folder. The default value is 'D:\Applications\FlightGear'.
GeometryModelName	Specify the name of the folder containing the desired model geometry in the *FlightGear*\data\Aircraft folder. The default value is 'HL20'.
DestinationIp-Address	Specify your destination IP address. The default value is '127.0.0.1'.
DestinationPort	Specify your network flight dynamics model (fdm) port. This destination port should be an unused port that you can use when you launch FlightGear. The default value is '5502'.
AirportId	Specify the airport ID. The list of supported airports is available in the FlightGear interface, under **Location**. The default value is 'KSFO'.
RunwayId	Specify the runway ID. The default value is '10L'.
InitialAltitude	Specify the initial altitude of the aircraft, in feet. The default value is 7224 feet.

Properties	Description
`InitialHeading`	Specify the initial heading of the aircraft, in degrees. The default value is `113` degrees.
`OffsetDistance`	Specify the offset distance of the aircraft from the airport, in miles. The default value is `4.72` miles.
`OffsetAzimuth`	Specify the offset azimuth of the aircraft, in degrees. The default value is `0` degrees.
`TStart`	Specify start time as a double.
`TFinal`	Specify end time as a double.

The time series data, stored in the property `'TimeseriesSource'`, is interpreted according to the `'TimeseriesSourceType'` property, which can be one of:

`'Timeseries'`	MATLAB time series data with six values per time: `lat lon alt phi theta psi` The values are resampled.
`'StructureWithTime'`	Simulink struct with time (for example, Simulink root outport logging `'Structure with time'`): • `signals(1).values: lat lon alt` • `signals(2).values: phi theta psi` Signals are linearly interpolated vs. time using `interp1`.

'Array6DoF'	A double-precision array in n rows and 7 columns for 6-DoF data: time lat lon alt phi theta psi. If a double-precision array of 8 or more columns is in 'TimeseriesSource', the first 7 columns are used as 6-DoF data.
'Array3DoF'	A double-precision array in n rows and 4 columns for 3-DoF data: time lat alt theta. If a double-precision array of 5 or more columns is in 'TimeseriesSource', the first 4 columns are used as 3-DoF data.
'Custom'	Position and angle data is retrieved from 'TimeseriesSource' by the currently registered 'TimeseriesReadFcn'.

Examples

Construct a FlightGear animation object, h:

```
h = fganimation
```

See Also

fganimation | generaterunscript | play

Aero.Geometry

Purpose

Construct 3-D geometry for use with animation object

Syntax

```
h = Aero.Geometry
```

Description

`h = Aero.Geometry` defines a 3-D geometry for use with an animation object.

This object supports the attachment of transparency data from an Ac3d file to patch generation.

Constructor Summary

Constructor	Description
`Geometry`	Construct 3-D geometry for use with animation object.

Method Summary

Method	Description
`read`	Read geometry data using current reader.

Property Summary

Property	Description	Values
`Name`	Specify name of geometry.	string
`Source`	Specify geometry data source.	string {[`'Auto'`], `'Variable'`, `'MatFile'`, `'Ac3dFile'`, `'Custom'`}
`Reader`	Specify geometry reader.	MATLAB array

Property	Description	Values	
FaceVertexColorData	Specify the color of the geometry face vertex.	MATLAB structure with the following fields	
		name	String that contains the name of the geometry being loaded.
		faces	See Faces on Patch Properties in the *MATLAB Function Reference*.
		vertices	See Vertices on Patch Properties in the *MATLAB Function Reference*.
		cdata	See CData on Patch Properties in the *MATLAB Function Reference*.
		alpha	See FaceVertexAlphaData on Patch Properties in the *MATLAB Function Reference*.

See Also

read

Aero.Node

Purpose

Create node object for use with virtual reality animation

Syntax

```
h = Aero.Node
```

Description

`h = Aero.Node` creates a node object for use with virtual reality animation. Typically, you do not need to create a node object with this method. This is because the `.wrl` file stores the information for a virtual reality scene. During the initialization of the virtual reality animation object, any node with a `DEF` statement in the specified `.wrl` file has a node object created.

Constructor Summary

Constructor	Description
`Node`	Create node object for use with virtual reality animation.

Method Summary

Method	Description
`findstart-stoptimes`	Return start and stop times for time series data.
`move`	Change node translation and rotation.
`update`	Change node position and orientation versus time data.

Property Summary

Property	Description	Values
`Name`	Specify name of the node object.	string
`VRNode`	Return the handle to the vrnode object associated with the node object (see the *Simulink 3D Animation User's Guide*).	MATLAB array
`CoordtransformFcn`	Specify a function that controls the coordinate transformation.	MATLAB array
`TimeseriesSource`	Specify time series source.	MATLAB array
`Timeseries-SourceType`	Specify the type of time series data stored in `'TimeseriesSource'`. Five values are available. They are listed in the following table. The default value is `'Array6DoF'`.	string
`Timeseries-ReadFcn`	Specify time series read function.	MATLAB array

The time series data, stored in the property `'TimeseriesSource'`, is interpreted according to the `'TimeseriesSourceType'` property, which can be one of:

`'Timeseries'`	MATLAB time series data with six values per time: `lat lon alt phi theta psi` The values are resampled.
`'StructureWithTime'`	Simulink struct with time (for example, Simulink root outport logging `'Structure with time'`): • `signals(1).values: lat lon alt` • `signals(2).values: phi theta psi` Signals are linearly interpolated vs. time using `interp1`.
`'Array6DoF'`	A double-precision array in `n` rows and 7 columns for 6-DoF data: `time lat lon alt phi theta psi`. If a double-precision array of 8 or more columns is in `'TimeseriesSource'`, the first 7 columns are used as 6-DoF data.
`'Array3DoF'`	A double-precision array in `n` rows and 4 columns for 3-DoF data: `time lat alt theta`. If a double-precision array of 5 or more columns is in `'TimeseriesSource'`, the first 4 columns are used as 3-DoF data.
`'Custom'`	Position and angle data is retrieved from `'TimeseriesSource'` by the currently registered `'TimeseriesReadFcn'`.

Purpose

Create viewpoint object for use in virtual reality animation

Syntax

```
h = Aero.Viewpoint
```

Description

`h = Aero.Viewpoint` creates a viewpoint object for use with virtual reality animation.

Constructor Summary

Constructor	Description
`Viewpoint`	Create node object for use with virtual reality animation.

Property Summary

Property	Description	Values
`Name`	Specify name of the node object.	string
`Node`	Specify node object that contains the viewpoint node.	MATLAB array

Aero.VirtualRealityAnimation

Purpose

Construct virtual reality animation object

Syntax

```
h = Aero.VirtualRealityAnimation
```

Description

`h = Aero.VirtualRealityAnimation` constructs a virtual reality animation object. The animation object is returned to `h`.

The animation object has the following methods and properties.

Constructor Summary

Constructor	Description
`VirtualReality-Animation`	Construct virtual reality animation object.

Method Summary

Method	Description
`addNode`	Add existing node to current virtual reality world.
`addRoute`	Add VRML ROUTE statement to virtual reality animation.
`addViewpoint`	Add viewpoint for virtual reality animation.
`delete`	Destroy virtual reality animation object.
`initialize`	Create and populate virtual reality animation object.
`nodeInfo`	Create list of nodes associated with virtual reality animation object.
`play`	Animate virtual reality world for given position and angle in time series data.
`removeNode`	Remove node from virtual reality animation object.
`removeViewpoint`	Remove viewpoint node from virtual reality animation.

Method	Description
saveas	Save virtual reality world associated with virtual reality animation object.
updateNodes	Set new translation and rotation of moveable items in virtual reality animation.

Notes on Aero.VirtualRealityAnimation Methods

Aero.VirtualRealityAnimation methods that change the current virtual reality world use a temporary `.wrl` file to manage those changes. These methods include:

- `addNode`
- `removeNode`
- `addViewpoint`
- `removeViewpoint`
- `addRoute`

Be aware of the following behavior:

- After the methods make the changes, they reinitialize the world, using the information stored in the temporary `.wrl` file.
- When you delete the virtual reality animation object, this action deletes the temporary file.
- Use the `saveas` method to save the temporary `.wrl` file.
- These methods do not affect user-created `.wrl` files.

Property Summary

Property	Description	Values
Name	Specify name of the animation object.	string
VRWorld	Returns the vrworld object associated with the animation object.	MATLAB array
VRWorldFilename	Specify the .wrl file for the vrworld.	string
VRWorld-OldFilename	Specify the old .wrl files for the vrworld.	MATLAB array
VRWorld-TempFilename	Specify the temporary .wrl file for the animation object.	string
VRFigure	Returns the vrfigure object associated with the animation object.	MATLAB array
Nodes	Specify the nodes that the animation object contains.	MATLAB array
Viewpoints	Specify the viewpoints that the animation object contains.	MATLAB array
TimeScaling	Specify the time scaling, in seconds.	double
Tstart	Specify the time, in seconds.	double
TFinal	Specify end time, in seconds.	double
TCurrent	Specify current time, in seconds.	double

Property	Description	Values
`FramesPerSecond`	Specify rate, in frames per second.	double
`ShowSaveWarning`	Specify save warning display setting.	double

airspeed

Purpose

Airspeed from velocity

Syntax

```
airspeed = airspeed(velocities)
```

Description

`airspeed = airspeed(`*`velocities`*`)` computes `m` airspeeds, `airspeed`, from an *m*-by-3 array of velocities, *`velocities`*.

Examples

Determine the airspeed for velocity one array:

```
as = airspeed([84.3905  33.7562  10.1269])

as =

   91.4538
```

Determine the airspeed for velocity for multiple arrays:

```
as = airspeed([50 20 6; 5 0.5 2])

as =

   54.1849
    5.4083
```

See Also

`alphabeta` | `correctairspeed` | `dpressure` | `machnumber`

Purpose

Incidence and sideslip angles

Syntax

`[incidence sideslip] = alphabeta(velocities)`

Description

`[incidence sideslip] = alphabeta(velocities)` computes *m* incidence and sideslip angles, *incidence* and *sideslip* , between the velocity vector and the body. *velocities* is an `m`-by-3 array of velocities in body axes. *incidence* and *sideslip* are in radians.

Examples

Determine the incidence and sideslip angles for velocity for one array:

```
[alpha beta] = alphabeta([84.3905  33.7562  10.1269])

alpha =

    0.1194


beta =

    0.3780
```

Determine the incidence and sideslip angles for velocity for two arrays:

```
[alpha beta] = alphabeta([50 20 6; 5 0.5 2])

alpha =

    0.1194
    0.3805

beta =

    0.3780
    0.0926
```

See Also

airspeed | machnumber

Purpose

Create direction cosine matrix from rotation angles

Syntax

```
dcm = angle2dcm(rotationAng1, rotationAng2, rotationAng3)
dcm = angle2dcm(rotationAng1, rotationAng2, rotationAng3,
   rotationSequence)
```

Description

dcm = angle2dcm(*rotationAng1*, *rotationAng2*, *rotationAng3*) calculates the direction cosine matrix given three sets of rotation angles.

dcm = angle2dcm(*rotationAng1*, *rotationAng2*, *rotationAng3*, *rotationSequence*) calculates the direction cosine matrix using a rotation sequence.

Input Arguments

`rotationAng1`

m-by-1 array of first rotation angles, in radians.

`rotationAng2`

m-by-1 array of second rotation angles, in radians.

`rotationAng3`

m-by-1 array of third rotation angles, in radians.

`rotationSequence`

String that defines rotation sequence. For example, the default `'ZYX'` represents a sequence where *rotationAng1* is *z*-axis rotation, *rotationAng2* is *y*-axis rotation, and *rotationAng3* is *x*-axis rotation.

```
'ZYX'
'ZYZ'
'ZXY'
'ZXZ'
'YXZ'
'YXY'
'YZX'
'YZY'
```

'XYZ'
'XZY'
'XYX'
'XZX'
'ZYX' (default)

Output Arguments

dcm

3-by-3-by-*m* matrix containing *m* direction cosine matrices.

Examples

Determine the direction cosine matrix from rotation angles:

```
yaw = 0.7854;
pitch = 0.1;
roll = 0;
dcm = angle2dcm( yaw, pitch, roll )

dcm =

    0.7036    0.7036   -0.0998
   -0.7071    0.7071         0
    0.0706    0.0706    0.9950
```

Determine the direction cosine matrix from rotation angles and rotation sequence:

```
yaw = [0.7854 0.5];
pitch = [0.1 0.3];
roll = [0 0.1];
dcm = angle2dcm( pitch, roll, yaw, 'YXZ' )

dcm(:,:,1) =

    0.7036    0.7071   -0.0706
   -0.7036    0.7071    0.0706
    0.0998         0    0.9950
```

```
dcm(:,:,2) =

    0.8525    0.4770   -0.2136
   -0.4321    0.8732    0.2254
    0.2940   -0.0998    0.9506
```

See Also

angle2quat | dcm2angle | dcm2quat | quat2dcm | quat2angle

angle2quat

Purpose Convert rotation angles to quaternion

Syntax

```
quaternion = angle2quat(rotationAng1,rotationAng2,
   rotationAng3)
quaternion = angle2quat(rotationAng1,rotationAng2,
   rotationAng3,rotationSequence)
```

Description

quaternion = `angle2quat(`*rotationAng1*,*rotationAng2*,*rotationAng3*`)` calculates the quaternion for three rotation angles.

quaternion = `angle2quat(`*rotationAng1*,*rotationAng2*,*rotationAng3*,*rotationSequence*`)` calculates the quaternion using a rotation sequence.

Input Arguments

`rotationAng1`

m-by-1 array of first rotation angles, in radians.

`rotationAng2`

m-by-1 array of second rotation angles, in radians.

`rotationAng3`

m-by-1 array of third rotation angles, in radians.

`rotationSequence`

String that defines rotation sequence. For example, the default `'ZYX'` represents a sequence where *rotationAng1* is z-axis rotation, *rotationAng2* is y-axis rotation, and *rotationAng3* is x-axis rotation.

```
'ZYX'
'ZYZ'
'ZXY'
'ZXZ'
'YXZ'
'YXY'
```

'YZX'
'YZY'
'XYZ'
'XZY'
'XYX'
'XZX'
'ZYX' (default)

Output Arguments

`quaternion`

m-by-4 matrix containing *m* quaternions. *quaternion* has its scalar number as the first column.

Examples

Determine the quaternion from rotation angles:

```
yaw = 0.7854;
pitch = 0.1;
roll = 0;
q = angle2quat(yaw, pitch, roll)
q =
    0.9227   -0.0191    0.0462    0.3822
```

Determine the quaternion from rotation angles and rotation sequence:

```
yaw = [0.7854 0.5];
pitch = [0.1 0.3];
roll = [0 0.1];
q = angle2quat(pitch, roll, yaw, 'YXZ')
q =
    0.9227    0.0191    0.0462    0.3822
    0.9587    0.0848    0.1324    0.2371
```

See Also

`angle2dcm` | `dcm2angle` | `dcm2quat` | `quat2angle` | `quat2dcm`

Purpose

Use 1976 COESA model

Syntax

`[T, a, P, Rho] = atmoscoesa(height, action)`

Description

Committee on Extension to the Standard Atmosphere has the acronym COESA. `[T, a, P, Rho] = atmoscoesa(height, action)` implements the mathematical representation of the 1976 COESA United States standard lower atmospheric values. These values are absolute temperature, pressure, density, and speed of sound for the input geopotential altitude.

Below the geopotential altitude of 0 m (0 feet) and above the geopotential altitude of 84,852 m (approximately 278,386 feet), the function extrapolates values. It extrapolates temperature values linearly and pressure values logarithmically.

Input Arguments

`height`

Array of *m*-by-1 geopotential heights, in meters.

`action`

String that defines action for out-of-range input. Specify one:

`'Error'`
`'Warning'` (default)
`'None'`

Output Arguments

`T`

Array of *m*-by-1 temperatures, in kelvin.

`a`

Array of *m*-by-1 speeds of sound, in meters per second. The function calculates speed of sound using a perfect gas relationship.

`P`

Array of *m*-by-1 pressures, in pascal.

`Rho`

Array of *m*-by-1 densities, in kilograms per meter cubed. The function calculates density using a perfect gas relationship.

Examples

Calculate the COESA model at 1000 m with warnings for out-of-range inputs:

```
[T, a, P, rho] = atmoscoesa(1000)

T =

  281.6500

a =

  336.4341

P =

  8.9875e+004

rho =

    1.1116
```

Calculate the COESA model at 1000, 11,000, and 20,000 m with errors for out-of-range inputs:

```
[T, a, P, rho] = atmoscoesa([1000 11000 20000], 'Error')

T =

  281.6500  216.6500  216.6500

a =

  336.4341  295.0696  295.0696
```

```
P =

  1.0e+004 *

    8.9875    2.2632    0.5475

rho =

    1.1116    0.3639    0.0880
```

References

U.S. Standard Atmosphere, 1976, U.S. Government Printing Office, Washington, D.C.

See Also

`atmoscira` | `atmosisa` | `atmoslapse` | `atmosnonstd` | `atmospalt`

Purpose

Use COSPAR International Reference Atmosphere 1986 model

Syntax

```
[T altitude zonalWind] = atmoscira(latitude, ctype, coord,
   mtype, month, action)
```

Description

`[T altitude zonalWind] = atmoscira(latitude, ctype, coord, mtype, month, action)` implements the mathematical representation of the Committee on Space Research (COSPAR) International Reference Atmosphere (CIRA) from 1986 model. The CIRA 1986 model provides a mean climatology. The mean climatology consists of temperature, zonal wind, and geopotential height or pressure. It encompasses nearly pole-to-pole coverage (80 degrees S to 80 degrees N) for 0 km to 120 km. This provision also encompasses the troposphere, middle atmosphere, and lower thermosphere. Use this mathematical representation as a function of pressure or geopotential height.

This function uses a corrected version of the CIRA data files provided by J. Barnett in July 1990 in ASCII format.

This function has the limitations of the CIRA 1986 model and limits the values for the CIRA 1986 model.

The CIRA 1986 model limits values to the regions of 80 degrees S to 80 degrees N on Earth. It also limits geopotential heights from 0 km to 120 km. In each monthly mean data set, the model omits values at 80 degrees S for 101,300 pascal or 0 m. It omits these values because these levels are within the Antarctic land mass. For zonal mean pressure in constant altitude coordinates, pressure data is not available below 20 km. Therefore, this value is the bottom level of the CIRA climatology.

Input Arguments

`latitude`

Array of *m* geopotential heights, in meters.

`ctype`

String that defines representation of coordinate type. Specify:

'Pressure'	Pressure in pascal
'GPHeight'	Geopotential height in meters

coord

Depending on the value of ctype, this argument specifies one of the following arrays:

m	Pressures in pascal
m	Geopotential height in meters

mtype

String that selects one of the following mean value types:

'Monthly' (default)	Monthly values.
'Annual'	Annual values. Valid when ctype has a value of 'Pressure'.

month

Scalar value that selects the month in which the model takes the mean values. This argument applies only when *mtype* has a value of 'Monthly'.

1 (default)	January
2	February
3	March
4	April
5	May
6	June
7	July

8	August
9	September
10	October
11	November
12	December

`action`

String that defines action for out-of-range input. Specify one:

`'Error'`
`'Warning'` (default)
`'None'`

Output Arguments

`T`

Array of temperatures:

If *m* is `'Monthly'`	Array of *m* temperatures, in kelvin
If *mtype* is `'Annual'`	Array of *m*-by-7 values: • Annual mean temperature in kelvin • Annual temperature cycle amplitude in kelvin • Annual temperature cycle phase in month of maximum • Semiannual temperature cycle amplitude in kelvin • Semiannual temperature cycle phase in month of maximum • Terannual temperature cycle amplitude in kelvin

- Terannual temperature cycle phase in month of maximum

`altitude`

If *mtype* is 'Monthly', an array of *m* geopotential heights or *m* air pressures:

If *ctype* is 'Pressure'	Array *m* geopotential heights
If *ctype* is 'GPHeight'	Array *m* air pressure

If *mtype* is 'Annual', an array of *m*-by-7 values for geopotential heights. The function defines this array only for the northern hemisphere (*latitude* is greater than 0).

- Annual mean geopotential heights in meters
- Annual geopotential heights cycle amplitude in meters
- Annual geopotential heights cycle phase in month of maximum
- Semiannual geopotential heights cycle amplitude in meters
- Semiannual geopotential heights cycle phase in month of maximum
- Terannual geopotential heights cycle amplitude in meters
- Terannual geopotential heights cycle phase in month of maximum

`zonalWind`

Array of zonal winds:

If *mtype* is 'Monthly'	Array in meters per second.
If *mtype* is 'Annual'	Array of *m*-by-7 values: • Annual mean zonal winds in meters per second • Annual zonal winds cycle amplitude in meters per second • Annual zonal winds cycle phase in month of maximum • Semiannual zonal winds cycle amplitude in meters per second • Semiannual zonal winds cycle phase in month of maximum • Terannual zonal winds cycle amplitude in meters per second • Terannual zonal winds cycle phase in month of maximum

Examples

Using the CIRA 1986 model at 45 degrees latitude and 101,300 pascal for January with out-of-range actions generating warnings, calculate the mean monthly values. Calculate values for temperature (T), geopotential height (*alt*), and zonal wind (*zwind*).

```
[T alt zwind] = atmoscira( 45, 'Pressure', 101300 )
T =
  280.6000
alt =
   -18
zwind =
    3.3000
```

Using the CIRA 1986 model at 45 degrees latitude and 20,000 m for October with out-of-range actions generating warnings, calculate the mean monthly values. Calculate values for temperature (`T`), pressure (*`pres`*), and zonal wind (*`zwind`*).

```
[T pres zwind] = atmoscira( 45, 'GPHeight', 20000, 'Monthly', 10)
T =
  215.8500
pres =
  5.5227e+003
zwind =
    9.5000
```

Use the CIRA 1986 model at 45 and –30 degrees latitude and 20,000 m for October with out-of-range actions generating errors. Calculate values for temperature (*`T`*), pressure (*`pres`*), and zonal wind (*`zwind`*).

```
[T pres zwind] = atmoscira( [45 -30], 'GPHeight', 20000, 10, 'error')
T =
  215.8500  213.9000
pres =
  1.0e+003 *
    5.5227    5.6550
zwind =
    9.5000    4.3000
```

For September, with out-of-range actions generating warnings, use the CIRA 1986 model at 45 degrees latitude and –30 degrees latitude. Also use the model at 2000 pascal and 101,300 pascal. Calculate mean monthly values for temperature (*`T`*), geopotential height (*`alt`*), and zonal wind (*`zwind`*).

```
[T alt zwind] = atmoscira( [45 -30], 'Pressure', [2000 101300], 9)
T =
  223.5395  290.9000
```

```
alt =
  1.0e+004 *
    2.6692    0.0058
zwind =
    0.6300   -1.1000
```

Using the CIRA 1986 model at 45 degrees latitude and 2000 pascal with out-of-range actions generating warnings, calculate annual values. Calculate values for temperature (*T*), geopotential height (`alt`), and zonal wind (`zwind`).

```
[T alt zwind] = atmoscira( 45, 'Pressure', 2000, 'Annual' )
T =
  221.9596    5.0998    6.5300    1.9499    1.3000    1.0499    1.3000
alt =
  1.0e+004 *
    2.6465    0.0417    0.0007    0.0087    0.0001    0.0015    0.0002
zwind =
    4.6099   14.7496    0.6000    1.6499    4.6000    0.5300    1.4000
```

References

Fleming, E. L., Chandra, S., Shoeberl, M. R., Barnett, J. J., *Monthly Mean Global Climatology of Temperature, Wind, Geopotential Height and Pressure for 0-120 k*m, NASA TM100697, February 1988

`http://modelweb.gsfc.nasa.gov/atmos/cospar1.html`

See Also

`atmoscoesa` | `atmosisa` | `atmoslapse` | `atmosnonstd` | `atmosnrlmsise00` | `atmospalt`

atmosisa

Purpose

Use International Standard Atmosphere model

Syntax

`[T, a, P, rho] = atmosisa(height)`

Description

`[T, a, P, rho] = atmosisa(height)` implements the mathematical representation of the International Standard Atmosphere values for ambient temperature, pressure, density, and speed of sound for the input geopotential altitude.

This function assumes that below the geopotential altitude of 0 km and above the geopotential altitude of the tropopause, temperature and pressure values are held.

Input Arguments

`height`

Array of *m*-by-1 geopotential heights, in meters.

Output Arguments

`T`

Array of *m* temperatures, in kelvin.

`a`

Array of *m* speeds of sound, in meters per second. The function calculates speed of sound using a perfect gas relationship.

`rho`

Array of *m* densities, in kilograms per meter cubed. The function calculates density using a perfect gas relationship.

`P`

Array of *m* pressures, in pascal.

Examples

Calculate the International Standard Atmosphere at 1000 m:

```
[T, a, P, rho] = atmosisa(1000)

T =
```

```
  281.6500

a =

  336.4341

P =

  8.9875e+004

rho =

    1.1116
```

Calculate the International Standard Atmosphere at 1000, 11,000, and 20,000 m:

```
[T, a, P, rho] = atmosisa([1000 11000 20000])

T =

  281.6500  216.6500  216.6500

a =

  336.4341  295.0696  295.0696

P =

  1.0e+004 *

    8.9875    2.2632    0.5475

rho =

    1.1116    0.3639    0.0880
```

References

U.S. Standard Atmosphere, 1976, U.S. Government Printing Office, Washington, D.C.

See Also

`atmoscira` | `atmoscoesa` | `atmoslapse` | `atmosnonstd` | `atmospalt`

Purpose

Use Lapse Rate Atmosphere model

Syntax

```
[T, a, P, rho] = atmoslapse(height, g, heatRatio,
   characteristicGasConstant, lapseRate, heightTroposphere,
   heightTropopause, density0, pressure0, temperature0)
```

Description

`[T, a, P, rho] = atmoslapse(height, g, heatRatio, characteristicGasConstant, lapseRate, heightTroposphere, heightTropopause, density0, pressure0, temperature0)` implements the mathematical representation of the lapse rate atmospheric equations for ambient temperature, pressure, density, and speed of sound for the input geopotential altitude. To customize this atmospheric model, specify the atmospheric properties in the function input.

The function holds temperature and pressure values below the geopotential altitude of 0 km and above the geopotential altitude of the tropopause.

Input Arguments

`height`

Array of *m*-by-1 geopotential heights, in meters.

`g`

Scalar of acceleration due to gravity, in meters per second squared.

`heatRatio`

Scalar of specific heat ratio.

`characteristicGasConstant`

Scalar of characteristic gas constant, in joule per kilogram-kelvin.

`lapseRate`

Scalar of lapse rate, in kelvin per meter.

`heightTroposphere`

Scalar of height of troposphere, in meters.

`heightTropopause`

Scalar of height of tropopause, in meters.

`density0`

Scalar of air density at mean sea level, in kilograms per meter cubed.

`pressure0`

Scalar of static pressure at mean sea level, in pascal.

`temperature0`

Scalar of absolute temperature at mean sea level, in kelvin.

Output Arguments

`T`

Array of *m*-by-1 temperatures, in kelvin.

`a`

Array of *m*-by-1 speeds of sound, in meters per second. The function calculates speed of sound using a perfect gas relationship.

`P`

Array of *m*-by-1 pressures, in pascal.

`rho`

Array of *m*-by-1 densities, in kilograms per meter cubed. The function calculates density using a perfect gas relationship.

Examples

Calculate the atmosphere at 1000 m with the International Standard Atmosphere input values:

```
[T, a, P, rho] = atmoslapse(1000, 9.80665, 1.4, 287.0531, 0.0065, ...
    11000, 20000, 1.225, 101325, 288.15 )

T =

  281.6500
```

```
a =

  336.4341

P =

  8.9875e+004

rho =

    1.1116
```

References

U.S. Standard Atmosphere, 1976, U.S. Government Printing Office, Washington, D.C.

See Also

atmoscira | atmoscoesa | atmosisa | atmosnonstd | atmospalt

atmosnonstd

Purpose

Use climatic data from MIL-STD-210 or MIL-HDBK-310

Syntax

```
[T, a, P, rho] = atmosnonstd(height, atmosphericType,
   extremeParameter, frequency, extremeAltitude, action,
   specification)
```

Description

`[T, a, P, rho] = atmosnonstd(height, atmosphericType, extremeParameter, frequency, extremeAltitude, action, specification)` implements a portion of the climatic data of the MIL-STD-210C or MIL-HDBK-310 worldwide air environment to 80 km geometric (or approximately 262,000 feet geometric). This implementation provides absolute temperature, pressure, density, and speed of sound for the input geopotential altitude.

This function holds all values below the geometric altitude of 0 m (0 feet) and above the geometric altitude of 80,000 m (approximately 262,000 feet). The envelope atmospheric model has exceptions where values are held below the geometric altitude of 1 km (approximately 3281 feet). It also has exceptions above the geometric altitude of 30,000 m (approximately 98,425 feet). These exceptions are due to lack of data in MIL-STD-210 or MIL-HDBK-310 for these conditions.

In general, this function interpolates temperature values linearly and density values logarithmically. It calculates pressure and speed of sound using a perfect gas relationship. The envelope atmospheric model has exceptions where the extreme value is the only value provided as an output. In these cases, the function interpolates pressure logarithmically. These envelope atmospheric model exceptions apply to all cases of high and low pressure, high and low temperature, and high and low density. These exceptions exclude the extreme values and 1% frequency of occurrence. These exceptions are due to lack of data in MIL-STD-210 or MIL-HDBK-310 for these conditions.

A limitation is that MIL-STD-210 and MIL-HDBK-310 exclude from consideration climatic data for the region south of 60 degrees S latitude.

This function uses the metric version of data from the MIL-STD-210 or MIL-HDBK-310 specifications. A limitation is some inconsistent data between the metric and English data. Locations where these inconsistencies occur are within the envelope data for low density, low temperature, high temperature, low pressure, and high pressure. The most noticeable differences occur in the following values:

- For low density envelope data with 5% frequency, the density values in metric units are inconsistent at 4 km and 18 km. In addition, the density values in English units are inconsistent at 14 km.
- For low density envelope data with 10% frequency, the density values in metric units are inconsistent at 18 km. In addition, the density values in English units are inconsistent at 14 km.
- For low density envelope data with 20% frequency, the density values in English units are inconsistent at 14 km.
- For high-pressure envelope data with 10% frequency, the pressure values at 8 km are inconsistent.

Input Arguments

`height`

Array of *m*-by-1 geopotential heights, in meters.

`atmosphericType`

String selecting the representation of `'Profile'` or `'Envelope'` for the atmospheric data:

`'Profile'`	Is the realistic atmospheric profiles associated with extremes at specified altitudes. Use `'Profile'` for simulation of vehicles vertically traversing the atmosphere, or when you need the total influence of the atmosphere.
`'Envelope'`	Uses extreme atmospheric values at each altitude. Use `'Envelope'` for vehicles traversing the atmosphere horizontally, without much change in altitude.

`extremeParameter`

String selecting the atmospheric parameter that is the extreme value. Atmospheric parameters that you can specify are:

- 'High temperature'
- 'Low temperature'
- 'High density'
- 'Low density'
- 'High pressure', available only if *atmosphericType* is 'Envelope'
- 'Low pressure', available only if *atmosphericType* is 'Envelope'

frequency

String selecting percent of time that extreme values would occur. When using *atmosphericType* of 'Envelope' and *frequency* of '5%', '10%', and '20%', only the *extreme** parameter that you specify (temperature, density, or pressure) has a valid output. All other parameter outputs are zero.

- 'Extreme values', available only if *atmosphericType* is 'Envelope'
- '1%'
- '5%', available only if *atmosphericType* is 'Envelope'
- '10%
- '20%', available only if *atmosphericType* is 'Envelope'

extremeAltitude

Scalar value, in kilometers, selecting geometric altitude at which the extreme values occur. *extremeAltitude* applies only when *atmosphericType* is 'Profile'.

5	16404 ft
10	32808 ft
20	65617 ft

30	98425 ft
40	131234 ft

`action`

String that defines action for out-of-range input:

`'Error'`
`'Warning'` (default)
`'None'`

`specification`

String specifying the atmosphere model:

'210c'	MIL-STD-210C
'310'	MIL-HDBK-310 (default)

Output Arguments

`T`

Array of *m*-by-1 temperatures, in kelvin. This function interpolates temperature values linearly.

`a`

Array of *m*-by-1 speeds of sound, in meters per second. This function calculates speed of sound using a perfect gas relationship.

`P`

Array of *m*-by-1 pressures, in pascal. This function calculates pressure using a perfect gas relationship.

`rho`

Array of *m*-by-1 densities, in kilograms per meter cubed. This function interpolates density values logarithmically.

Examples

Calculate the nonstandard atmosphere profile. Use high density occurring 1% of the time at 5 km from MIL-HDBK-310 at 1000 m with warnings for out-of-range inputs:

```
[T, a, P, rho] = atmosnonstd( 1000,'Profile','High density','1%',5 )

T =

  248.1455

a =

  315.7900

P =

  8.9893e+004

rho =

    1.2620
```

Calculate the nonstandard atmosphere envelope with high pressure. Assume that high pressure occurs 20% of the time from MIL-STD-210C at 1000, 11,000, and 20,000 m with errors for out-of-range inputs:

```
[T, a, P, rho] = atmosnonstd([1000 11000 20000],'Envelope', ...
                              'High pressure','20%','Error','210c' )

T =

  0     0     0

a =

  0     0     0
```

```
P =

  1.0e+004 *
    9.1598    2.5309    0.6129

rho =

    0     0     0
```

References

Global Climatic Data for Developing Military Products (MIL-STD-210C), 9 January 1987, Department of Defense, Washington, D.C.

Global Climatic Data for Developing Military Products (MIL-HDBK-310), 23 June 1997, Department of Defense, Washington, D.C.

See Also

`atmoscira` | `atmoscoesa` | `atmosisa` | `atmoslapse` | `atmospalt`

atmosnrlmsise00

Purpose

Implement mathematical representation of 2001 United States Naval Research Laboratory Mass Spectrometer and Incoherent Scatter Radar Exosphere

Syntax

```
[T rho] = atmosnrlmsise00(altitude, latitude, longitude,
   year, dayOfYear, UTseconds)
[T rho] = atmosnrlmsise00(altitude, latitude, longitude,
   year, dayOfYear, UTseconds, localApparentSolarTime)
[T rho] = atmosnrlmsise00(altitude, latitude, longitude,
   year, dayOfYear, UTseconds, f107Average, f107Daily,
   magneticIndex)
[T rho] = atmosnrlmsise00(altitude, latitude, longitude,
   year, dayOfYear, UTseconds, flags)
[T rho] = atmosnrlmsise00(altitude, latitude, longitude,
   year, dayOfYear, UTseconds, otype)
[T rho] = atmosnrlmsise00(altitude, latitude, longitude,
   year, dayOfYear, UTseconds, action)
```

Description

`[T rho] = atmosnrlmsise00(altitude, latitude, longitude, year, dayOfYear, UTseconds)` implements the mathematical representation of the 2001 United States Naval Research Laboratory Mass Spectrometer and Incoherent Scatter Radar Exosphere (NRLMSISE-00). NRLMSISE-00 calculates the neutral atmosphere empirical model from the surface to lower exosphere (0 m to 1,000,000 m). Optionally, it performs this calculation including contributions from anomalous oxygen that can affect satellite drag above 500,000 m.

`[T rho] = atmosnrlmsise00(altitude, latitude, longitude, year, dayOfYear, UTseconds, localApparentSolarTime)` specifies an array of `m` local apparent solar time (hours).

`[T rho] = atmosnrlmsise00(altitude, latitude, longitude, year, dayOfYear, UTseconds, f107Average, f107Daily, magneticIndex)` specifies arrays of *m* 81 day average of F10.7 flux (centered on `doy`), *m*-by-1 daily F10.7 flux for previous day, and `m`-by-7 of magnetic index information.

[*T rho*] = atmosnrlmsise00(*altitude*, *latitude*, *longitude*, *year*, *dayOfYear*, *UTseconds*, *flags*) specifies an array of 23 to enable or disable particular variations for the outputs.

[*T rho*] = atmosnrlmsise00(*altitude*, *latitude*, longitude, *year*, *dayOfYear*, *UTseconds*, *otype*) specifies a string for total mass density output.

[*T rho*] = atmosnrlmsise00(*altitude*, *latitude*, *longitude*, *year*, *dayOfYear*, *UTseconds*, *action*) specifies out-of-range input action.

This function has the limitations of the NRLMSISE-00 model. For more information, see the NRLMSISE-00 model documentation.

The NRLMSISE-00 model uses *UTseconds*, *localApparentSolarTime*, and *longitude* independently. These arguments are not of equal importance for every situation. For the most physically realistic calculation, choose these three variables to be consistent by default:

```
localApparentSolarTime = UTseconds/3600 + longitude/15
```

If available, you can include departures from this equation for *localApparentSolarTime*, but they are of minor importance.

Input Arguments

action

String that defines action for out-of-range input. Specify one:

'Error'
'Warning' (default)
'None'

altitude

Array of *m*-by-1 altitudes, in meters.

dayOfYear

Array *m*-by-1 day of year.

f107Average

Array of *m*-by-1 81 day average of F10.7 flux (centered on day of year (*dayOfYear*)). If you specify*f107Average*, you must also specify *f107Daily* and *magneticIndex*. The effects of *f107Average* are not large or established below 80,000 m; therefore, the default value is 150.

These *f107Average* values correspond to the 10.7 cm radio flux at the actual distance of the Earth from the Sun. The *f107Average* values do not correspond to the radio flux at 1 AU. The following site provides both classes of values: `ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SOLAR_RADIO/FLUX/`

See the limitations in "Description" on page 4-60 for more information.

`f107Daily`

Array of *m*-by-1 daily F10.7 flux for previous day. If you specify *f107Daily*, you must also specify *f107Average* and *magneticIndex*. The effects of *f107Daily* are not large or established below 80,000 m; therefore, the default value is 150.

These *f107Daily* values correspond to the 10.7 cm radio flux at the actual distance of the Earth from the Sun. The *f107Daily* values do not correspond to the radio flux at 1 AU. The following site provides both classes of values: `ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SOLAR_RADIO/FLUX/`

See the limitations in "Description" on page 4-60 for more information.

`flags`

Array of 23 to enable or disable particular variations for the outputs. If *flags* array length, *m*, is 23 and you have not specified all available inputs, this function assumes that *flags* is set.

The flags, associated with the *flags* input, enable or disable particular variations for the outputs:

Field	Description
Flags(1)	F10.7 effect on mean
Flags(2)	Independent of time
Flags(3)	Symmetrical annual
Flags(4)	Symmetrical semiannual
Flags(5)	Asymmetrical annual
Flags(6)	Asymmetrical semiannual
Flags(7)	Diurnal
Flags(8)	Semidiurnal
Flags(9)	Daily AP. If you set this field to -1, the block uses the entire matrix of magnetic index information (APH) instead of APH(:,1).
Flags(10)	All UT, longitudinal effects
Flags(11)	Longitudinal
Flags(12)	UT and mixed UT, longitudinal
Flags(13)	Mixed AP, UT, longitudinal
Flags(14)	Terdiurnal
Flags(15)	Departures from diffusive equilibrium
Flags(16)	All exospheric temperature variations
Flags(17)	All variations from 120,000 meter temperature (TLB)
Flags(18)	All lower thermosphere (TN1) temperature variations
Flags(19)	All 120,000 meter gradient (S) variations
Flags(20)	All upper stratosphere (TN2) temperature variations
Flags(21)	All variations from 120,000 meter values (ZLB)

Field	Description
`Flags(22)`	All lower mesosphere temperature (TN3) variations
`Flags(23)`	Turbopause scale height variations

`latitude`

Array of *m*-by-1 geodetic latitudes, in meters.

`longitude`

Array of *m*-by-1 longitudes, in degrees.

`localApparentSolarTime`

Array of *m*-by-1 local apparent solar time (hours). To obtain a physically realistic value, the function sets *`localApparentSolarTime`* to (`sec/3600 + lon/15`) by default. See "Description" on page 4-60 for more information.

`magneticIndex`

An array of *m*-by-7 of magnetic index information. If you specify *`magneticIndex`*, you must also specify *`f107Average`* and *`f107Daily`*. This information consists of:

Daily magnetic index (AP)
3 hour AP for current time
3 hour AP for 3 hours before current time
3 hour AP for 6 hours before current time
3 hour AP for 9 hours before current time
Average of eight 3 hour AP indices from 12 to 33 hours before current time
Average of eight 3 hour AP indices from 36 to 57 hours before current time

The effects of daily magnetic index are not large or established below 80,000 m. As a result, the function sets the default value to 4. See the limitations in "Description" on page 4-60 for more information.

`otype`

String for total mass density output:

`` `Oxygen' ``	Total mass density outputs include anomalous oxygen number density.
`` `NoOxygen' ``	Total mass density outputs do not include anomalous oxygen number density.

`UTseconds`

Array of *m*-by-1 seconds in day in universal time (UT)

`year`

This function ignores the value of *year*.

Output Arguments

`T`

Array of *N*-by-2 values of temperature, in kelvin. The first column is exospheric temperature, in kelvin. The second column is temperature at altitude, in kelvin.

`rho`

An array of *N*-by-9 values of densities (kg/m^3 or $1/m^3$) in selected density units. The column order is:

Density of He, in $1/m^3$
Density of O, in $1/m^3$
Density of N2, in $1/m^3$
Density of O2, in $1/m^3$
Density of Ar, in $1/m^3$
Total mass density, in $1/kg^3$
Density of H, in $1/m^3$
Density of N, in $1/m^3$
Anomalous oxygen number density, in $1/m^3$

`density(6)`, total mass density, is the sum of the mass densities of He, O, N2, O2, Ar, H, and N. Optionally, `density(6)` can include the mass density of anomalous oxygen making `density(6)`, the effective total mass density for drag.

Examples

Calculate the temperatures, densities not including anomalous oxygen using the NRLMSISE-00 model at 10,000 m, 45 degrees latitude, -50 degrees longitude. This calculation uses the date January 4, 2007 at 0 UT. It uses default values for flux, magnetic index data, and local solar time with out-of-range actions generating warnings:

```
[T rho] = atmosnrlmsise00( 10000, 45, -50, 2007, 4, 0)

T =

  281.6500  216.6500  216.6500

a =

  336.4341  295.0696  295.0696

P =

  1.0e+004 *

    8.9875    2.2632    0.5475

rho =

    1.1116    0.3639    0.0880

>> [T rho] = atmosnrlmsise00( 10000, 45, -50, 2007, 4, 0)

T =

  1.0e+003 *

    1.0273    0.2212
```

```
rho =

  1.0e+024 *

    0.0000   0    6.6824    1.7927    0.0799    0.0000     0     0     0
```

Calculate the temperatures, densities not including anomalous oxygen using the NRLMSISE-00 model. Use the model at 10,000 m, 45 degrees latitude, –50 degrees longitude and 25,000 m, 47 degrees latitude, –55 degrees longitude.

This calculation uses the date January 4, 2007 at 0 UT. It uses default values for flux, magnetic index data, and local solar time with out-of-range actions generating warnings:

```
[T rho] = atmosnrlmsise00( [10000; 25000], [45; 47], ...
[-50; -55], [2007; 2007], [4; 4], [0; 0])

[-50; -55], [2007; 2007], [4; 4], [0; 0])

T =

  1.0e+003 *

    1.0273    0.2212
    1.0273    0.2116


rho =

  1.0e+024 *

    0.0000      0    6.6824    1.7927    0.0799    0.0000      0      0      0
    0.0000      0    0.6347    0.1703    0.0076    0.0000      0      0      0
```

Calculate the temperatures, densities including anomalous oxygen using the NRLMSISE-00 model at 10,000 m, 45 degrees latitude, –50 degrees longitude. This calculation uses the date January 4, 2007 at 0 UT. It uses default values for flux, magnetic index data, and local solar time with out-of-range actions generating errors:

```
[T rho] = atmosnrlmsise00( 10000, 45, -50, 2007, ...
4, 0, 'Oxygen', 'Error')

T =

  1.0e+003 *

    1.0273    0.2212


rho =

  1.0e+024 *

    0.0000         0    6.6824    1.7927    0.0799    0.0000         0         0         0
```

Calculate the temperatures, densities including anomalous oxygen using the NRLMSISE-00 model at 100,000 m, 45 degrees latitude, –50 degrees longitude. This calculation uses the date January 4, 2007 at 0 UT. It uses defined values for flux, and magnetic index data, and default local solar time. It specifies that the out-of-range action is to generate no message:

```
aph = [17.375 15 20 15 27 (32+22+15+22+9+18+12+15)/8 (39+27+9+32+39+9+7+12)/8]
f107 = 87.7
nov_6days  = [ 78.6 78.2 82.4 85.5 85.0 84.1]
dec_31daymean = 84.5
jan_31daymean = 83.5
feb_13days = [ 89.9 90.3 87.3 83.7 83.0 81.9 82.0 78.4 76.7 75.9 74.7 73.6 72.7]
f107a = (sum(nov_6days) + sum(feb_13days) + (dec_31daymean + jan_31daymean)*31)/81
```

```
flags = ones(1,23)
flags(9) = -1
[T rho] = atmosnrlmsise00( 100000, 45, -50, 2007, 4, 0, f107a, f107, ...
aph, flags, 'Oxygen', 'None')
aph =

   17.3750   15.0000   20.0000   15.0000   27.0000   18.1250   21.7500


f107 =

   87.7000


nov_6days =

   78.6000   78.2000   82.4000   85.5000   85.0000   84.1000


dec_31daymean =

   84.5000


jan_31daymean =

   83.5000


feb_13days =

  Columns 1 through 10

   89.9000 90.3000 87.3000 83.7000 83.0000 81.9000 82.0000 78.4000 76.7000 75.9000

  Columns 11 through 13
```

```
   74.7000   73.6000   72.7000


f107a =

   83.3568


flags =

  Columns 1 through 17

     1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1

  Columns 18 through 23

     1   1   1   1   1   1


flags =

  Columns 1 through 17

     1   1   1   1   1   1   1   1  -1   1   1   1   1   1   1   1   1

  Columns 18 through 23

     1   1   1   1   1   1


T =

  1.0e+003 *

    1.0273    0.1917
```

```
rho =

  1.0e+018 *

    0.0001  0.4241  7.8432  1.9721  0.0808  0.0000  0.0000  0.0000  0.0000
```

References

http://ccmc.gsfc.nasa.gov/modelweb/atmos/nrlmsise00.html

See Also

atmoscira

atmospalt

Purpose

Calculate pressure altitude based on ambient pressure

Syntax

`pressureAltitude = atmospalt(pressure, action)`

Description

`pressureAltitude = atmospalt(pressure, action)` computes the pressure altitude based on ambient pressure. Pressure altitude is the altitude with specified ambient pressure in the 1976 Committee on Extension to the Standard Atmosphere (COESA) United States standard. Pressure altitude is the same as the mean sea level (MSL) altitude.

This function extrapolates altitude values logarithmically below the pressure of 0.3961 Pa (approximately 0.00006 psi) and above the pressure of 101,325 Pa (approximately 14.7 psi).

This function assumes that air is dry and an ideal gas.

Input Arguments

`pressure`

Array of *m*-by-1 ambient pressures, in pascal.

`action`

String that defines action for out-of-range input. Specify one:

`'Error'`
`'Warning'` (default)
`'None'`

Output Arguments

`pressureAltitude`

Array of *m*-by-1 pressure altitudes or MSL altitudes, in meters.

Examples

Calculate the pressure altitude at a static pressure of 101,325 Pa with warnings for out-of-range inputs:

```
h = atmospalt(101325)


h =
```

```
     0
```

Calculate the pressure altitude at static pressures of 101,325 Pa and 26,436 Pa with errors for out-of-range inputs:

```
h = atmospalt([101325 26436], 'Error' )


h =

   1.0e+004 *

         0    1.0000
```

References

U.S. Standard Atmosphere, 1976, U.S. Government Printing Office, Washington, D.C.

See Also

`atmoscira` | `atmoscoesa` | `atmosisa` | `atmoslapse` | `atmosnonstd`

Body (Aero.Body)

Purpose

Construct body object for use with animation object

Syntax

`h = Aero.Body`

Description

`h = Aero.Body` constructs a body for an animation object. The animation object is returned in `h`. To use the Aero.Body object, you typically:

1. Create the animation body.
2. Configure or customize the body object.
3. Load the body.
4. Generate patches for the body (requires an axes from a figure).
5. Set the source for the time series data.
6. Move or update the body.

The animation object has the following properties:

By default, an `Aero.Body` object natively uses aerospace body coordinates for the body geometry and the time series data. Convert time series data from other coordinate systems on the fly by registering a different `CoordTransformFcn` function.

See `Aero.Body` for further details.

See Also

`Aero.Body`

Purpose

Construct camera object for use with animation object

Syntax

`h = Aero.Camera`

Description

`h = Aero.Camera` constructs a camera object `h` for use with an animation object. The camera object uses the registered coordinate transform. By default, this is an aerospace body coordinate system. Axes of custom coordinate systems must be orthogonal.

The animation object has the following properties:

By default, an `Aero.Body` object natively uses aerospace body coordinates for the body geometry and the time series data. Convert time series data from other coordinate systems on the fly by registering a different `CoordTransformFcn` function.

See `Aero.Camera` for further details.

See Also

`Aero.Camera`

ClearTimer (Aero.FlightGearAnimation)

Purpose

Clear and delete timer for animation of FlightGear flight simulator

Syntax

```
ClearTimer(h)
h.ClearTimer
```

Description

`ClearTimer(h)` and `h.ClearTimer` clear and delete the MATLAB timer for the animation of the FlightGear flight simulator.

Examples

Clear and delete the MATLAB timer for animation of the FlightGear animation object, `h`:

```
h = Aero.FlightGearAnimation
h.SetTimer
h.ClearTimer
h.SetTimer('FGTimer')
```

See Also

`SetTimer`

Purpose

Convert from acceleration units to desired acceleration units

Syntax

```
convertedValues = convacc(valuesToConvert, inputAccelUnits,
   outputAccelUnits)
```

Description

`convertedValues = convacc(valuesToConvert, inputAccelUnits, outputAccelUnits)` computes the conversion factor from specified input acceleration units to specified output acceleration units. It then applies the conversion factor to the input to produce the output in the desired units.

Input Arguments

`valuesToConvert`

Floating-point array of size *m*-by-*n* values that the function is to convert. All values must have the same unit conversions from *inputAccelUnits* to *outputAccelUnits*.

`inputAccelUnits`

Specified input acceleration units, as strings. Supported unit strings are:

'ft/s^2'	Feet per second squared
'm/s^2'	Meters per second squared
'km/s^2'	Kilometers per second squared
'in/s^2'	Inches per second squared
'km/h-s'	Kilometers per hour per second
'mph/s'	Miles per hour per second
'G''s'	g-units

`outputAccelUnits`

Specified output acceleration units, as strings. Supported unit strings are:

'ft/s^2'	Feet per second squared
'm/s^2'	Meters per second squared
'km/s^2'	Kilometers per second squared
'in/s^2'	Inches per second squared
'km/h-s'	Kilometers per hour per second
'mph/s'	Miles per hour per second
'G''s'	g-units

Output Arguments

`convertedValues`

Floating-point array of size *m*-by-*n* values that the function has converted.

Examples

Convert three accelerations from feet per second squared to meters per second squared:

```
a = convacc([3 10 20],'ft/s^2','m/s^2')

a =

    0.9144    3.0480    6.0960
```

See Also

`convang` | `convangacc` | `convangvel` | `convdensity` | `convforce` | `convlength` | `convmass` | `convpres` | `convtemp` | `convvel`

Purpose

Convert from angle units to desired angle units

Syntax

```
convertedValues = convang(valuesToConvert, inputAngleUnits,
   outputAngleUnits)
```

Description

convertedValues = convang(*valuesToConvert*, *inputAngleUnits*, *outputAngleUnits*) computes the conversion factor from specified input angle units to specified output angle units. It then applies the conversion factor to the input to produce the output in the desired units. *inputAngleUnits* and *outputAngleUnits* are strings.

Input Arguments

valuesToConvert

Floating-point array of size *m*-by-*n* values the function is to convert. All values must have the same unit conversions from *inputAngleUnits* to *outputAngleUnits*.

inputAngleUnits

Specified input angle units, as strings. Supported unit strings are:

'deg'	Degrees
'rad'	Radians
'rev'	Revolutions

outputAngleUnits

Specified output angle units, as strings. Supported unit strings are:

'deg'	Degrees
'rad'	Radians
'rev'	Revolutions

Output Arguments

`convertedValues`

Floating-point array of size *m*-by-*n* values that the function has converted.

Examples

Convert three angles from degrees to radians:

```
a = convang([3 10 20],'deg','rad')

a =

    0.0524    0.1745    0.3491
```

See Also

`convacc` | `convangacc` | `convangvel` | `convdensity` | `convforce` | `convlength` | `convmass` | `convpres` | `convtemp` | `convvel`

Purpose

Convert from angular acceleration units to desired angular acceleration units

Syntax

```
convertedValues = convangacc(valuesToConvert,
   inputAngularUnits, outputAngularUnits)
```

Description

convertedValues = convangacc(*valuesToConvert*, *inputAngularUnits*, *outputAngularUnits*) computes the conversion factor from specified input angular acceleration units to specified output angular acceleration units. It then applies the conversion factor to the input to produce the output in the desired units.

Input Arguments

`valuesToConvert`

Floating-point array of size *m*-by-*n* values that the function is to convert. All values must have the same unit conversions from *inputAngularUnits* to *outputAngularUnits*.

`inputAngularUnits`

Specified input angular acceleration units, as strings. Supported unit strings are:

`'deg/s^2'`	Degrees per second squared
`'rad/s^2'`	Radians per second squared
`'rpm/s'`	Revolutions per minute per second

`outputAngularUnits`

Specified output angular acceleration units, as strings. Supported unit strings are:

`'deg/s^2'`	Degrees per second squared
`'rad/s^2'`	Radians per second squared
`'rpm/s'`	Revolutions per minute per second

Output Arguments

`convertedValues`

Floating-point array of size *m*-by-*n* values that the function has converted.

Examples

Convert three angular accelerations from degrees per second squared to radians per second squared:

```
a = convangacc([0.3 0.1 0.5],'deg/s^2','rad/s^2')

a =

    0.0052    0.0017    0.0087
```

See Also

`convacc` | `convang` | `convangvel` | `convdensity` | `convforce` | `convlength` | `convmass` | `convpres` | `convtemp` | `convvel`

Purpose

Convert from angular velocity units to desired angular velocity units

Syntax

```
convertedValues = convangvel(valuesToConvert,
   inputAngularVelocityUnits, outputAngularVelocityUnits)
```

Description

convertedValues = convangvel(*valuesToConvert*, *inputAngularVelocityUnits*, *outputAngularVelocityUnits*) computes the conversion factor from specified input angular velocity units to specified output angular velocity units. It then applies the conversion factor to the input to produce the output in the desired units.

Input Arguments

valuesToConvert

Floating-point array of size *m*-by-*n* values that the function is to convert. All values must have the same unit conversions from *inputAngularVelocityUnits* to *outputAngularVelocityUnits*.

inputAngularVelocityUnits

Specified input angular velocity units, as strings. Supported unit strings are:

'deg/s'	Degrees per second
'rad/s'	Radians per second
'rpm'	Revolutions per minute

outputAngularVelocityUnits

Specified output angular velocity units, as strings. Supported unit strings are:

'deg/s'	Degrees per second
'rad/s'	Radians per second
'rpm'	Revolutions per minute

Output Arguments

`convertedValues`

Floating-point array of size *m*-by-*n* values that the function has converted.

Examples

Convert three angular velocities from degrees per second to radians per second:

```
a = convangvel([0.3 0.1 0.5],'deg/s','rad/s')

a =

    0.0052    0.0017    0.0087
```

See Also

`convacc` | `convang` | `convangacc` | `convdensity` | `convforce` | `convlength` | `convmass` | `convpres` | `convtemp` | `convvel`

Purpose

Convert from density units to desired density units

Syntax

```
convertedValues = convdensity(valuesToConvert,
   inputDensityUnits, outputDensityUnits)
```

Description

convertedValues = convdensity(*valuesToConvert*, *inputDensityUnits*, *outputDensityUnits*) computes the conversion factor from specified input density units to specified output density units. It then applies the conversion factor to the input to produce the output in the desired units.

Input Arguments

valuesToConvert

Floating-point array of size *m*-by-*n* values that the function is to convert. All values must have the same unit conversions from *inputDensityUnits* to *outputDensityUnits*.

inputDensityUnits

Specified input density units, as strings. Supported unit strings are:

'lbm/ft^3'	Pound mass per feet cubed
'kg/m^3'	Kilograms per meters cubed
'slug/ft^3'	Slugs per feet cubed
'lbm/in^3'	Pound mass per inch cubed

outputDensityUnits

Specified output density units, as strings. Supported unit strings are:

'lbm/ft^3'	Pound mass per feet cubed
'kg/m^3'	Kilograms per meters cubed

'slug/ft^3'	Slugs per feet cubed
'lbm/in^3'	Pound mass per inch cubed

Output Arguments

`convertedValues`

Floating-point array of size *m*-by-*n* values that the function has converted.

Examples

Convert three densities from pound mass per feet cubed to kilograms per meters cubed:

```
a = convdensity([0.3 0.1 0.5],'lbm/ft^3','kg/m^3')

a =

    4.8055    1.6018    8.0092
```

See Also

convacc | convang | convangacc | convangvel | convforce | convlength | convmass | convpres | convtemp | convvel

Purpose

Convert from force units to desired force units

Syntax

```
convertedValues = convforce(valuesToConvert,
inputForceUnits,
   outputForceUnits)
```

Description

convertedValues = convforce(*valuesToConvert*, *inputForceUnits*, *outputForceUnits*) computes the conversion factor from specified input force units to specified output force units. It then applies the conversion factor to the input to produce the output in the desired units.

Input Arguments

valuesToConvert

Floating-point array of size *m*-by-*n* values that the function is to convert. All values must have the same unit conversions from *inputForceUnits* to *outputForceUnits*.

inputForceUnits

Specified input force units, as strings. Supported unit strings are:

'lbf'	Pound force
'N'	Newton

outputForceUnits

Specified output force units, as strings. Supported unit strings are:

'lbf'	Pound force
'N'	Newton

Output Arguments

convertedValues

Floating-point array of size *m*-by-*n* values that the function has converted.

Examples

Convert three forces from pound force to newtons:

```
a = convforce([120 1 5],'lbf','N')

a =

  533.7866    4.4482   22.2411
```

See Also

convacc | convang | convangacc | convangvel | convdensity | convlength | convmass | convpres | convtemp | convvel

Purpose

Convert from length units to desired length units

Syntax

```
convertedValues = convlength(valuesToConvert,
   inputLengthUnits, outputLengthUnits)
m
```

Description

convertedValues = convlength(*valuesToConvert*, *inputLengthUnits*, *outputLengthUnits*) computes the conversion factor from specified input length units to specified output length units. It then applies the conversion factor to the input to produce the output in the desired units.

Input Arguments

valuesToConvert

Floating-point array of size m-by-*n* values that the function is to convert. All values must have the same unit conversions from *inputLengthUnits* to *outputLengthUnits*.

inputLengthUnits

Specified input length units, as strings. Supported unit strings are:

'ft'	Feet
'm'	Meters
'km'	Kilometers
'in'	Inches
'mi'	Miles
'naut mi'	Nautical miles

outputLengthUnits

Specified output length units, as strings. Supported unit strings are:

'ft'	Feet
'm'	Meters
'km'	Kilometers
'in'	Inches
'mi'	Miles
'naut mi'	Nautical miles

Output Arguments

`convertedValues`

Floating-point array of size *m*-by-*n* values that the function has converted.

Examples

Convert three lengths from feet to meters:

```
a = convlength([3 10 20],'ft','m')

a =

    0.9144    3.0480    6.0960
```

See Also

convacc | convang | convangacc | convangvel | convdensity | convforce | convmass | convpres | convtemp | convvel

Purpose

Convert from mass units to desired mass units

Syntax

```
convertedValues = convmass(valuesToConvert, inputMassUnits,
   outputMassUnits)
```

Description

convertedValues = convmass(*valuesToConvert*, *inputMassUnits*, *outputMassUnits*) computes the conversion factor from specified input mass units to specified output mass units. It then applies the conversion factor to the input to produce the output in the desired units.

Input Arguments

valuesToConvert

Floating-point array of size *m*-by-*n* values that the function is to convert. All values must have the same unit conversions from *inputMassUnits* to *outputMassUnits*.

inputMassUnits

Specified input mass units, as strings. Supported unit strings are:

'lbm'	Pound mass
'kg'	Kilograms
'slugs'	Slugs

outputMassUnits

Specified output mass units, as strings. Supported unit strings are:

'lbm'	Pound mass
'kg'	Kilograms
'slugs'	Slugs

Output Arguments

convertedValues

Floating-point array of size *m*-by-*n* values that the function has converted.

Examples

Convert three masses from pound mass to kilograms:

```
a = convmass([3 1 5],'lbm','kg')

a =

    1.3608    0.4536    2.2680
```

See Also

convacc | convang | convangacc | convangvel | convdensity | convforce | convlength | convpres | convtemp | convvel

Purpose

Convert from pressure units to desired pressure units

Syntax

```
convertedValues= convpres(valuesToConvert,
   inputPressureUnits, outputPressureUnits)
```

Description

convertedValues= `convpres(`*valuesToConvert*, *inputPressureUnits*, *outputPressureUnits*`)` computes the conversion factor from specified input pressure units to specified output pressure units. It then applies the conversion factor to the input to produce the output in the desired units.

Input Arguments

`valuesToConvert`

Floating-point array of size *m*-by-*n* values that the function is to convert. All values must have the same unit conversions from *inputPressureUnits* to *outputPressureUnits*.

`inputPressureUnits`

Specified input pressure units, as strings. Supported unit strings are:

'psi'	Pound force per square inch
'Pa'	Pascal
'psf'	Pound force per square foot
'atm'	Atmosphere

`outputPressureUnits`

Specified output pressure units, as strings. Supported unit strings are:

'psi'	Pound force per square inch
'Pa'	Pascal

'psf'	Pound force per square foot
'atm'	Atmosphere

Output Arguments

`convertedValues`

Floating-point array of size *m*-by-*n* values that the function has converted.

Examples

Convert two pressures from pound force per square inch to atmospheres:

```
a = convpres([14.696  35],'psi','atm')

a =

    1.0000    2.3816
```

See Also

convacc | convang | convangacc | convangvel | convdensity | convforce | convlength | convmass | convtemp | convvel

Purpose

Convert from temperature units to desired temperature units

Syntax

```
convertedValues = convtemp(valuesToConvert,
   inputTemperatureUnits, outputTemperatureUnits)
```

Description

convertedValues = convtemp(*valuesToConvert*, *inputTemperatureUnits*, *outputTemperatureUnits*) computes the conversion factor from specified input temperature units to specified output temperature units. It then applies the conversion factor to the input, to produce the output in the desired units.

Input Arguments

`valuesToConvert`

Floating-point array of size *m*-by-*n* values that the function is to convert. All values must have the same unit conversions from *inputTemperatureUnits* to *outputTemperatureUnits*.

`inputTemperatureUnits`

Specified input temperature units, as strings. Supported unit strings are:

'K'	Kelvin
'F'	Degrees Fahrenheit
'C'	Degrees Celsius
'R'	Degrees Rankine

`outputTemperatureUnits`

Specified output temperature units, as strings. Supported unit strings are:

'K'	Kelvin
'F'	Degrees Fahrenheit

'C'	Degrees Celsius
'R'	Degrees Rankine

Output Arguments

`convertedValues`

Floating-point array of size *m*-by-*n* values that the function has converted.

Examples

Convert three temperatures from degrees Celsius to degrees Fahrenheit:

```
a = convtemp([0 100 15],'C','F')

a =

    32.0000  212.0000   59.0000
```

See Also

convacc | convang | convangacc | convangvel | convdensity | convforce | convlength | convmass | convpres | convvel

Purpose

Convert from velocity units to desired velocity units

Syntax

```
convertedValues = convvel(valuesToConvert,
   inputVelocityUnits, outputVelocityUnits)
```

Description

convertedValues = convvel(*valuesToConvert*, *inputVelocityUnits*, *outputVelocityUnits*) computes the conversion factor from specified input velocity units to specified output velocity units. It then applies the conversion factor to the input to produce the output in the desired units.

Input Arguments

valuesToConvert

Floating-point array of size *m*-by-*n* values that the function is to convert. All values must have the same unit conversions from *inputVelocityUnits* to *outputVelocityUnits*.

inputVelocityUnits

Specified input velocity units, as strings. Supported unit strings are:

'ft/s'	Feet per second
'm/s'	Meters per second
'km/s'	Kilometers per second
'in/s'	Inches per second
'km/h'	Kilometers per hour
'mph'	Miles per hour
'kts'	Knots
'ft/min'	Feet per minute

outputVelocityUnits

Specified output velocity units, as strings. Supported unit strings are:

'ft/s'	Feet per second
'm/s'	Meters per second
'km/s'	Kilometers per second
'in/s'	Inches per second
'km/h'	Kilometers per hour
'mph'	Miles per hour
'kts'	Knots
'ft/min'	Feet per minute

Output Arguments

`convertedValues`

Floating-point array of size *m*-by-*n* values that the function has converted.

Examples

Convert three velocities from feet per minute to meters per second:

```
a = convvel([30 100 250],'ft/min','m/s')

a =

    0.1524    0.5080    1.2700
```

See Also

convacc | convang | convangacc | convangvel | convdensity | convforce | convlength | convmass | convpres | convtemp

Purpose

Calculate equivalent airspeed (EAS), calibrated airspeed (CAS), or true airspeed (TAS) from one of other two airspeeds

Syntax

```
outputAirpseed = correctairspeed(inputAirspeed,
speedOfSound,
   pressure0, inputAirspeedType, outputAirspeedType)
```

Description

outputAirpseed = correctairspeed(*inputAirspeed*, *speedOfSound*, *pressure0*, *inputAirspeedType*, *outputAirspeedType*) computes the conversion factor from specified input airspeed to specified output airspeed using speed of sound and static pressure. The function applies the conversion factor to the input airspeed to produce the output in the desired airspeed.

This function is based on an assumption of compressible, isentropic (subsonic flow), dry air with constant specific heat ratio (gamma).

Input Arguments

inputAirspeed

Floating-point array of size *m*-by-1 of airspeeds in meters per second. All values must have the same airspeed conversions from *inputAirspeedType* to *outputAirspeedType*.

speedOfSound

Floating-point array of size *m*-by-1 of speeds of sound, in meters per second.

pressure0

Floating-point array of size *m*-by-1 of static air pressures, in pascal.

inputAirspeedType

Input airspeed string. Supported airspeed strings are:

'TAS'	True airspeed
'CAS'	Calibrated airspeed
'EAS'	Equivalent airspeed

`outputAirspeedType`

Output airspeed string. Supported airspeed strings are:

'TAS'	True airspeed
'CAS'	Calibrated airspeed
'EAS'	Equivalent airspeed

Output Arguments

`outputAirpseed`

Floating-point array of size *m*-by-1 of airspeeds in meters per second.

Examples

Convert three airspeeds from true airspeed to equivalent airspeed at 1000 ms:

```
as = correctairspeed([25.7222; 10.2889; 3.0867], 336.4, 89874.6,'TAS','EAS')

as =

   24.5057
    9.8023
    2.9407
```

Convert airspeeds from true airspeed to equivalent airspeed at 1000 m and 0 m:

```
ain = [25.7222; 10.2889; 3.0867];
sos = [336.4; 340.3; 340.3];
P0 = [89874.6; 101325; 101325];
as = correctairspeed(ain, sos, P0,'TAS','EAS')

as =

   24.5057
```

```
10.2887
 3.0866
```

References

Lowry, J.T., *Performance of Light Aircraft*, AIAA Education Series, Washington, D.C., 1999

Aeronautical Vestpocket Handbook, United Technologies Pratt & Whitney, August1986

See Also

`airspeed`

Aero.Animation.createBody

Purpose

Create body and its associated patches in animation

Syntax

```
idx = createBody(h,bodyDataSrc)
idx = h.createBody(bodyDataSrc)
idx = createBody(h,bodyDataSrc,geometrysource)
idx = h.createBody(bodyDataSrc,geometrysource)
```

Description

`idx = createBody(h,bodyDataSrc)` and `idx = h.createBody(bodyDataSrc)` create a new body using the `bodyDataSrc`, makes its patches, and adds it to the animation object `h`. This command assumes a default geometry source type set to `Auto`.

`idx = createBody(h,bodyDataSrc,geometrysource)` and `idx = h.createBody(bodyDataSrc,geometrysource)` create a new body using the `bodyDataSrc` file, makes its patches, and adds it to the animation object `h`. `geometrysource` is the geometry source type for the body.

Input Arguments

`bodyDataSrc` — Source of data for body.

`geometrysource` — Geometry source type for body:

- `Auto` — Recognizes `.mat` extensions as MAT-files, `.ac` extensions as Ac3d files, and structures containing fields of `name`, `faces`, `vertices`, and `cdata` as MATLAB variables. Default.
- `Variable` — Recognizes structures containing fields of `name`, `faces`, `vertices`, and `cdata` as MATLAB variables.
- `MatFile` — Recognizes `.mat` extensions as MAT-files.
- `Ac3d` — Recognizes `.ac` extensions as Ac3d files.
- `Custom` — Recognizes custom extensions.

Output Arguments

idx	Index of the body to be created.

Examples

Create a body for the animation object, `h`. Use the Ac3d format data source `pa24-250_orange.ac`, for the body.

```
h = Aero.Animation;
idx1 = h.createBody('pa24-250_orange.ac','Ac3d');
```

datcomimport

Purpose

Bring DATCOM file into MATLAB environment

Syntax

```
aero = datcomimport(file)
aero = datcomimport(file, usenan)
aero = datcomimport(file, usenan, verbose)
aero = datcomimport(file, usenan, verbose, filetype)
```

Description

`aero = datcomimport(file)` takes a file name, `file`, as a string (or a cell array of file names as strings), and imports aerodynamic data from `file` into a cell array of structures, `aero`. Before reading the DATCOM file, the function initializes values to 99999 to show when there is not a full set of data for the DATCOM case.

`aero = datcomimport(file, usenan)` is an alternate method allowing the replacement of data points with NaN or zero where no DATCOM methods exist or where the method is not applicable. The default value for `usenan` is `true`.

`aero = datcomimport(file, usenan, verbose)` is an alternate method to display the status of the DATCOM file being read. The default value for `verbose` is `2`, which displays a wait bar. Other options are `0`, which displays no information, and `1`, which displays text to the MATLAB Command Window.

`aero = datcomimport(file, usenan, verbose, filetype)` is an alternate method that allows you to specify which type of DATCOM file to read. The possible values are:

`filetype` Value	Output File from DATCOM
6	(Default) `for006.dat` output by all DATCOM versions
21	`for021.dat` output by DATCOM 2007 and DATCOM 2008
42	`for042.csv` output by DATCOM 2008

for `filetype` is `6`, which reads the `for006.dat` file output by DATCOM. The other option is `21`, which reads the `for021.dat` file output by DATCOM 2007.

Note If `filetype` is `21`, the last entry in `aero` is a table the function reads breakpoints collected from all of the cases.

Fields for the 1976, 1999, 2007, and 2008 versions of the type `6` output files are described in the following:

- "Fields for 1976 Version (File Type 6)" on page 4-105
- "Fields for 1999 Version (File Type 6)" on page 4-125
- "Fields for 2007 and 2008 Version (File Type 6)" on page 4-130
-

Fields for 2007 and 2008 version of the type 21 output file are described in

- "Fields for 2007 and 2008 Version (File Type 21)" on page 4-135

Fields for 2008 version of the type 42 output file are described in

- "Fields for 2008 Version (File Type 42)" on page 4-140

Fields for 1976 Version (File Type 6)

The fields of `aero` depend on the data within the DATCOM file:

Common Fields for the 1976 Version (File Type 6)

Field	Description	Default
`case`	String containing the case ID.	`[]`
`mach`	Array of Mach numbers.	`[]`

Common Fields for the 1976 Version (File Type 6) (Continued)

Field	Description	Default
alt	Array of altitudes.	[]
alpha	Array of angles of attack.	[]
nmach	Number of Mach numbers.	0
nalt	Number of altitudes.	0
nalpha	Number of angles of attack.	0
rnnub	Array of Reynolds numbers.	[]
hypers	Logical denoting, when true, that mach numbers above tsmach are hypersonic. Default values are supersonic.	false
loop	Scalar denoting the type of looping done to generate the DATCOM file. When loop is 1, mach and alt are varied together. When loop is 2, mach varies while alt is fixed. Altitude is then updated and Mach numbers are cycled through again. When loop is 3, mach is fixed while alt varies. mach is then updated and altitudes are cycled through again.	1
sref	Scalar denoting the reference area for the case.	[]
cbar	Scalar denoting the longitudinal reference length.	[]
blref	Scalar denoting the lateral reference length.	[]

Common Fields for the 1976 Version (File Type 6) (Continued)

Field	Description	Default
dim	String denoting the specified system of units for the case.	'ft'
deriv	String denoting the specified angle units for the case.	'deg'
stmach	Scalar value setting the upper limit of subsonic Mach numbers.	0.6
tsmach	Scalar value setting the lower limit of supersonic Mach numbers.	1.4
save	Logical denoting whether the input values for this case are used in the next case.	false
stype	Scalar denoting the type of asymmetric flap for the case.	[]
trim	Logical denoting the reading of trim data for the case. When trim runs are read, this value is set to true.	false
damp	Logical denoting the reading of dynamic derivative data for the case. When dynamic derivative runs are read, this value is set to true.	false
build	Scalar denoting the reading of build data for the case. When build runs are read, this value is set to 10.	1
part	Logical denoting the reading of partial data for the case. When partial runs are written for each Mach number, this value is set to true.	false

Common Fields for the 1976 Version (File Type 6) (Continued)

Field	Description	Default
highsym	Logical denoting the reading of symmetric flap high-lift data for the case. When symmetric flap runs are read, this value is set to true.	false
highasy	Logical denoting the reading of asymmetric flap high-lift data for the case. When asymmetric flap runs are read, this value is set to true.	false
highcon	Logical denoting the reading of control/trim tab high-lift data for the case. When control/trim tab runs are read, this value is set to true.	false
tjet	Logical denoting the reading of transverse-jet control data for the case. When transverse-jet control runs are read, this value is set to true.	false
hypeff	Logical denoting the reading of hypersonic flap effectiveness data for the case. When hypersonic flap effectiveness runs are read, this value is set to true.	false
lb	Logical denoting the reading of low aspect ratio wing or lifting body data for the case. When low aspect ratio wing or lifting body runs are read, this value is set to true.	false

Common Fields for the 1976 Version (File Type 6) (Continued)

Field	Description	Default
pwr	Logical denoting the reading of power effects data for the case. When power effects runs are read, this value is set to true.	false
grnd	Logical denoting the reading of ground effects data for the case. When ground effects runs are read, this value is set to true.	false
wsspn	Scalar denoting the semi-span theoretical panel for wing. This value is used to determine if the configuration contains a canard.	1
hsspn	Scalar denoting the semi-span theoretical panel for horizontal tail. This value is used to determine if the configuration contains a canard.	1
ndelta	Number of control surface deflections: delta, deltal, or deltar.	0
delta	Array of control-surface streamwise deflection angles.	[]
deltal	Array of left lifting surface streamwise control deflection angles, which are defined positive for trailing-edge down.	[]
deltar	Array of right lifting surface streamwise control deflection angles, which are defined positive for trailing-edge down.	[]

Common Fields for the 1976 Version (File Type 6) (Continued)

Field	Description	Default
ngh	Scalar denoting the number of ground altitudes.	0
grndht	Array of ground heights.	[]

config	Structure of logicals denoting whether the case contains horizontal tails.	false, as follows.
		
		config.downwash = false;
		config.body = false;
		config.wing = false;
		config.htail = false;
		config.vtail = false;
		config.vfin = false;

version	Version of DATCOM file.	1976

Static Longitude and Lateral Stability Fields Available for the 1976 Version (File Type 6)

Field	Matrix of...	Function of...
cd	Drag coefficients, which are defined positive for an aft-acting load.	alpha, mach, alt, build, grndht, delta
cl	Lift coefficients, which are defined positive for an up-acting load.	alpha, mach, alt, build, grndht, delta
cm	Pitching-moment coefficients, which are defined positive for a nose-up rotation.	alpha, mach, alt, build, grndht, delta
cn	Normal-force coefficients, which are defined positive for a normal force in the +Z direction.	alpha, mach, alt, build, grndht, delta

Static Longitude and Lateral Stability Fields Available for the 1976 Version (File Type 6) (Continued)

Field	Matrix of...	Function of...
ca	Axial-force coefficients, which are defined positive for a normal force in the +X direction.	alpha, mach, alt, build, grndht, delta
xcp	Distances between moment reference center and the center of pressure divided by the longitudinal reference length. Distances are defined positive for a location forward of the center of gravity.	alpha, mach, alt, build, grndht, delta
cla	Derivatives of lift coefficients with respect to alpha.	alpha, mach, alt, build, grndht, delta
cma	Derivatives of pitching-moment coefficients with respect to alpha.	alpha, mach, alt, build, grndht, delta
cyb	Derivatives of side-force coefficients with respect to sideslip angle.	alpha, mach, alt, build, grndht, delta
cnb	Derivatives of yawing-moment coefficients with respect to sideslip angle.	alpha, mach, alt, build, grndht, delta
clb	Derivatives of rolling-moment coefficients with respect to sideslip angle.	alpha, mach, alt, build, grndht, delta
qqinf	Ratios of dynamic pressure at the horizontal tail to the freestream value.	alpha, mach, alt, build, grndht, delta
eps	Downwash angle at horizontal tail in degrees.	alpha, mach, alt, build, grndht, delta
depsdalp	Downwash angle with respect to angle of attack.	alpha, mach, alt, build, grndht, delta

Dynamic Derivative Fields for the 1976 Version (File Type 6)

Field	Matrix of...	Function of...
clq	Rolling-moment derivatives due to pitch rate.	alpha, mach, alt, build
cmq	Pitching-moment derivatives due to pitch rate.	alpha, mach, alt, build
clad	Lift-force derivatives due to rate of angle of attack.	alpha, mach, alt, build
cmad	Pitching-moment derivatives due to rate of angle of attack.	alpha, mach, alt, build
clp	Rolling-moment derivatives due to roll rate.	alpha, mach, alt, build
cyp	Lateral-force derivatives due to roll rate.	alpha, mach, alt, build
cnp	Yawing-moment derivatives due to roll rate.	alpha, mach, alt, build
cnr	Yawing-moment derivatives due to yaw rate.	alpha, mach, alt, build
clr	Rolling-moment derivatives due to yaw rate.	alpha, mach, alt, build

High-Lift and Control Fields for Symmetric Flaps for the 1976 Version (File Type 6)

Field	Matrix of...	Function of...
dcl_sym	Incremental lift coefficients due to deflection of control surface, valid in the linear-lift angle of attack range.	delta, mach, alt
dcm_sym	Incremental pitching-moment coefficients due to deflection of control surface, valid in the linear-lift angle of attack range.	delta, mach, alt
dclmax_sym	Incremental maximum lift coefficients.	delta, mach, alt
dcdmin_sym	Incremental minimum drag coefficients due to control or flap deflection.	delta, mach, alt

High-Lift and Control Fields for Symmetric Flaps for the 1976 Version (File Type 6) (Continued)

Field	Matrix of...	Function of...
clad_sym	Lift-curve slope of the deflected, translated surface.	delta, mach, alt
cha_sym	Control-surface hinge-moment derivatives due to angle of attack. These derivatives, when defined positive, will tend to rotate the flap trailing edge down.	delta, mach, alt
chd_sym	Control-surface hinge-moment derivatives due to control deflection. When defined positive, these derivatives will tend to rotate the flap trailing edge down.	delta, mach, alt
dcdi_sym	Incremental induced drag coefficients due to flap detection.	alpha, delta, mach, alt

High-Lift and Control Fields Available for Asymmetric Flaps for the 1976 Version (File Type 6)

Field	Matrix of...	Function of...
xsc	Streamwise distances from wing leading edge to spoiler tip.	delta, mach, alt
hsc	Projected height of spoiler measured from normal to airfoil meanline.	delta, mach, alt
ddc	Projected height of deflector for spoiler-slot-deflector control.	delta, mach, alt
dsc	Projected height of spoiler control.	delta, mach, alt

High-Lift and Control Fields Available for Asymmetric Flaps for the 1976 Version (File Type 6) (Continued)

Field	Matrix of...	Function of...
clroll	Incremental rolling-moment coefficients due to asymmetrical deflection of control surface. The coefficients are defined positive when right wing is down.	delta, mach, and alt, or alpha, delta, mach, and alt for differential horizontal stabilizer
cn_asy	Incremental yawing-moment coefficients due to asymmetrical deflection of control surface. The coefficients are defined positive when nose is right.	delta, mach, and alt, or alpha, delta, mach, and alt for plain flaps

High-Lift and Control Fields Available for Control/Trim Tabs for the 1976 Version (File Type 6)

Field	Matrix of...	Function of...
fc_con	Stick forces or stick force coefficients.	alpha, delta, mach, alt
fhmcoeff_free	Flap-hinge moment coefficients tab free.	alpha, delta, mach, alt
fhmcoeff_lock	Flap-hinge moment coefficients tab locked.	alpha, delta, mach, alt
fhmcoeff_gear	Flap-hinge moment coefficients due to gearing.	alpha, delta, mach, alt
ttab_def	Trim-tab deflections for zero stick force.	alpha, delta, mach, alt

High-Lift and Control Fields Available for Trim for the 1976 Version (File Type 6)

Field	Matrix of...	Function of...
cl_utrim	Untrimmed lift coefficients, which are defined positive for an up-acting load.	alpha, mach, alt
cd_utrim	Untrimmed drag coefficients, which are defined positive for an aft-acting load.	alpha, mach, alt
cm_utrim	Untrimmed pitching-moment coefficients, which are defined positive for a nose-up rotation.	alpha, mach, alt
delt_trim	Trimmed control-surface streamwise deflection angles.	alpha, mach, alt
dcl_trim	Trimmed incremental lift coefficients in the linear-lift angle of attack range due to deflection of control surface.	alpha, mach, alt
dclmax_trim	Trimmed incremental maximum lift coefficients.	alpha, mach, alt
dcdi_trim	Trimmed incremental induced drag coefficients due to flap deflection.	alpha, mach, alt
dcdmin_trim	Trimmed incremental minimum drag coefficients due to control or flap deflection.	alpha, mach, alt
cha_trim	Trimmed control-surface hinge-moment derivatives due to angle of attack.	alpha, mach, alt
chd_trim	Trimmed control-surface hinge-moment derivatives due to control deflection.	alpha, mach, alt
cl_tailutrim	Untrimmed stabilizer lift coefficients, which are defined positive for an up-acting load.	alpha, mach, alt
cd_tailutrim	Untrimmed stabilizer drag coefficients, which are defined positive for an aft-acting load.	alpha, mach, alt

High-Lift and Control Fields Available for Trim for the 1976 Version (File Type 6) (Continued)

Field	Matrix of...	Function of...
`cm_tailutrim`	Untrimmed stabilizer pitching-moment coefficients, which are defined positive for a nose-up rotation.	`alpha`, `mach`, `alt`
`hm_tailutrim`	Untrimmed stabilizer hinge-moment coefficients, which are defined positive for a stabilizer rotation with leading edge up and trailing edge down.	`alpha`, `mach`, `alt`
`aliht_tailtrim`	Stabilizer incidence required to trim.	`alpha`, `mach`, `alt`
`cl_tailtrim`	Trimmed stabilizer lift coefficients, which are defined positive for an up-acting load.	`alpha`, `mach`, `alt`
`cd_tailtrim`	Trimmed stabilizer drag coefficients, which are defined positive for an aft-acting load.	`alpha`, `mach`, `alt`
`cm_tailtrim`	Trimmed stabilizer pitching-moment coefficients, which are defined positive for a nose-up rotation.	`alpha`, `mach`, `alt`
`hm_tailtrim`	Trimmed stabilizer hinge-moment coefficients, which are defined positive for a stabilizer rotation with leading edge up and trailing edge down.	`alpha`, `mach`, `alt`
`cl_trimi`	Lift coefficients at trim incidence. These coefficients are defined positive for an up-acting load.	`alpha`, `mach`, `alt`
`cd_trimi`	Drag coefficients at trim incidence. These coefficients are defined positive for an aft-acting load.	`alpha`, `mach`, `alt`

Transverse Jet Control Fields for the 1976 Version (File Type 6)

Field	Description	Stored with Indices of...
time	Matrix of times.	mach, alt, alpha
ctrlfrc	Matrix of control forces.	mach, alt, alpha
locmach	Matrix of local Mach numbers.	mach, alt, alpha
reynum	Matrix of Reynolds numbers.	mach, alt, alpha
locpres	Matrix of local pressures.	mach, alt, alpha
dynpres	Matrix of dynamic pressures.	mach, alt, alpha
blayer	Cell array of strings containing the state of the boundary layer.	mach, alt, alpha
ctrlcoeff	Matrix of control force coefficients.	mach, alt, alpha
corrcoeff	Matrix of corrected force coefficients.	mach, alt, alpha
sonicamp	Matrix of sonic amplification factors.	mach, alt, alpha
ampfact	Matrix of amplification factors.	mach, alt, alpha
vacthr	Matrix of vacuum thrusts.	mach, alt, alpha
minpres	Matrix of minimum pressure ratios.	mach, alt, alpha
minjet	Matrix of minimum jet pressures.	mach, alt, alpha
jetpres	Matrix of jet pressures.	mach, alt, alpha
massflow	Matrix of mass flow rates.	mach, alt, alpha
propelwt	Matrix of propellant weights.	mach, alt, alpha

Hypersonic Fields for the 1976 Version (File Type 6)

Field	Matrix of...	Stored with Indices of...
df_normal	Increments in normal force per spanwise foot of control.	alpha, delta, mach
df_axial	Increments in axial force per spanwise foot of control.	alpha, delta, mach
cm_normal	Increments in pitching moment due to normal force per spanwise foot of control.	alpha, delta, mach
cm_axial	Increments in pitching moment due to axial force per spanwise foot of control.	alpha, delta, mach
cp_normal	Center of pressure locations of normal force.	alpha, delta, mach
cp_axial	Center of pressure locations of axial force.	alpha, delta, mach

Auxiliary and Partial Fields Available for the 1976 Version (File Type 6)

Field	Matrix of...	Stored with Indices of...
wetarea_b	Body wetted area.	mach, alt, number of runs
xcg_b	Longitudinal locations of the center of gravity.	mach, alt, number of runs (normally 1, 2 for hypers = true)
zcg_b	Vertical locations of the center of gravity.	mach, alt, number of runs (normally 1, 2 for hypers = true)
basearea_b	Body base area.	mach, alt, number of runs (normally 1, 2 for hypers = true)
cd0_b	Body zero lift drags.	mach, alt, number of runs (normally 1, 2 for hypers = true)

Auxiliary and Partial Fields Available for the 1976 Version (File Type 6) (Continued)

Field	Matrix of...	Stored with Indices of...
basedrag_b	Body base drags.	mach, alt, number of runs (normally 1, 2 for hypers = true)
fricdrag_b	Body friction drags.	mach, alt, number of runs (normally 1, 2 for hypers = true)
presdrag_b	Body pressure drags.	mach, alt, number of runs (normally 1, 2 for hypers = true)
lemac	Leading edge mean aerodynamic chords.	mach, alt
sidewash	sidewash	mach, alt
hiv_b_w	iv-b(w)	alpha, mach, alt
hiv_w_h	iv-w(h)	alpha, mach, alt
hiv_b_h	iv-b(h)	alpha, mach, alt
gamma	gamma*2*pi*alpha*v*r	alpha, mach, alt
gamma2pialpvr	gamma*(2*pi*alpha*v*r)t	alpha, mach, alt
clpgammacl0	clp(gamma=cl=0)	mach, alt
clpgammaclp	clp(gamma)/cl (gamma=0)	mach, alt
cnptheta	cnp/theta	mach, alt
cypgamma	cyp/gamma	mach, alt
cypcl	cyp/cl (cl=0)	mach, alt
clbgamma	clb/gamma	mach, alt
cmothetaw	(cmo/theta)w	mach, alt
cmothetah	(cmo/theta)h	mach, alt

Auxiliary and Partial Fields Available for the 1976 Version (File Type 6) (Continued)

Field	Matrix of...	Stored with Indices of...
espeff	(epsoln)eff	alpha, mach, and alt
despdalpeff	d(epsoln)/d(alpha) eff	alpha, mach, alt
dragdiv	drag divergence mach number	mach, alt
cd0mach	Four Mach numbers for the zero lift drag.	index, mach, alt
cd0	Four zero lift drags.	index, mach, alt
clbclmfb_****	(clb/cl)mfb, where **** is either wb (wing-body) or bht (body-horizontal tail).	mach, alt.
cnam14_****	(cna)m=1.4, where **** is either wb (wing-body) or bht (body-horizontal tail).	mach,alt
area_*_**	Areas, where * is either w (wing), ht (horizontal tail), vt (vertical tail), or vf (ventral fin) and ** is either tt (total theoretical), ti (theoretical inboard), te (total exposed), ei (exposed inboard), or o (outboard).	mach, alt, number of runs (normally 1, 2 for hypers = true)
taperratio_*_**	Taper ratios, where * is either w (wing), ht (horizontal tail), vt (vertical tail), or vf (ventral fin) and ** is either tt (total theoretical), ti (theoretical inboard), te (total exposed), ei (exposed inboard), or o (outboard).	mach, alt, number of runs (normally 1, 2 for hypers = true)

Auxiliary and Partial Fields Available for the 1976 Version (File Type 6) (Continued)

Field	Matrix of...	Stored with Indices of...
aspectratio_*_**	Aspect ratios, where * is either w (wing), ht (horizontal tail), vt (vertical tail), or vf (ventral fin) and ** is either tt (total theoretical), ti (theoretical inboard), te (total exposed), ei (exposed inboard), or o (outboard).	mach, alt, number of runs (normally 1, 2 for hypers = true)
qcsweep_*_**	Quarter chord sweeps, where * is either w (wing), ht (horizontal tail), vt (vertical tail), or vf (ventral fin) and ** is either tt (total theoretical), ti (theoretical inboard), te (total exposed), ei (exposed inboard), or o (outboard).	mach, alt, number of runs (normally 1, 2 for hypers = true)
mac_*_**	Mean aerodynamic chords, where * is either w (wing), ht (horizontal tail), vt (vertical tail), or vf (ventral fin) and ** is either tt (total theoretical), ti (theoretical inboard), te (total exposed), ei (exposed inboard), or o (outboard).	mach, alt, number of runs (normally 1, 2 for hypers = true)

Auxiliary and Partial Fields Available for the 1976 Version (File Type 6) (Continued)

Field	Matrix of...	Stored with Indices of...
qcmac_*_**	Quarter chord x(mac), where * is either w (wing), ht (horizontal tail), vt (vertical tail), or vf (ventral fin) and ** is either tt (total theoretical), ti (theoretical inboard), te (total exposed), ei (exposed inboard), or o (outboard).	mach, alt, number of runs (normally 1, 2 for hypers = true)
ymac_*_**	y(mac), where * is either w (wing), ht (horizontal tail), vt (vertical tail), or vf (ventral fin) and ** is either tt (total theoretical), ti (theoretical inboard), te (total exposed), ei (exposed inboard), or o (outboard).	mach, alt, number of runs (normally 1, 2 for hypers = true)
cd0_*_**	Zero lift drags, where * is either w (wing), ht (horizontal tail), vt (vertical tail), or vf (ventral fin) and ** is either tt (total theoretical), ti (theoretical inboard), te (total exposed), ei (exposed inboard), or o (outboard).	mach, alt, number of runs (normally 1, 2 for hypers = true)

Auxiliary and Partial Fields Available for the 1976 Version (File Type 6) (Continued)

Field	Matrix of...	Stored with Indices of...
friccoeff_*_**	Friction coefficients, where * is either w (wing), ht (horizontal tail), vt (vertical tail), or vf (ventral fin) and ** is either tt (total theoretical), ti (theoretical inboard), te (total exposed), ei (exposed inboard), or o (outboard).	mach, alt, number of runs (normally 1, 2 for hypers = true)
cla_b_***	cla-b(***), where *** is either w (wing) or ht (stabilizer).	mach, alt, number of runs (normally 1, 2 for hypers = true)
cla_***_b	cla-***(b), where *** is either w (wing) or ht (stabilizer).	mach, alt, number of runs (normally 1, 2 for hypers = true)
k_b_***	k-b(***), where *** is either w (wing) or ht (stabilizer).	mach, alt, number of runs (normally 1, 2 for hypers = true)
k_***_b	k-***(b), where *** is either w (wing) or ht (stabilizer).	mach, alt, number of runs (normally 1, 2 for hypers = true)
xacc_b_***	xac/c-b(***), where *** is either w (wing) or ht (stabilizer).	mach, alt, number of runs (normally 1, 2 for hypers = true)
cdlcl2_***	cdl/cl^2, where *** is either w (wing) or ht (stabilizer).	mach, alt
clbcl_***	clb/cl, where *** is either w (wing) or ht (stabilizer).	mach, alt

Auxiliary and Partial Fields Available for the 1976 Version (File Type 6) (Continued)

Field	Matrix of...	Stored with Indices of...
fmach0_***	Force break Mach numbers with zero sweep, where *** is either w (wing) or ht (stabilizer).	mach, alt
fmach_***	Force break Mach numbers with sweep, where *** is either w (wing) or ht (stabilizer).	mach, alt
macha_***	mach(a), where *** is either w (wing) or ht (stabilizer).	mach, alt
machb_***	mach(b), where *** is either w (wing) or ht (stabilizer).	mach, alt
claa_***	cla(a), where *** is either w (wing) or ht (stabilizer).	mach, alt
clab_***	cla(b), where *** is either w (wing) or ht (stabilizer).	mach, alt
clbm06_***	(clb/cl)m=0.6, where *** is either w (wing) or ht (stabilizer).	mach, alt
clbm14_***	(clb/cl)m=1.4, where *** is either w (wing) or ht (stabilizer).	mach, alt
clalpmach_***	Five Mach numbers for the lift curve slope, where *** is either w (wing) or ht (stabilizer).	index, mach, alt
clalp_***	Five lift-curve slope values, where *** is either w (wing) or ht (stabilizer).	index, mach, alt

Fields for 1999 Version (File Type 6)

Common Fields for the 1999 Version (File Type 6)

Field	Description	Default
case	String containing the case ID.	[]
mach	Array of Mach numbers.	[]
alt	Array of altitudes.	[]
alpha	Array of angles of attack.	[]
nmach	Number of Mach numbers.	0
nalt	Number of altitudes.	1
nalpha	Number of angles of attack.	0
rnnub	Array of Reynolds numbers.	[]
beta	Scalar containing sideslip angle.	0
phi	Scalar containing aerodynamic roll angle.	0
loop	Scalar denoting the type of looping performed to generate the DATCOM file. When `loop` is `1`, `mach` and `alt` are varied together. The only loop option for the version 1999 of DATCOM is `loop` is equal to `1`.	1
sref	Scalar denoting the reference area for the case.	[]
cbar	Scalar denoting the longitudinal reference length.	[]
blref	Scalar denoting the lateral reference length.	[]

Common Fields for the 1999 Version (File Type 6) (Continued)

Field	Description	Default
dim	String denoting the specified system of units for the case.	'ft'
deriv	String denoting the specified angle units for the case.	'deg'
save	Logical denoting whether the input values for this case are used in the next case.	false
stype	Scalar denoting the type of asymmetric flap for the case.	[]
trim	Logical denoting the reading of trim data for the case. When trim runs are read, this value is set to true.	false
damp	Logical denoting the reading of dynamic derivative data for the case. When dynamic derivative runs are read, this value is set to true.	false
build	Scalar denoting the reading of build data for the case. When build runs are read, this value is set to the number of build runs depending on the vehicle configuration.	1
part	Logical denoting the reading of partial data for the case. When partial runs are written for each Mach number, this value is set to true.	false
hypeff	Logical denoting the reading of hypersonic data for the case. When hypersonic data is read, this value is set to true.	false

Common Fields for the 1999 Version (File Type 6) (Continued)

Field	Description	Default
ngh	Scalar denoting the number of ground altitudes.	0
nolat	Logical denoting the calculation of the lateral-direction derivatives is inhibited.	false

config	Structure of logicals and structures detailing the case configuration and fin deflections.	config.body = false
		config.fin1.avail = false;
		config.fin1.npanel = [];
		config.fin1.delta = [];
		config.fin2.avail = false;
		config.fin2.npanel = [];
		config.fin2.delta = [];
		config.fin3.avail = false;
		config.fin3.npanel = [];
		config.fin3.delta = [];
		config.fin4.avail = false;
		config.fin4.npanel = [];
		config.fin4.delta = [];

version	Version of DATCOM file.	1999

Static Longitude and Lateral Stability Fields Available for the 1999 Version (File Type 6)

Field	Matrix of...	Function of...
cd	Drag coefficients, which are defined positive for an aft-acting load.	alpha, mach, alt, build
cl	Lift coefficients, which are defined positive for an up-acting load.	alpha,mach, alt, build

Static Longitude and Lateral Stability Fields Available for the 1999 Version (File Type 6) (Continued)

Field	Matrix of...	Function of...
`cm`	Pitching-moment coefficients, which are defined positive for a nose-up rotation.	`alpha`, `machalt`, `build`
`cn`	Normal-force coefficients, which are defined positive for a normal force in the +Z direction.	`alpha`, `mach`, `alt`, `build`
`ca`	Axial-force coefficients, which are defined positive for a normal force in the +X direction.	`alpha`, `mach`, `alt`, `build`
`xcp`	Distances between moment reference center and the center of pressure divided by the longitudinal reference length. These distances are defined positive for a location forward of the center of gravity.	`alpha`, `mach`, `alt`, `build`
`cna`	Derivatives of normal-force coefficients with respect to `alpha`.	`alpha`, `mach`, `alt`, `build`
`cma`	Derivatives of pitching-moment coefficients with respect to `alpha`.	`alpha`, `mach`, `alt`, `build`
`cyb`	Derivatives of side-force coefficients with respect to sideslip angle.	`alpha`, `mach`, `alt`, `build`
`cnb`	Derivatives of yawing-moment coefficients with respect to sideslip angle.	`alpha`, `mach`, `alt`, `build`
`clb`	Derivatives of rolling-moment coefficients with respect to sideslip angle.	`alpha`, `mach`, `alt`, `build`
`clod`	Ratios of lift coefficient to drag coefficient.	`alpha`, `mach`, `alt`, `build`
`cy`	Side-force coefficients.	`alpha`, `mach`, `alt`, `build`
`cln`	Yawing-moment coefficient in body-axis.	`alpha`, `mach`, `alt`, `build`
`cll`	Rolling-moment coefficient in body-axis.	`alpha`, `mach`, `alt`, `build`

Dynamic Derivative Fields for the 1999 Version (File Type 6)

Field	Matrix of...	Function of...
`cnq`	Normal-force derivatives due to pitch rate.	`alpha`, `mach`, `alt`, `build`
`cmq`	Pitching-moment derivatives due to pitch rate.	`alpha`, `mach`, `alt`, `build`
`caq`	Axial-force derivatives due to pitch rate.	`alpha`, `mach`, `alt`, `build`
`cnad`	Normal-force derivatives due to rate of angle of attack.	`alpha`, `mach`, `alt`, `build`
`cmad`	Pitching-moment derivatives due to rate of angle of attack.	`alpha`, `mach`, `alt`, `build`
`clp`	Rolling-moment derivatives due to roll rate.	`alpha`, `mach`, `alt`, `build`
`cyp`	Lateral force derivatives due to roll rate.	`alpha`, `mach`, `alt`, `build`
`cnp`	Yawing-moment derivatives due to roll rate.	`alpha`, `mach`, `alt`, `build`
`cnr`	Yawing-moment derivatives due to yaw rate.	`alpha`, `mach`, `alt`, `build`
`clr`	Rolling-moment derivatives due to yaw rate.	`alpha`, `mach`, `alt`, `build`
`cyr`	Side force derivatives due to yaw rate.	`alpha`, `mach`, `alt`, `build`

Fields for 2007 and 2008 Version (File Type 6)

Common Fields for the 2007 and 2008 Version (File Type 6)

Field	Description	Default
case	String containing the case ID.	[]
mach	Array of Mach numbers.	[]
alt	Array of altitudes.	[]
alpha	Array of angles of attack.	[]
nmach	Number of Mach numbers.	0
nalt	Number of altitudes.	1
nalpha	Number of angles of attack.	0
rnnub	Array of Reynolds numbers.	[]
beta	Scalar containing sideslip angle.	0
phi	Scalar containing aerodynamic roll angle.	0
loop	Scalar denoting the type of looping performed to generate the DATCOM file. When `loop` is `1`, `mach` and `alt` are varied together. The only loop option for the version 2007 of DATCOM is `loop` is equal to `1`.	1
sref	Scalar denoting the reference area for the case.	[]
cbar	Scalar denoting the longitudinal reference length.	[]

Common Fields for the 2007 and 2008 Version (File Type 6) (Continued)

Field	Description	Default
`blref`	Scalar denoting the lateral reference length.	`[]`
`dim`	String denoting the specified system of units for the case.	`'ft'`
`deriv`	String denoting the specified angle units for the case.	`'deg'`
`save`	Logical denoting whether the input values for this case are used in the next case.	`false`
`stype`	Scalar denoting the type of asymmetric flap for the case.	`[]`
`trim`	Logical denoting the reading of trim data for the case. When trim runs are read, this value is set to `true`.	`false`
`damp`	Logical denoting the reading of dynamic derivative data for the case. When dynamic derivative runs are read, this value is set to `true`.	`false`
`build`	Scalar denoting the reading of build data for the case. When build runs are read, this value is set to the number of build runs depending on the vehicle configuration.	`1`
`part`	Logical denoting the reading of partial data for the case. When partial runs are written for each Mach number, this value is set to `true`.	`false`

Common Fields for the 2007 and 2008 Version (File Type 6) (Continued)

Field	Description	Default
`hypeff`	Logical denoting the reading of hypersonic data for the case. When hypersonic data is read, this value is set to `true`.	`false`
`ngh`	Scalar denoting the number of ground altitudes.	`0`
`nolat`	Logical denoting the calculation of the lateral-direction derivatives is inhibited.	`false`

`config`	Structure of logicals and structures detailing the case configuration and fin deflections.	`config.body = false;`
		`config.fin1.avail = false;`
		`config.fin1.npanel = [];`
		`config.fin1.delta = [];`
		`config.fin2.avail = false;`
		`config.fin2.npanel = [];`
		`config.fin2.delta = [];`
		`config.fin3.avail = false;`
		`config.fin3.npanel = [];`
		`config.fin3.delta = [];`
		`config.fin4.avail = false;`
		`config.fin4.npanel = [];`
		`config.fin4.delta = [];`

`nolat_-namelist`	Logical denoting the calculation of the lateral-direction derivatives is inhibited in the DATCOM input case.	`false`
`version`	Version of DATCOM file.	`2007`

Static Longitude and Lateral Stability Fields Available for the 2007 and 2008 Version (File Type 6)

Field	Matrix of...	Function of...
cd	Drag coefficients, which are defined positive for an aft-acting load.	alpha, mach, alt, build
cl	Lift coefficients, which are defined positive for an up-acting load.	alpha,mach, alt, build
cm	Pitching-moment coefficients, which are defined positive for a nose-up rotation.	alpha, machalt, build
cn	Normal-force coefficients, which are defined positive for a normal force in the +Z direction.	alpha, mach, alt, build
ca	Axial-force coefficients, which are defined positive for a normal force in the +X direction.	alpha, mach, alt, build
xcp	Distances between moment reference center and the center of pressure divided by the longitudinal reference length. These distances are defined positive for a location forward of the center of gravity.	alpha, mach, alt, build
cna	Derivatives of normal-force coefficients with respect to alpha.	alpha, mach, alt, build
cma	Derivatives of pitching-moment coefficients with respect to alpha.	alpha, mach, alt, build
cyb	Derivatives of side-force coefficients with respect to sideslip angle.	alpha, mach, alt, build
cnb	Derivatives of yawing-moment coefficients with respect to sideslip angle.	alpha, mach, alt, build
clb	Derivatives of rolling-moment coefficients with respect to sideslip angle.	alpha, mach, alt, build
clod	Ratios of lift coefficient to drag coefficient.	alpha, mach, alt, build

Static Longitude and Lateral Stability Fields Available for the 2007 and 2008 Version (File Type 6) (Continued)

Field	Matrix of...	Function of...
`cy`	Side-force coefficients.	`alpha`, `mach`, `alt`, `build`
`cln`	Yawing-moment coefficient in body-axis.	`alpha`, `mach`, `alt`, `build`
`cll`	Rolling-moment coefficient in body-axis.	`alpha`, `mach`, `alt`, `build`

Dynamic Derivative Fields for the 2007 and 2008 Version (File Type 6)

Field	Matrix of...	Function of...
`cnq`	Normal-force derivatives due to pitch rate.	`alpha`, `mach`, `alt`, `build`
`cmq`	Pitching-moment derivatives due to pitch rate.	`alpha`, `mach`, `alt`, `build`
`caq`	Axial-force derivatives due to pitch rate.	`alpha`, `mach`, `alt`, `build`
`cnad`	Normal-force derivatives due to rate of angle of attack.	`alpha`, `mach`, `alt`, `build`
`cmad`	Pitching-moment derivatives due to rate of angle of attack.	`alpha`, `mach`, `alt`, `build`
`clp`	Rolling-moment derivatives due to roll rate.	`alpha`, `mach`, `alt`, `build`
`cyp`	Lateral-force derivatives due to roll rate.	`alpha`, `mach`, `alt`, `build`
`cnp`	Yawing-moment derivatives due to roll rate.	`alpha`, `mach`, `alt`, `build`
`cnr`	Yawing-moment derivatives due to yaw rate.	`alpha`, `mach`, `alt`, `build`
`clr`	Rolling-moment derivatives due to yaw rate	`alpha`, `mach`, `alt`, `build`
`cyr`	Side-force derivatives due to yaw rate.	`alpha`, `mach`, `alt`, `build`

Fields for 2007 and 2008 Version (File Type 21)

Common Fields for the 2007 and 2008 Version (File Type 21)

Field	Description	Default
mach	Array of Mach numbers.	[]
alt	Array of altitudes.	[]
alpha	Array of angles of attack.	[]
nalpha	Number of angles of attack.	0
beta	Scalar containing sideslip angle.	0
total_col	Scalar denoting the type of looping performed to generate the DATCOM file. When loop is 1, mach and alt are varied together. The only loop option for the 2007 and 2008 versions of DATCOM is loop is equal to 1.	[]
deriv_col	Logical denoting the calculation of the lateral-direction derivatives is inhibited.	0

config	Structure of logicals and structures detailing the case configuration and fin deflections.	config.fin1.delta = zeros(1,8);
		config.fin2.delta = zeros(1,8);
		config.fin3.delta = zeros(1,8);
		config.fin4.delta = zeros(1,8);

version	Version of DATCOM file.	2007

Static Longitude and Lateral Stability Fields Available for the 2007 and 2008 Version (File Type 21)

Field	Matrix of...	Function of...
`cn`	Normal-force coefficients, which are defined positive for a normal force in the +Z direction.	`alpha`, `mach`, `alt`, `beta`, `config.fin1.delta`, `config.fin2.delta`, `config.fin3.delta`, `config.fin4.delta`
`cm`	Pitching-moment coefficients, which are defined positive for a nose-up rotation.	`alpha`, `mach`, `alt`, `beta`, `config.fin1.delta`, `config.fin2.delta`, `config.fin3.delta`, `config.fin4.delta`
`ca`	Axial-force coefficients, which are defined positive for a normal force in the +X direction.	`alpha`, `mach`, `alt`, `beta`, `config.fin1.delta`, `config.fin2.delta`, `config.fin3.delta`, `config.fin4.delta`
`cy`	Side-force coefficients.	`alpha`, `mach`, `alt`, `beta`, `config.fin1.delta`, `config.fin2.delta`, `config.fin3.delta`, `config.fin4.delta`
`cln`	Yawing-moment coefficient in body-axis.	`alpha`, `mach`, `alt`, `beta`, `config.fin1.delta`, `config.fin2.delta`, `config.fin3.delta`, `config.fin4.delta`
`cll`	Rolling-moment coefficient in body-axis.	`alpha`, `mach`, `alt`, `beta`, `config.fin1.delta`, `config.fin2.delta`, `config.fin3.delta`, `config.fin4.delta`

Dynamic Derivative Fields for the 2007 and 2008 Version (File Type 21)

Field	Matrix of...	Function of...
cnad	Normal-force derivatives due to rate of angle of attack.	alpha, mach, alt, beta, config.fin1.delta, config.fin2.delta, config.fin3.delta, config.fin4.delta
cmad	Pitching-moment derivatives due to rate of angle of attack.	alpha, mach, alt, beta, config.fin1.delta, config.fin2.delta, config.fin3.delta, config.fin4.delta
cnq	Normal-force derivatives due to pitch rate.	alpha, mach, alt, beta, config.fin1.delta, config.fin2.delta, config.fin3.delta, config.fin4.delta
cmq	Pitching-moment derivatives due to pitch rate.	alpha, mach, alt, beta, config.fin1.delta, config.fin2.delta, config.fin3.delta, config.fin4.delta
caq	Axial-force derivatives due to pitch rate.	alpha, mach, alt, beta, config.fin1.delta, config.fin2.delta, config.fin3.delta, config.fin4.delta
cyq	Side-force due to pitch rate.	alpha, mach, alt, beta, config.fin1.delta, config.fin2.delta, config.fin3.delta, config.fin4.delta

Dynamic Derivative Fields for the 2007 and 2008 Version (File Type 21) (Continued)

Field	Matrix of...	Function of...
`clnq`	Yawing-moment due to pitch rate.	`alpha`, `mach`, `alt`, `beta`, `config.fin1.delta`, `config.fin2.delta`, `config.fin3.delta`, `config.fin4.delta`
`cllq`	Rolling-moment due to pitch rate.	`alpha`, `mach`, `alt`, `beta`, `config.fin1.delta`, `config.fin2.delta`, `config.fin3.delta`, `config.fin4.delta`
`cnp`	Yawing-moment derivatives due to roll rate.	`alpha`, `mach`, `alt`, `beta`, `config.fin1.delta`, `config.fin2.delta`, `config.fin3.delta`, `config.fin4.delta`
`cap`	Axial-force due to roll rate.	`alpha`, `mach`, `alt`, `beta`, `config.fin1.delta`, `config.fin2.delta`, `config.fin3.delta`, `config.fin4.delta`
`cyp`	Lateral-force derivatives due to roll rate.	`alpha`, `mach`, `alt`, `beta`, `config.fin1.delta`, `config.fin2.delta`, `config.fin3.delta`, `config.fin4.delta`

Dynamic Derivative Fields for the 2007 and 2008 Version (File Type 21) (Continued)

Field	Matrix of...	Function of...
clnp	Yawing-moment due to roll rate.	alpha, mach, alt, beta, config.fin1.delta, config.fin2.delta, config.fin3.delta, config.fin4.delta
cllp	Rolling-moment due to roll rate.	alpha, mach, alt, beta, config.fin1.delta, config.fin2.delta, config.fin3.delta, config.fin4.delta
cnr	Yawing-moment derivatives due to yaw rate.	alpha, mach, alt, beta, config.fin1.delta, config.fin2.delta, config.fin3.delta, config.fin4.delta
car	Axial-force due to yaw rate.	alpha, mach, alt, beta, config.fin1.delta, config.fin2.delta, config.fin3.delta, config.fin4.delta
cyr	Side-force derivatives due to yaw rate.	alpha, mach, alt, beta, config.fin1.delta, config.fin2.delta, config.fin3.delta, config.fin4.delta

Dynamic Derivative Fields for the 2007 and 2008 Version (File Type 21) (Continued)

Field	Matrix of...	Function of...
clnr	Yawing-moment due to yaw rate.	alpha, mach, alt, beta, config.fin1.delta, config.fin2.delta, config.fin3.delta, config.fin4.delta
cllr	Rolling-moment due to yaw rate.	alpha, mach, alt, beta, config.fin1.delta, config.fin2.delta, config.fin3.delta, config.fin4.delta

Fields for 2008 Version (File Type 42)

Fields for the 2008 Version (File Type 42)

Field	Description	Default
case	String containing the case ID.	[]
totalCol	Scalar containing number of columns of data in file.	[]
mach	Array of Mach numbers.	[]
alt	Array of altitudes.	[]
alpha	Array of angles of attack.	[]
nmach	Number of Mach numbers.	0
nalpha	Number of angles of attack.	0
rnnub	Array of Reynolds numbers.	[]
q	Dynamic pressure.	[]

Fields for the 2008 Version (File Type 42) (Continued)

Field	Description	Default
beta	Scalar containing sideslip angle.	0
phi	Scalar containing aerodynamic roll angle.	0
sref	Scalar denoting the reference area for the case.	[]
cbar	Scalar denoting the longitudinal reference length.	[]
blref	Scalar denoting the lateral reference length.	[]
xcg	Distance from nose to center of gravity.	[]
xmrp	Distance from nose to center of gravity, measured in calibers.	[]
deriv	String denoting the specified angle units for the case.	'deg'
trim	Logical denoting the reading of trim data for the case. When trim runs are read, this value is set to `true`.	false
damp	Logical denoting the reading of dynamic derivative data for the case. When dynamic derivative runs are read, this value is set to `true`.	false
build	Scalar denoting the reading of partial data for the case. This value is set to the number of partial runs depending on the vehicle configuration.	1

Fields for the 2008 Version (File Type 42) (Continued)

Field	Description	Default
`part`	Logical denoting the reading of partial data for the case. When partial runs are written for each Mach number, this value is set to `true`.	`false`
`nolat`	Logical denoting the calculation of the lateral-direction derivatives is inhibited.	`true`

`config`	Structure of logicals and structures detailing the case configuration and fin deflections.	`config.body = false;`
		`config.fin1.avail = false;`
		`config.fin1.npanel = [];`
		`config.fin1.delta = [];`
		`config.fin2.avail = false;`
		`config.fin2.npanel = [];`
		`config.fin2.delta = [];`
		`config.fin3.avail = false;`
		`config.fin3.npanel = [];`
		`config.fin3.delta = [];`
		`config.fin4.avail = false;`
		`config.fin4.npanel = [];`

Static Longitude and Lateral Stability Fields Available for the 2008 Version (File Type 42)

Field	Matrix of...	Function of...
`delta`	Trim deflection angles.	`alpha`, `mach`
`cd`	Drag coefficients, which are defined positive for an aft-acting load.	`alpha`, `mach`, `build`

Static Longitude and Lateral Stability Fields Available for the 2008 Version (File Type 42) (Continued)

Field	Matrix of...	Function of...
`cl`	Lift coefficients, which are defined positive for an up-acting load.	`alpha`, `mach`, `build`
`cm`	Pitching-moment coefficients, which are defined positive for a nose-up rotation.	`alpha`, `mach`, `build`
`cn`	Normal-force coefficients, which are defined positive for a normal force in the +Z direction.	`alpha`, `mach`, `build`
`ca`	Axial-force coefficients, which are defined positive for a normal force in the +X direction.	`alpha`, `mach`, `build`
`caZeroBase`	Axial-force coefficient with no base drag included.	`alpha`, `mach`, `build`
`caFullBase`	Axial-force coefficient with full base drag included.	`alpha`, `mach`, `build`
`xcp`	Distance from nose to center of pressure.	`alpha`, `mach`, `build`
`cna`	Derivatives of normal-force coefficients with respect to `alpha`.	`alpha`, `mach`, `build`
`cma`	Derivatives of pitching-moment coefficients with respect to `alpha`.	`alpha`, `mach`, `build`
`cyb`	Derivatives of side-force coefficients with respect to sideslip angle.	`alpha`, `mach`, `build`
`cnb`	Derivatives of yawing-moment coefficients with respect to sideslip angle.	`alpha`, `mach`, `build`

Static Longitude and Lateral Stability Fields Available for the 2008 Version (File Type 42) (Continued)

Field	Matrix of...	Function of...
clb	Derivatives of rolling-moment coefficients with respect to sideslip angle.	alpha, mach, build
clod	Ratios of lift coefficient to drag coefficient.	alpha, mach, build
cy	Side-force coefficient.	alpha, mach, build
cln	Yawing-moment coefficient.	alpha, mach, build
cll	Rolling-moment coefficient.	alpha, mach, build

Dynamic Derivative Fields for the 2008 Version (File Type 42)

Field	Matrix of...	Function of...
cnq	Normal-force derivatives due to pitch rate.	alpha, mach, alt, build
cmq	Pitching-moment derivatives due to pitch rate.	alpha, mach, alt, build
caq	Axial-force derivatives due to pitch rate.	alpha, mach, alt, build
cnad	Normal-force derivatives due to rate of angle of attack.	alpha, mach, alt, build
cmad	Pitching-moment derivatives due to rate of angle of attack.	alpha, mach, alt, build
cyq	Lateral-force derivatives due to pitch rate.	alpha, mach, alt, build
clnq	Yawing-moment derivatives due to pitch rate.	alpha, mach, alt, build
cllq	Rolling-moment derivatives due to pitch rate.	alpha, mach, alt, build

Dynamic Derivative Fields for the 2008 Version (File Type 42) (Continued)

Field	Matrix of...	Function of...
cyr	Side-force derivatives due to yaw rate.	alpha, mach, alt, build
clnr	Yawing-moment derivatives due to yaw rate.	alpha, mach, alt, build
cllr	Rolling-moment derivatives due to yaw rate.	alpha, mach, alt, build
cyp	Lateral-force derivatives due to roll rate.	alpha, mach, alt, build
clnp	Yawing-moment derivatives due to roll rate.	alpha, mach, alt, build
cllp	Rolling-moment derivatives due to roll rate.	alpha, mach, alt, build
cnp	Normal-force derivatives due to roll rate.	alpha, mach, alt, build
cmp	Pitching-moment derivatives due to roll rate.	alpha, mach, alt, build
cap	Axial-force derivatives due to roll rate.	alpha, mach, alt, build
cnr	Normal-force derivatives due to yaw rate.	alpha, mach, alt, build
cmr	Pitching-moment derivatives due to roll rate.	alpha, mach, alt, build
car	Axial-force derivatives due to yaw rate.	alpha, mach, alt, build

Examples

Read the 1976 version Digital DATCOM output file astdatcom.out:

```
aero = datcomimport('astdatcom.out')
```

Read the 1976 Digital DATCOM output file astdatcom.out using zeros to replace data points where no DATCOM methods exist and displaying status information in the MATLAB Command Window:

```
usenan = false;
aero = datcomimport('astdatcom.out', usenan, 1 )
```

Assumptions and Limitations

The operational limitations of the 1976 version DATCOM apply to the data contained in AERO. For more information on DATCOM limitations, see [1], section 2.4.5.

USAF Digital DATCOM data for wing section, horizontal tail section, vertical tail section and ventral fin section are not read.

References

1. AFFDL-TR-79-3032: *The USAF Stability and Control DATCOM*, Volume 1, User's Manual

2. AFRL-VA-WP-TR-1998-3009: *MISSILE DATCOM*, User's Manual – 1997 FORTRAN 90 Revision

3. AFRL-RB-WP-TR-2009-3015: *MISSILE DATCOM*, User's Manual – 2008 Revision

Purpose

Convert direction cosine matrix to angle of attack and sideslip angle

Syntax

`[a b] = dcm2alphabeta(n)`

Description

`[a b] = dcm2alphabeta(n)` calculates the angle of attack and sideslip angle, `a` and `b`, for a given direction cosine matrix, `n`. `n` is a 3-by-3-by-`m` matrix containing `m` orthogonal direction cosine matrices. `a` is an `m` array of angles of attack. `b` is an `m` array of sideslip angles. `n` performs the coordinate transformation of a vector in body-axes into a vector in wind-axes. Angles of attack and sideslip angles are output in radians.

Examples

Determine the angle of attack and sideslip angle from direction cosine matrix:

```
dcm = [ 0.8926    0.1736    0.4162; ...
       -0.1574    0.9848   -0.0734; ...
       -0.4226         0    0.9063];
[alpha beta] = dcm2alphabeta(dcm)

alpha =

    0.4363


beta =

    0.1745
```

Determine the angle of attack and sideslip angle from multiple direction cosine matrices:

```
dcm = [ 0.8926    0.1736    0.4162; ...
       -0.1574    0.9848   -0.0734; ...
       -0.4226         0    0.9063];
dcm(:,:,2) = [ 0.9811    0.0872    0.1730; ...
              -0.0859    0.9962   -0.0151; ...
              -0.1736         0    0.9848];
```

```
[alpha beta] = dcm2alphabeta(dcm)


alpha =

    0.4363
    0.1745


beta =

    0.1745
    0.0873
```

See Also

angle2dcm | dcm2angle | dcmbody2wind

Purpose

Create rotation angles from direction cosine matrix

Syntax

```
[r1 r2 r3] = dcm2angle(n)
[r1 r2 r3] = dcm2angle(n, s)
[r1 r2 r3] = dcm2angle(n, s, lim)
```

Description

`[r1 r2 r3] = dcm2angle(n)` calculates the set of rotation angles, `r1`, `r2`, `r3`, for a given direction cosine matrix, `n`. `n` is a 3-by-3-by-`m` matrix containing `m` direction cosine matrices. `r1` returns an `m` array of first rotation angles. `r2` returns an `m` array of second rotation angles. `r3` returns an `m` array of third rotation angles. Rotation angles are output in radians.

`[r1 r2 r3] = dcm2angle(n, s)` calculates the set of rotation angles, `r1`, `r2`, `r3`, for a given direction cosine matrix, `n`, and a specified rotation sequence, `s`.

The default rotation sequence is `'ZYX'`, where `r1` is *z*-axis rotation, `r2` is *y*-axis rotation, and `r3` is *x*-axis rotation.

Supported rotation sequence strings are `'ZYX'`, `'ZYZ'`, `'ZXY'`, `'ZXZ'`, `'YXZ'`, `'YXY'`, `'YZX'`, `'YZY'`, `'XYZ'`, `'XYX'`, `'XZY'`, and `'XZX'`.

`[r1 r2 r3] = dcm2angle(n, s, lim)` calculates the set of rotation angles, `r1`, `r2`, `r3`, for a given direction cosine matrix, `n`, a specified rotation sequence, `s`, and a specified angle constraint, `lim`. `lim` is a string specifying either `'Default'` or `'ZeroR3'`. See "Assumptions and Limitations" on page 4-150 for full definitions of angle constraints.

Examples

Determine the rotation angles from direction cosine matrix:

```
dcm = [1 0 0; 0 1 0; 0 0 1];
[yaw, pitch, roll] = dcm2angle( dcm )
yaw =

     0

pitch =
```

```
      0

roll =

      0
```

Determine the rotation angles from multiple direction cosine matrices:

```
dcm        = [ 1 0 0; 0 1 0; 0 0 1];
dcm(:,:,2) = [ 0.85253103550038   0.47703040785184  -0.21361840626067; ...
              -0.43212157513194   0.87319830445628   0.22537893734811; ...
               0.29404383655186  -0.09983341664683   0.95056378592206];
 [pitch, roll, yaw] = dcm2angle( dcm, 'YXZ' )

pitch =

         0
    0.3000

roll =

         0
    0.1000

yaw =

         0
    0.5000
```

Assumptions and Limitations

The 'Default' limitations for the 'ZYX', 'ZXY', 'YXZ', 'YZX', 'XYZ', and 'XZY' implementations generate an r2 angle that lies between ±90 degrees, and r1 and r3 angles that lie between ±180 degrees.

The 'Default' limitations for the 'ZYZ', 'ZXZ', 'YXY', 'YZY', 'XYX', and 'XZX' implementations generate an r2 angle that lies between 0 and 180 degrees, and r1 and r3 angles that lie between ±180 degrees.

The `'ZeroR3'` limitations for the `'ZYX'`, `'ZXY'`, `'YXZ'`, `'YZX'`, `'XYZ'`, and `'XZY'` implementations generate an `r2` angle that lies between ±90 degrees, and `r1` and `r3` angles that lie between ±180 degrees. However, when `r2` is ±90 degrees, `r3` is set to 0 degrees.

The `'ZeroR3'` limitations for the `'ZYZ'`, `'ZXZ'`, `'YXY'`, `'YZY'`, `'XYX'`, and `'XZX'` implementations generate an `r2` angle that lies between 0 and 180 degrees, and `r1` and `r3` angles that lie between ±180 degrees. However, when `r2` is 0 or ±180 degrees, `r3` is set to 0 degrees.

See Also

`angle2dcm` | `dcm2quat` | `quat2dcm` | `quat2angle`

dcm2latlon

Purpose

Convert direction cosine matrix to geodetic latitude and longitude

Syntax

```
[lat lon] = dcm2latlon(n)
```

Description

`[lat lon] = dcm2latlon(n)` calculates the geodetic latitude and longitude, `lat` and `lon`, for a given direction cosine matrix, `n`. `n` is a 3-by-3-by-`m` matrix containing `m` orthogonal direction cosine matrices. `lat` is an `m` array of geodetic latitudes. `lon` is an `m` array of longitudes. `n` performs the coordinate transformation of a vector in Earth-centered Earth-fixed (ECEF) axes into a vector in north-east-down (NED) axes. Geodetic latitudes and longitudes are output in degrees.

Examples

Determine the geodetic latitude and longitude from direction cosine matrix:

```
dcm = [ 0.3747    0.5997    0.7071; ...
        0.8480   -0.5299         0; ...
        0.3747    0.5997   -0.7071];
[lat lon] = dcm2latlon(dcm)

lat =

   44.9995


lon =

  -122.0005
```

Determine the geodetic latitude and longitude from multiple direction cosine matrices:

```
dcm = [ 0.3747    0.5997    0.7071; ...
        0.8480   -0.5299         0; ...
        0.3747    0.5997   -0.7071];
dcm(:,:,2) = [-0.0531    0.6064    0.7934; ...
               0.9962    0.0872         0; ...
```

```
                -0.0691    0.7903   -0.6088];
[lat lon] = dcm2latlon(dcm)


lat =

   44.9995
   37.5028


lon =

 -122.0005
  -84.9975
```

See Also

`angle2dcm` | `dcm2angle` | `dcmecef2ned`

dcm2quat

Purpose

Convert direction cosine matrix to quaternion

Syntax

```
q = dcm2quat(n)
```

Description

`q = dcm2quat(n)` calculates the quaternion, `q`, for a given direction cosine matrix, `n`. Input `n` is a 3-by-3-by-`m` matrix of orthogonal direction cosine matrices. The direction cosine matrix performs the coordinate transformation of a vector in inertial axes to a vector in body axes. `q` returns an `m`-by-4 matrix containing `m` quaternions. `q` has its scalar number as the first column.

Examples

Determine the quaternion from direction cosine matrix:

```
dcm = [0 1 0; 1 0 0; 0 0 1];
q = dcm2quat(dcm)

q =

    0.7071         0         0         0
```

Determine the quaternions from multiple direction cosine matrices:

```
dcm        = [ 0 1 0; 1 0 0; 0 0 1];
dcm(:,:,2) = [ 0.4330    0.2500   -0.8660; ...
               0.1768    0.9186    0.3536; ...
               0.8839   -0.3062    0.3536];
q = dcm2quat(dcm)

q =

    0.7071         0         0         0
    0.8224    0.2006    0.5320    0.0223
```

See Also

`angle2dcm` | `dcm2angle` | `angle2quat` | `quat2dcm` | `quat2angle`

Purpose

Convert angle of attack and sideslip angle to direction cosine matrix

Syntax

```
n = dcmbody2wind(a, b)
```

Description

`n = dcmbody2wind(a, b)` calculates the direction cosine matrix, `n`, for given angle of attack and sideslip angle, `a`, `b`. `a` is an `m` array of angles of attack. `b` is an `m` array of sideslip angles. `n` returns a 3-by-3-by-`m` matrix containing `m` direction cosine matrices. `n` performs the coordinate transformation of a vector in body-axes into a vector in wind-axes. Angles of attack and sideslip angles are input in radians.

Examples

Determine the direction cosine matrix from angle of attack and sideslip angle:

```
alpha = 0.4363;
beta = 0.1745;
dcm = dcmbody2wind(alpha, beta)

dcm =

    0.8926    0.1736    0.4162
   -0.1574    0.9848   -0.0734
   -0.4226         0    0.9063
```

Determine the direction cosine matrix from multiple angles of attack and sideslip angles:

```
alpha = [0.4363 0.1745];
beta = [0.1745 0.0873];
dcm = dcmbody2wind(alpha, beta)

dcm(:,:,1) =

    0.8926    0.1736    0.4162
   -0.1574    0.9848   -0.0734
   -0.4226         0    0.9063
```

```
dcm(:,:,2) =

    0.9811    0.0872    0.1730
   -0.0859    0.9962   -0.0151
   -0.1736         0    0.9848
```

See Also

angle2dcm | dcm2alphabeta | dcm2angle

Purpose

Convert geodetic latitude and longitude to direction cosine matrix

Syntax

```
n = dcmecef2ned(lat, lon)
```

Description

`n = dcmecef2ned(lat, lon)` calculates the direction cosine matrix, `n`, for a given set of geodetic latitude and longitude, `lat`, `lon`. `lat` is an `m` array of geodetic latitudes. `lon` is an `m` array of longitudes. `n` returns a 3-by-3-by-`m` matrix containing `m` direction cosine matrices. `n` performs the coordinate transformation of a vector in Earth-centered Earth-fixed (ECEF) axes into a vector in north-east-down (NED) axes. Geodetic latitudes and longitudes are input in degrees.

Examples

Determine the direction cosine matrix from geodetic latitude and longitude:

```
lat = 45;
lon = -122;
dcm = dcmecef2ned(lat, lon)

dcm =

    0.3747    0.5997    0.7071
    0.8480   -0.5299         0
    0.3747    0.5997   -0.7071
```

Determine the direction cosine matrix from multiple geodetic latitudes and longitudes:

```
lat = [45 37.5];
lon = [-122 -85];
dcm = dcmecef2ned(lat, lon)

dcm(:,:,1) =

    0.3747    0.5997    0.7071
    0.8480   -0.5299         0
    0.3747    0.5997   -0.7071
```

```
dcm(:,:,2) =

   -0.0531    0.6064    0.7934
    0.9962    0.0872         0
   -0.0691    0.7903   -0.6088
```

See Also

angle2dcm | dcm2angle | dcm2latlon

Purpose

Calculate decimal year

Syntax

```
dy = decyear(v)
dy = decyear(s,f)
dy = decyear(y,mo,d)
dy = decyear([y,mo,d])
dy = decyear(y,mo,d,h,mi,s)
dy = decyear([y,mo,d,h,mi,s])
```

Description

`dy = decyear(v)` converts one or more date vectors, `v`, into decimal year, `dy`. Input `v` can be an `m`-by-6 or `m`-by-3 matrix containing `m` full or partial date vectors, respectively. `decyear` returns a column vector of `m` decimal years.

A date vector contains six elements, specifying year, month, day, hour, minute, and second. A partial date vector has three elements, specifying year, month, and day. Each element of `v` must be a positive double-precision number.

`dy = decyear(s,f)` converts one or more date strings, `s`, to decimal year, `dy`, using format string `f`. `s` can be a character array where each row corresponds to one date string, or a one-dimensional cell array of strings. `decyear` returns a column vector of `m` decimal years, where `m` is the number of strings in `s`.

All of the date strings in `s` must have the same format `f`, which must be composed of date format symbols listed in the `datestr` function reference page. Formats containing the letter `Q` are not accepted by `decyear`.

Certain formats may not contain enough information to compute a date number. In those cases, hours, minutes, and seconds default to 0, days default to 1, months default to January, and years default to the current year. Date strings with two-character years are interpreted to be within the 100 years centered around the current year.

`dy = decyear(y,mo,d)` and `dy = decyear([y,mo,d])` return the decimal year for corresponding elements of the `y,mo,d` (year,month,day) arrays. `y`, `mo`, and `d` must be arrays of the same size (or any of them can be a scalar).

`dy = decyear(y,mo,d,h,mi,s)` and `dy = decyear([y,mo,d,h,mi,s])` return the decimal year for corresponding elements of the `y,mo,d,h,mi,s` (year,month,day,hour,minute,second) arrays. The six arguments must be arrays of the same size (or any of them can be a scalar).

Examples

Calculate decimal year for May 24, 2005:

```
dy = decyear('24-May-2005','dd-mmm-yyyy')

dy =

  2.0054e+003
```

Calculate decimal year for December 19, 2006:

```
dy = decyear(2006,12,19)

dy =

  2.0070e+003
```

Calculate decimal year for October 10, 2004, at 12:21:00 p.m.:

```
dy = decyear(2004,10,10,12,21,0)

dy =

  2.0048e+003
```

Assumptions and Limitations

The calculation of decimal year does not take into account leap seconds.

See Also

`juliandate` | `leapyear` | `mjuliandate`

Purpose

Destroy animation object

Syntax

```
delete(h)
h.delete
```

Description

`delete(h)` and `h.delete` destroy the animation object `h`. This function also destroys the animation object figure, and any objects that the animation object contained (for example, bodies, camera, and geometry).

Input Arguments

`h`	Animation object.

Examples

Delete the animation object, `h`.

```
h=Aero.Animation;
h.delete;
```

delete (Aero.FlightGearAnimation)

Purpose Destroy FlightGear animation object

Syntax

```
delete(h)
h.delete
```

Description `delete(h)` and `h.delete` destroy the FlightGear animation object `h`. This function also destroys the animation object timer, and closes the socket that the FlightGear animation animation object contains.

Examples Delete the FlightGear animation object, `h`.

```
h=Aero.FlightGearAnimation;
h.delete;
```

See Also `initialize`

delete (Aero.VirtualRealityAnimation)

Purpose Destroy virtual reality animation object

Syntax

```
delete(h)
h.delete
```

Description `delete(h)` and `h.delete` destroy the virtual reality animation object `h`. This function also destroys the temporary file, if it exists, cleans up the vrfigure object, the animation object timer, and closes the vrworld object.

Examples Delete the virtual reality animation object, h.

```
h=Aero.VirtualRealityAnimation;
h.delete;
```

See Also `initialize`

dpressure

Purpose Compute dynamic pressure using velocity and density

Syntax

```
q = dpressure(v, r)
```

Description

`q = dpressure(v, r)` computes `m` dynamic pressures, `q`, from an `m`-by-3 array of velocities, `v`, and an array of `m` densities, `r`. `v` and `r` must have the same length units.

Examples

Determine dynamic pressure for velocity in feet per second and density in slugs per feet cubed:

```
q = dpressure([84.3905  33.7562  10.1269], 0.0024)


q =

   10.0365
```

Determine dynamic pressure for velocity in meters per second and density in kilograms per meters cubed:

```
q = dpressure([25.7222 10.2889 3.0867], [1.225  0.3639])


q =

  475.9252
  141.3789
```

Determine dynamic pressure for velocity in meters per second and density in kilograms per meters cubed:

```
q = dpressure([50 20 6; 5 0.5 2], [1.225  0.3639])


q =
```

```
    1.0e+003 *

       1.7983
       0.0053
```

See Also

airspeed | machnumber

ecef2lla

Purpose

Convert Earth-centered Earth-fixed (ECEF) coordinates to geodetic coordinates

Syntax

```
lla = ecef2lla(p)
lla = ecef2lla(p, model)
lla = ecef2lla(p, f, Re)
```

Description

`lla = ecef2lla(p)` converts the `m`-by-3 array of ECEF coordinates, `p`, to an `m`-by-3 array of geodetic coordinates (latitude, longitude and altitude), `lla`. `lla` is in [degrees degrees meters]. `p` is in meters. The default ellipsoid planet is WGS84.

`lla = ecef2lla(p, model)` is an alternate method for converting the coordinates for a specific ellipsoid planet. Currently only `'WGS84'` is supported for `model`.

`lla = ecef2lla(p, f, Re)` is another alternate method for converting the coordinates for a custom ellipsoid planet defined by flattening, `f`, and the equatorial radius, `Re`, in meters.

Examples

Determine latitude, longitude, and altitude at a coordinate:

```
lla = ecef2lla([4510731 4510731 0])


lla =

          0   45.0000  999.9564
```

Determine latitude, longitude, and altitude at multiple coordinates, specifying WGS84 ellipsoid model:

```
lla = ecef2lla([4510731 4510731 0; 0 4507609 4498719], 'WGS84')


lla =

          0   45.0000  999.9564
```

```
    45.1358   90.0000  999.8659
```

Determine latitude, longitude, and altitude at multiple coordinates, specifying custom ellipsoid model:

```
f = 1/196.877360;
Re = 3397000;
lla = ecef2lla([4510731 4510731 0; 0 4507609 4498719], f, Re)


lla =

  1.0e+006 *

         0    0.0000    2.9821
    0.0000    0.0001    2.9801
```

See Also

geoc2geod | geod2geoc | lla2ecef

fganimation (Aero.FlightGearAnimation)

Purpose

Construct FlightGear animation object

Syntax

```
h = fganimation
h = Aero.FlightGearAnimation
```

Description

`h = fganimation` and `h = Aero.FlightGearAnimation` construct a FlightGear animation object. The FlightGear animation object is returned to `h`.

Examples

Construct a FlightGear animation object, `h`:

```
h = fganimation
```

See Also

`Aero.FlightGearAnimation`

Purpose

Return start and stop times of time series data

Syntax

```
[tstart,tstop] = findstartstoptimes(h,tsdata)
[tstart,stop] = h.findstartstoptimes(tsdata)
```

Description

`[tstart,tstop] = findstartstoptimes(h,tsdata)` and `[tstart,stop] = h.findstartstoptimes(tsdata)` return the start and stop times of time series data `tsdata` for the animation body object `h`.

Examples

Find the start and stop times of the time series data, *`tsdata`*.

```
b=Aero.Body;
b.load('pa24-250_orange.ac','Ac3d');
tsdata = [ ...
    0,  1,1,1, 0,0,0; ...
    10  2,2,2, 1,1,1; ];
 b.TimeSeriesSource = tsdata;
[tstart,tstop] = findstartstoptimes(b,tsdata);
```

See Also

`load`

findstartstoptimes (Aero.Node)

Purpose

Return start and stop times for time series data

Syntax

```
[tstart,tstop] = findstartstoptimes(h,tsdata)
[tstart,stop] = h.findstartstoptimes(tsdata)
```

Description

`[tstart,tstop] = findstartstoptimes(h,tsdata)` and `[tstart,stop] = h.findstartstoptimes(tsdata)` return the start and stop times of time series data `tsdata` for the virtual reality animation object `h`.

Examples

Find the start and stop times of the time series data, `takeoffData`.

```
h = Aero.VirtualRealityAnimation;
h.VRWorldFilename = [matlabroot,'/toolbox/aero/astdemos/asttkoff.wrl'];
copyfile(h.VRWorldFilename,[tempdir,'asttkoff.wrl'],'f');
h.VRWorldFilename = [tempdir,'asttkoff.wrl'];
h.initialize();
load takeoffData;
h.Nodes{7}.TimeseriesSource = takeoffData;
h.Nodes{7}.TimeseriesSourceType = 'StructureWith Time';
[tstart,stop]=h.Nodes{7}.findstartstoptimes;
```

Purpose

Estimate array of geodetic latitude, longitude, and altitude coordinates from flat Earth position

Syntax

```
lla = flat2lla(flatearth_pos, llo, psio, href)
lla = flat2lla(flatearth_pos, llo, psio, href,
   ellipsoidModel)
lla = flat2lla(flatearth_pos, llo, psio, href, flattening,
   equatorialRadius)
```

Description

`lla = flat2lla(flatearth_pos, llo, psio, href)` estimates an array of geodetic coordinates, *`lla`*, from an array of flat Earth coordinates, *`flatearth_pos`*. This function estimates the `lla` value with respect to a reference location that `llo`, `psio`, and `href` define.

`lla = flat2lla(flatearth_pos, llo, psio, href, ellipsoidModel)` estimates the coordinates for a specific ellipsoid planet.

`lla = flat2lla(flatearth_pos, llo, psio, href, flattening, equatorialRadius)` estimates the coordinates for a custom ellipsoid planet defined by `flattening` and `equatorialRadius`.

Input Arguments

`flatearth_pos`

Flat Earth position coordinates, in meters.

`llo`

Reference location, in degrees, of latitude and longitude, for the origin of the estimation and the origin of the flat Earth coordinate system.

`psio`

Angular direction of flat Earth x-axis (degrees clockwise from north), which is the angle in degrees used for converting flat Earth x and y coordinates to North and East coordinates.

`href`

Reference height from the surface of the Earth to the flat Earth frame with regard to the flat Earth frame, in meters.

`ellipsoidModel`

String that specifies the specific ellipsoid planet model. This function supports only `'WGS84'`.

Default: WGS84

`flattening`

Custom ellipsoid planet defined by flattening.

`equatorialRadius`

Planetary equatorial radius, in meters.

Output Arguments

`lla`

m-by-3 array of geodetic coordinates (latitude, longitude, and altitude), in [degrees, degrees, meters].

Examples

Estimate latitude, longitude, and altitude at a specified coordinate:

```
lla = flat2lla( [ 4731 4511 120 ], [0 45], 5, -100)

lla =

    0.0391   45.0441  -20.0000
```

Estimate latitudes, longitudes, and altitudes at multiple coordinates, specifying the WGS84 ellipsoid model:

```
lla = flat2lla( [ 4731 4511 120; 0 5074 4498 ], [0 45], 5, -100, 'WGS84' )

lla =

  1.0e+003 *
```

```
     0.0000    0.0450   -0.0200
    -0.0000    0.0450   -4.3980
```

Estimate latitudes, longitudes, and altitudes at multiple coordinates, specifying a custom ellipsoid model:

```
f = 1/196.877360;
Re = 3397000;
lla = flat2lla( [ 4731 4511 120; 0 5074 4498 ], [0 45], 5, -100,  f, Re )

lla =

  1.0e+003 *

     0.0001    0.0451   -0.0200
    -0.0000    0.0451   -4.3980
```

Algorithms

The estimation begins by transforming the flat Earth *x* and *y* coordinates to North and East coordinates. The transformation has the form of

$$\begin{bmatrix} N \\ E \end{bmatrix} = \begin{bmatrix} \cos\psi & -\sin\psi \\ \sin\psi & \cos\psi \end{bmatrix} \begin{bmatrix} p_x \\ p_y \end{bmatrix}$$

where $(\bar{\psi})$ is the angle in degrees clockwise between the *x*-axis and north.

To convert the North and East coordinates to geodetic latitude and longitude, the estimation uses the radius of curvature in the prime vertical (R_N) and the radius of curvature in the meridian (R_M). (R_N) and (R_M) are defined by the following relationships:

$$R_N = \frac{R}{\sqrt{1-(2f-f^2)\sin^2\mu_0}}$$
$$R_M = R_N \frac{1-(2f-f^2)}{1-(2f-f^2)\sin^2\mu_0}$$

where (R) is the equatorial radius of the planet and $\left(\bar{f}\right)$ is the flattening of the planet.

Small changes in the latitude and longitude are approximated from small changes in the North and East positions by

$$d\mu = \text{atan}\left(\frac{1}{R_M}\right)dN$$
$$d\iota = \text{atan}\left(\frac{1}{R_N \cos\mu}\right)dE$$

The output latitude and longitude are the initial latitude and longitude plus the small changes in latitude and longitude.

$$\mu = \mu_0 + d\mu$$
$$\iota = \iota_0 + d\iota$$

The altitude is the negative flat Earth z-axis value minus the reference height (h_{ref}).

$$h = -p_z - h_{ref}$$

References

Etkin, B., *Dynamics of Atmospheric Flight*. NewYork: John Wiley & Sons, 1972.

Stevens, B. L., and F. L. Lewis, *Aircraft Control and Simulation*, 2nd ed. New York: John Wiley & Sons, 2003.

See Also

`lla2flat`

flowfanno

Purpose

Fanno line flow relations

Syntax

```
[mach, T, P, rho, velocity, P0, fanno] = flowfanno(gamma,
   fanno_flow, mtype)
```

Description

`[mach, T, P, rho, velocity, P0, fanno] = flowfanno(gamma, fanno_flow, mtype)` returns an array for each Fanno line flow relation. This function calculates the arrays for a given set of specific heat ratios (*gamma*), and any one of the Fanno flow types . You select the Fanno flow type with *mtype*.

This function uses Fanno variables given by the following. *F* is the Fanno parameter given by F = f*L/D. *f* is the friction coefficient. *L* is the length of constant area duct required to achieve sonic flow. *D* is the hydraulic diameter of the duct.

This function assumes that variables vary in one dimension only. It also assumes that the main mechanism for the change of flow variables is the change of cross-sectional area of the flow stream tubes.

If the temperature experiences large fluctuations, the perfect gas assumption might be invalid. If the stagnation temperature is above 1500 K, do not assume constant specific heats. In this case, the medium ceases to be a calorically perfect gas. Consider it a thermally perfect gas. See 2 for thermally perfect gas correction factors. If the temperature is so high that molecules dissociate and ionize (static temperature 5000 K for air), you cannot assume a perfect gas.

Input Arguments

`gamma`

Array of *N* specific heat ratios. *gamma* must be either a scalar or an array of *N* real numbers greater than 1. *gamma* must be a real, finite scalar greater than 1 for the following input modes: subsonic total pressure ratio, supersonic total pressure ratio, subsonic Fanno parameter, and supersonic Fanno parameter.

`fanno_flow`

Array of real numerical values for one Fanno flow. This argument can be one of the following:

- Array of Mach numbers. *flow_fanno* must be a scalar or an array of *N* real numbers greater than or equal to 0. If *flow_fanno* and *gamma* are arrays, they must be the same size.

  Use *flow_fanno* with the *mtype* value 'mach'. Because '*mach*' is the default of *mtype*, *mtype* is optional when this array is the input mode.

- Array of temperature ratios. The temperature ratio is the local static temperature over the reference static temperature for sonic flow. This array must be a scalar or array of *N* real numbers:

  - Greater than or equal to 0 (as the Mach number approaches infinity)

  - Less than or equal to (*gamma*+1)/2 (at Mach number equal 0)

  Use *flow_fanno* with *mtype* value '*temp*'.

- Array of pressure ratios. The pressure ratio is the local static pressure over the reference static pressure for sonic flow. *flow_fanno* must be a scalar or array of real numbers greater than or equal to 0. If *flow_fanno* and *gamma* are arrays, they must be the same size.

  Use *flow_fanno* with *mtype* value '*pres*'.

- Array of density ratios. The density ratio is the local density over the reference density for sonic flow. *flow_fanno* must be a scalar or array of real numbers. These numbers must be greater than or equal to:

  sqrt((*gamma*-1)/(*gamma*+1)) (as the Mach number approaches infinity).

  If *flow_fanno* and *gamma* are arrays, they must be the same size.

Use *flow_fanno* with *mtype* value '*dens*'.

- Array of velocity ratios. The velocity ratio is the local velocity over the reference velocity for sonic flow. *flow_fanno* must be a scalar or an array of *N* of real numbers:
  - Greater than or equal to 0
  - Less than or equal to sqrt((*gamma*+1)/(*gamma*-1)) (as the Mach number approaches infinity)

  If *flow_fanno* and *gamma* are both arrays, they must be the same size.

  Use *flow_fanno* with *mtype* value '*velo*'.

- Scalar value of total pressure ratio. The total pressure ratio is the local total pressure over the reference total pressure for sonic flow. *flow_fanno* must be greater than or equal to 1.

  Use *flow_fanno* with *mtype* values 'totalp' and 'totalpsup'.

- Scalar value for Fanno parameter. The Fanno parameter is flow_fanno= f*L/D. *f* is the friction coefficient. *L* is the length of constant area duct required to achieve sonic flow. *D* is the hydraulic diameter of the duct. In subsonic mode, *flow_fanno* must be greater than or equal to 0. In supersonic mode, *flow_fanno* must be:
  - Greater than or equal to 0 (at Mach number equal 1)
  - Less than or equal to (*gamma*+1)/(2**gamma*)*log((*gamma*+1)/(*gamma*-1))-1/*gamma* (as Mach number approaches infinity)

  Use *flow_fanno* with *mtype* values '*fannosub*' and '*fannosup*'.

`mtype`

A string that defines the input mode for the type of Fanno flow in *fanno_flow*.

Type	Description
'mach'	Default Mach number
'temp'	Temperature ratio
'pres'	Pressure ratio
'dens'	Density ratio
'velo'	Velocity ratio
'totalpsub'	Subsonic total pressure ratio
'totalpsup'	Supersonic total pressure ratio
'fannosub'	Subsonic Fanno parameter
'fannosup'	Supersonic Fanno parameter

Output Arguments

All outputs are the same size as the array inputs. If there are no array inputs, all outputs are scalars.

`mach`

Array of Mach numbers.

`T`

Array of temperature ratios. The temperature ratio is the local static temperature over the reference static temperature for sonic flow.

`P`

Array of pressure ratios. The pressure ratio is the local static pressure over the reference static pressure for sonic flow.

`rho`

Array of density ratio. The density ratio is the local density over the reference density for sonic flow.

`velocity`

Array of velocity ratios. The velocity ratio is the local velocity over the reference velocity for sonic flow.

`P0`

Array of stagnation (total) pressure ratio. The total pressure ratio is the local total pressure over the reference total pressure for sonic flow.

`fanno`

Array of Fanno parameters. The Fanno parameter is F = f*L/D. *`f`* is the friction coefficient. *`L`* is the length of constant area duct required to achieve sonic flow. *`D`* is the hydraulic diameter of the duct.

Examples

Calculate the Fanno line flow relations for air (`gamma` = 1.4) for subsonic Fanno parameter 1.2. The following returns scalar values for *`mach`*, *`T`*, *`P`*, *`rho`*, *`velocity`*, *`P0`*, and *`fanno`*.

```
[mach, T, P, rho, velocity, P0, fanno] = flowfanno(1.4, 1.2, 'fannosub')
```

Calculate the Fanno line flow relations for gases with specific heat ratios given in the following 1 x 4 row array for the Mach number 0.5. The following yields a 1 x 4 row array for *`mach`*, *`T`*, *`P`*, *`rho`*, *`velocity`*, *`P0`*, and *`fanno`*.

```
gamma = [1.3, 1.33, 1.4, 1.67];
[mach, T, P, rho, velocity, P0, fanno] = flowfanno(gamma, 0.5)
```

Calculate the Fanno line flow relations for a specific heat ratio of 1.4 and range of temperature ratios from 0.40 to 0.70 in increments of 0.10. The following returns a 4 x 1 column array for *`mach`*, *`T`*, *`P`*, *`rho`*, *`velocity`*, *`P0`*, and *`fanno`*.

```
[mach, T, P, rho, velocity, P0, fanno] = flowfanno(1.4, [1.1 1.2], 'temp')
```

Calculate the Fanno line flow relations for gases with specific heat ratio and velocity ratio combinations as shown. The following returns a 1 x 2 array for *mach*, *T*, *P*, *rho*, *velocity*, *P0*, and *fanno* each. The elements of each array correspond to the inputs element-wise.

```
gamma = [1.3, 1.4];
V = [0.53, 0.49];
[MACH, T, P, RHO, V, P0, F] = flowfanno(gamma, V, 'velo')
```

References

1. James, J. E. A., *Gas Dynamics, Second Edition*, Allyn and Bacon, Inc, Boston, 1984.

2. *NACA Technical Report 1135*, 1953, National Advisory Committee on Aeronautics, Ames Research Staff, Moffett Field, Calif. Pages 667–671.

See Also

`flowisentropic` | `flownormalshock` | `flowprandtlmeyer` | `flowrayleigh`

flowisentropic

Purpose

Isentropic flow ratios

Syntax

```
[mach, T, P, rho, area] = flowisentropic(gamma,
flow, mtype)
```

Description

`[mach, T, P, rho, area] = flowisentropic(gamma, flow, mtype)` returns an array. This array contains an isentropic flow Mach number (*mach*), temperature ratio (*T*), pressure ratio (*P*), density ratio (*rho*), and area ratio (*area*). This function calculates these arrays given a set of specific heat ratios (*gamma*), and any one of the isentropic flow types. You select the isentropic flow with *mtype*.

This function assumes that variables vary in one dimension only. It also assumes that the main mechanism for the change of flow variables is the change of cross-sectional area of the flow stream tubes.

This function assumes that the environment is a perfect gas. In the following instances, the function cannot assume a perfect gas environment. If there is a large change in either temperature or pressure without a proportionally large change in the other, the function cannot assume a perfect gas environment. . If the stagnation temperature is above 1500 K, do not assume that constant specific heats. In this case, the medium ceases to be a calorically perfect gas. Consider it a thermally perfect gas. See 2 for thermally perfect gas correction factors. If the temperature is so high that molecules dissociate and ionize (static temperature 5000 K for air), you cannot assume a calorically or thermally perfect gas.

Input Arguments

`gamma`

Array of *N* specific heat ratios. *gamma* must be a scalar or array of *N* real numbers greater than 1. For subsonic area ratio input mode and supersonic area ratio input mode, *gamma* must be a real, finite scalar greater than 1.

`flow`

Array of real numerical values for one of the isentropic flow relations. This argument can be one of the following:

- Array of Mach numbers. `flow` must be a scalar or an array of *N* real numbers greater than or equal to 0. If `flow` and *gamma* are arrays, they must be the same size.

  Use `flow` with the *mtype* value `'mach'`. Because `'mach'` is the default of *mtype*, *mtype* is optional when this array is the input mode.

- Array of temperature ratios. The temperature ratio is the local static temperature over the stagnation temperature. `flow` must be a scalar or an array of real numbers:

  - Greater than or equal to 0 (as the Mach number approaches infinity)
  - Less than or equal to 1 (at Mach number equal 0)

  If `flow` and *gamma* are both arrays, they must be the same size.

  Use `flow` with *mtype* value `'temp'`.

- Array of pressure ratios. The pressure ratio is the local static pressure over the stagnation pressure. `flow` must be a scalar or an array of real numbers:

  - Greater than or equal to 0 (as the Mach number approaches infinity)
  - Less than or equal to 1 (at Mach number equal 0)

  If `flow` and *gamma* are both arrays, they must be the same size.

  Use `flow` with *mtype* value `'pres'`.

- Array of density ratios. The density ratio is the local density over the stagnation density. `flow` must be a scalar or an array of real numbers:

  - Greater than or equal to 0 (as the Mach number approaches infinity)
  - Less than or equal to 1 (at Mach number equal 0)

  If `flow` and *gamma* are both arrays, they must be the same size.

Use *flow* with *mtype* value '*dens*'.

- Scalar value of area ratio. *flow* must be a real value greater than or equal to 1.

  Use *flow* with *mtype* value '*sup*'.

`mtype`

A string that defines the input mode for the isentropic flow in *flow*.

Type	Description
'mach'	Default. Mach number.
'temp'	Temperature ratio.
'pres'	Pressure ratio.
'dens'	Density ratio.
'sub'	Subsonic area ratio. The subsonic area ratio is the local subsonic stream tube area over the reference stream tube area for sonic conditions.
'sup'	Supersonic area ratio. The supersonic area ratio is the local supersonic stream tube area over the reference stream tube area for sonic conditions.

Output Arguments

All outputs are the same size as the array inputs. If there are no array inputs, all outputs are scalars.

`mach`

Array of Mach numbers.

`T`

Array of temperature ratios. The temperature ratio is the local static temperature over the stagnation temperature.

`P`

Array of pressure ratios. The pressure ratio is the local static pressure over the stagnation pressure.

`rho`

Array of density ratios. The density ratio is the local density over the stagnation density.

`area`

Array of area ratios. The area ratio is the local stream tube area over the reference stream tube area for sonic conditions.

Examples

Calculate the isentropic flow relations for air (*gamma* = 1.4) for a design subsonic area ratio of 1.255. This example returns scalar values for *mach*, *T*, *P*, *rho*, and *area*.

```
[mach, T, P, rho, area] = flowisentropic(1.4, 1.255, 'sub')
```

Calculate the isentropic flow relations for gases with specific heat ratios given in the following 1 x 4 row array for the Mach number 0.5. This example following returns a 1 x 4 row array for *mach*, *T*, *P*, *rho*, and *area*.

```
gamma = [1.3, 1.33, 1.4, 1.67];
[mach, T, P, rho, area] = flowisentropic(gamma, 0.5)
```

Calculate the isentropic flow relations for a specific heat ratio of 1.4. Also calculate range of temperature ratios from 0.40 to 0.70 in increments of 0.10. This example returns a 4 x 1 column array for *mach*, *T*, *P*, *rho*, and *area*.

```
[mach, T, P, rho, area] = flowisentropic(1.4, (0.40:0.10:0.70)', 'temp')
```

Calculate the isentropic flow relations for gases with provided specific heat ratio and density ratio combinations. This example returns a 1 x 2 array for *mach*, *T*, *P*, *rho*, and *area* each. The elements of each vector correspond to the inputs element-wise.

```
gamma = [1.3, 1.4];
rho = [0.13, 0.9];
[mach, T, P, rho, area] = flowisentropic(gamma, rho , 'dens')
```

References

1. James, J. E. A., *Gas Dynamics, Second Edition*, Allyn and Bacon, Inc, Boston, 1984.

2. *NACA Technical Report 1135*, 1953, National Advisory Committee on Aeronautics, Ames Research Staff, Moffett Field, Calif. Pages 667–671.

See Also

`flownormalshock` | `flowprandtlmeyer` | `flowfanno` | `flowrayleigh`

Purpose

Normal shock relations

Syntax

```
[mach, T, P, rho, downstream_mach, P0,
   P1] = flownormalshock(gamma, normal_shock_relations,
   mtype)
```

Description

`[mach, T, P, rho, downstream_mach, P0, P1] = flownormalshock(gamma, normal_shock_relations, mtype)` produces an array for each normal shock relation (*normal_shock_relations*). This function calculates these arrays for a given set of specific heat ratios (*gamma*) and any one of the normal shock relations (*normal_shock_relations*). *mtype* selects the normal shock relations that *normal_shock_relations* represents. All ratios are downstream value over upstream value. Consider upstream to be before or ahead of the shock; downstream is after or behind the shock.

This function assumes that the medium is a calorically perfect gas. It assumes that the flow is frictionless and adiabatic. It assumes that the flow variables vary in one dimension only. It assumes that the main mechanism for the change of flow variables is the change of cross-sectional area of the flow stream tubes.

If the temperature experiences large fluctuations, the perfect gas assumption might be invalid. If the stagnation temperature is above 1500 K, do not assume constant specific heats. In this case, the medium ceases to be a calorically perfect gas. You must then consider it a thermally perfect gas. See 2 for thermally perfect gas correction factors. If the temperature is so high that molecules dissociate and ionize (static temperature 5000 K for air), you cannot assume a perfect gas.

Input Arguments

`gamma`

Array of *N* specific heat ratios. *gamma* must be either a scalar or an array of *N* real numbers greater than 1. For temperature ratio, total pressure ratio, and Rayleigh-Pitot ratio input modes, *gamma* must be a real, finite scalar greater than 1.

`normal_shock_relations`

Array of real numerical values for one of the normal shock relations. This argument can be one of the following:

- Array of upstream Mach numbers. This array must be a scalar or an array of *N* real numbers greater than or equal to 1. If *normal_shock_relations* and *gamma* are arrays, they must be the same size.

  Use *normal_shock_relations* with *mtype* value 'mach'. Because '*mach*' is the default of *mtype*, *mtype* is optional when this array is the input mode.

- Scalar value of temperature ratio. The temperature ratio is the static temperature downstream of the shock over the static temperature upstream of the shock. *normal_shock_relations* must be a real scalar greater than or equal to 1.

  Use *normal_shock_relations* with *mtype* value '*temp*'.

- Array of pressure ratios. The pressure ratio is the static pressure downstream of the shock over the static pressure upstream of the shock. *normal_shock_relations* must be a scalar or array of real numbers greater than or equal to 1. If *normal_shock_relations* and *gamma* are arrays, they must be the same size.

  Use *normal_shock_relations* with *mtype* value '*pres*'.

- Array of density ratios. The density ratio is the density of the fluid downstream of the shock over the density upstream of the shock. *normal_shock_relations* must a scalar or array of real numbers be:

  - Greater than or equal to 1 (at Mach number equal 1)
  - Less than or equal to (*gamma*+1)/(*gamma*-1) (as the Mach number approaches infinity)

  If *normal_shock_relations* and *gamma* are arrays, they must be the same size. Use *normal_shock_relations* with *mtype* value '*dens*'.

- Array of downstream Mach numbers. *normal_shock_relations* must be scalar or array of real numbers:
  - Greater than or equal to 0 (as the Mach number approaches infinity)
  - Less than or equal to sqrt((*gamma*-1)/(2**gamma*)) (at Mach number equal 1)

  If *normal_shock_relations* and *gamma* are arrays, they must be the same size. Use *normal_shock_relations* with *mtype* value '*down*'.

- Scalar value of total pressure ratio. The total pressure ratio is the total pressure downstream of the shock over the total pressure upstream of the shock. *normal_shock_relations* must be:
  - Greater than or equal to 0 (as the Mach number approaches infinity)
  - Less than or equal to 1 (at Mach number equal 1)

  If *normal_shock_relations* and *gamma* are both arrays, they must be the same size. Use *normal_shock_relations* with *mtype* value 'totalp'.

- Scalar value of Rayleigh-Pitot ratio. The Rayleigh-Pitot ratio is the static pressure upstream of the shock over the total pressure downstream of the shock. *normal_shock_relations* must be:
  - Real scalar greater than or equal to 0 (as the Mach number approaches infinity)
  - Less than or equal to ((*gamma*+1)/2)^(-*gamma*/(*gamma*-1)) (at Mach number equal 1)

  If *normal_shock_relations* and *gamma* are both arrays, they must be the same size. Use *normal_shock_relations* with *mtype* value 'pito'.

`mtype`

A string that defines the input mode for the normal shock relations in *`normal_shock_relations`*.

Type	Description
`'mach'`	Default. Mach number.
`'temp'`	Temperature ratio.
`'pres'`	Pressure ratio.
`'dens'`	Density ratio.
`'velo'`	Velocity ratio.
`'totalp'`	Total pressure ratio.
`'pito'`	Rayleigh-Pitot ratio.

Output Arguments

`mach`

Array of upstream Mach numbers.

`P`

Array of pressure ratios. The pressure ratio is the static pressure downstream of the shock over the static pressure upstream of the shock.

`T`

Array of temperature ratios. The temperature ratio is the static temperature downstream of the shock over the static temperature upstream of the shock.

`rho`

Array of density ratios. The density ratio is the density of the fluid downstream of the shock over the density upstream of the shock.

`downstream_mach`

Array of downstream Mach numbers.

`P0`

Array of total pressure ratios. The total pressure ratio is the total pressure downstream of the shock over the total pressure upstream of the shock.

`P1`

Array of Rayleigh-Pitot ratios. The Rayleigh-Pitot ratio is the static pressure upstream of the shock over the total pressure downstream of the shock.

Examples

Calculate the normal shock relations for air (*gamma* = 1.4) for total pressure ratio of 0.61. The following returns scalar values for *mach*, *T*, *P*, *rho*, *downstream_mach*, *P0*, and *P1*.

```
[mach, T, P, rho, downstream_mach, P0, P1] = flownormalshock(1.4, 0.61, 'totalp')
```

Calculate the normal shock relations for gases with specific heat ratios given in the following 1 x 4 row array for upstream Mach number 1.5. The follow yields a 1 x 4 array for *mach*, *T*, *P*, *rho*, *downstream_mach*, *P0*, and *P1*.

```
gamma = [1.3, 1.33, 1.4, 1.67];
[mach, T, P, rho, downstream_mach, P0, P1] = flownormalshock(gamma, 1.5)
```

Calculate the normal shock relations for a specific heat ratio of 1.4 and range of density ratios from 2.40 to 2.70 in increments of 0.10. The following returns a 4 x 1 column array for *mach*, *T*, *P*, *rho*, *downstream_mach*, *P0*, and *P1*.

```
[mach, T, P, rho, downstream_mach, P0, P1] = flownormalshock(1.4,...
 (2.4:.1:2.7)', 'dens')
```

Calculate the normal shock relations for gases with specific heat ratio and downstream Mach number combinations as shown. The following example returns a 1 x 2 array for `mach`, `T`, `P`, `rho`, `downstream_mach`, `P0`, and `P1` each, where the elements of each vector corresponds to the inputs element-wise.

```
gamma = [1.3, 1.4];
downstream_mach = [.34, .49];
[mach, T, P, rho, downstream_mach, P0, P1] = flownormalshock(gamma,...
 downstream_mach, 'down')
```

References

1. James, J. E. A., *Gas Dynamics, Second Edition*, Allyn and Bacon, Inc, Boston, 1984.

2. *NACA Technical Report 1135*, 1953, National Advisory Committee on Aeronautics, Ames Research Staff, Moffett Field, Calif. Pages 667–671.

See Also

`flowisentropic` | `flowprandtlmeyer` | `flowfanno` | `flowrayleigh`

Purpose

Calculate Prandtl-Meyer functions for expansion waves

Syntax

```
[mach, nu, mu] = flowprandtlmeyer(gamma,
prandtlmeyer_array,
   mtype)
```

Description

`[mach, nu, mu] = flowprandtlmeyer(gamma, prandtlmeyer_array, mtype)` calculates the following: array of Mach numbers, *mach*, Prandtl-Meyer angles (*nu* in degrees) and Mach angles (*mu* in degrees). `flowprandtlmeyer` calculates these arrays for a given set of specific heat ratios, *gamma*, and any one of the Prandtl-Meyer types. You select the Prandtl-Meyer type with *mtype*.

The function assumes that the flow is two-dimensional. The function also assumes a smooth and gradual change in flow properties through the expansion fan.

Note, this function assumes that the environment is a perfect gas. In the following instances, it cannot assume a perfect gas environment. If there is a large change in either temperature or pressure without a proportionally large change in the other, it cannot assume a perfect gas environment. If the stagnation temperature is above 1500 K, the function cannot assume constant specific heats. In this case, you must consider it a thermally perfect gas. See 2 for thermally perfect gas correction factors. The local static temperature might be so high that molecules dissociate and ionize (static temperature 5000 K for air). In this case, you cannot assume a calorically or thermally perfect gas.

Input Arguments

`gamma`

Array of *N* specific heat ratios. *gamma* must be a scalar or array of *N* real numbers greater than 1. For subsonic area ratio input mode and supersonic area ratio input mode, *gamma* must be a real, finite scalar greater than 1.

`prandtlmeyer_array`

Array of real numerical values for one of the Prandtl-Meyer types. This argument can be one of the following:

- Array of Mach numbers. This array must be a scalar or an array of *N* real numbers greater than or equal to 0. If *prandtlmeyer_array* and *gamma* are arrays, they must be the same size.

  Use *prandtlmeyer_array* with *mtype* value `'mach'`. Note, because `'mach'` is the default of *mtype*, *mtype* is optional when this array is the input mode.

- Scalar value for Prandtl-Meyer angle in degrees. This value is the angle change required for a Mach 1 flow to achieve a given Mach number after expansion. *prandtlmeyer_array* must be:

  - Real scalar greater than or equal to 0 (at Mach number equal 1)
  - Less than or equal to 90 * (sqrt((*gamma*+1)/(*gamma*-1)) - 1) (as the Mach number approaches infinity).

  Use *prandtlmeyer_array* with *mtype* value `'nu'`.

- Array of Mach angles in degrees. These values are the angles between the flow direction and the lines of pressure disturbance caused by supersonic motion. The Mach angle is a function of Mach number only. *prandtlmeyer_array* must be a scalar or array of *N* real numbers that are:

  - Greater than or equal to 0 (as the Mach number approaches infinity).
  - Less than or equal to 90 (at Mach number equal 1).

  Use *prandtlmeyer_array* with *mtype* value `'mu'`.

`mtype`

A string for selecting the isentropic flow variable represented by *prandtlmeyer_array*.

Type	Description
'mach'	Default. Mach number..
'nu'	Prandtl-Meyer angle
'mu'	Mach angle.

Output Arguments

mach

Array of Mach numbers. In Prandtl-Meyer angle input mode, *mach* outputs are the same size as the array input or array inputs. If there are no array inputs, *mach* is a scalar.

nu

Array of Prandtl-Meyer angles. The Prandtl-Meyer angle is the angle change required for a Mach 1 flow to achieve a given Mach number after expansion.

mu

Array of Mach angles. The Mach angle is between the flow direction and the lines of pressure disturbance caused by supersonic motion.

Examples

Calculate the Prandtl-Meyer relations for air (*gamma* = 1.4) for Prandtl-Meyer angle 61 degrees. The following returns a scalar for *mach*, *nu*, and *mu*.

```
[mach, nu, mu] = flowprandtlmeyer(1.4, 61, 'nu')
```

Calculate the Prandtl-Meyer functions for gases with specific heat ratios. The following yields a 1 x 4 array for *nu*, but only a scalar for *mach* and *mu*.

```
gamma = [1.3, 1.33, 1.4, 1.67];
[mach, nu, mu] = flowprandtlmeyer(gamma, 1.5)
```

Calculate the Prandtl-Meyer angles for a specific heat ratio of 1.4 and range of Mach angles from 40 degrees to 70 degrees. This example uses increments of 10 degrees. The following returns a 4 x 1 column array for *mach*, *nu*, and *mu*.

```
[mach, nu, mu] = flowprandtlmeyer(1.4, (40:10:70)', 'mu')
```

Calculate the Prandtl-Meyer relations for gases with specific heat ratio and Mach number combinations as shown. The following returns a 1 x 2 array for *nu* and *mu* each, where the elements of each vector correspond to the inputs element-wise.

```
gamma = [1.3, 1.4];
prandtlmeyer_array = [1.13, 9];
[mach, nu, mu] = flowprandtlmeyer(gamma,prandtlmeyer_array)
```

References

1. James, J. E. A., *Gas Dynamics, Second Edition*, Allyn and Bacon, Inc, Boston, 1984.

2. *NACA Technical Report 1135*, 1953, National Advisory Committee on Aeronautics, Ames Research Staff, Moffett Field, Calif. Pages 667–671.

See Also

`flowisentropic` | `flownormalshock` | `flowrayleigh` | `flowfanno`

Purpose

Rayleigh line flow relations

Syntax

```
[mach, T, P, rho, velocity, T0, P0] = flowrayleigh(gamma,
   rayleigh_flow, mtype)
```

Description

`[mach, T, P, rho, velocity, T0, P0] = flowrayleigh(gamma, rayleigh_flow, mtype)` returns an array for each Rayleigh line flow relation. This function calculates these arrays for a given set of specific heat ratios (`gamma`), and any one of the Rayleigh line flow types. You select the Rayleigh flow type with `mtype`.

This function assumes that the medium is a calorically perfect gas in a constant area duct. It assumes that the flow is steady, frictionless, and one dimensional. It also assumes that the main mechanism for the change of flow variables is heat transfer.

This function assumes that the environment is a perfect gas. In the following instances, it cannot assume a perfect gas environment. If there is a large change in either temperature or pressure without a proportionally large change in the other, it cannot assume a perfect gas environment. If the stagnation temperature is above 1500 K, do not assume constant specific heats. In this case, the medium ceases to be a calorically perfect gas; you must then consider it a thermally perfect gas. See 2 for thermally perfect gas correction factors. The local static temperature might be so high that molecules dissociate and ionize (static temperature 5000 K for air). In this case, you cannot assume a calorically or thermally perfect gas.

Input Arguments

`gamma`

Array of *N* specific heat ratios. `gamma` must be either a scalar or an array of *N* real numbers greater than 1. `gamma` must be a real, finite scalar greater than 1 for the following input modes: low speed temperature ratio, high speed temperature ratio, subsonic total temperature, supersonic total temperature, subsonic total pressure, and supersonic total pressure.

`rayleigh_flow`

Array of real numerical values for one Rayleigh line flow. This argument can be one of the following:

- Array of Mach numbers. This array must be a scalar or an array of *N* real numbers greater than or equal to 0. If *rayleigh_flow* and *gamma* are arrays, they must be the same size.

  Use *rayleigh_flow* with *mtype* value 'mach'. Because '*mach*' is the default of *mtype*, *mtype* is optional when this array is the input mode.

- Scalar value of temperature ratio. The temperature ratio is the local static temperature over the reference static temperature for sonic flow. *rayleigh_flow* must be a real scalar:

  - Greater than or equal to 0 (at the Mach number equal 0 for low speeds or as Mach number approaches infinity for high speeds)
  - Less than or equal to 1/4*(*gamma*+1/*gamma*)+1/2 (at *mach* = 1/sqrt(*gamma*))

  Use *rayleigh_flow* with *mtype* values '*templo*' and '*temphi*'.

- Array of pressure ratios. The pressure ratio is the local static pressure over the reference static pressure for sonic flow. *rayleigh_flow* must be a scalar or array of real numbers less than or equal to *gamma*+1 (at the Mach number equal 0). If *rayleigh_flow* and *gamma* are arrays, they must be the same size.

  Use *rayleigh_flow* with *mtype* value '*pres*'.

- Array of density ratios. The density ratio is the local density over the reference density for sonic flow. *rayleigh_flow* must be a scalar or array of real numbers. These numbers must be greater than or equal to:

  gamma/(*gamma*+1) (as Mach number approaches infinity)

  If *rayleigh_flow* and *gamma* are arrays, they must be the same size.

Use *rayleigh_flow* with *mtype* value '*dens*'.

- Array of velocity ratios. The velocity ratio is the local velocity over the reference velocity for sonic flow. *rayleigh_flow* must be a scalar or an array of *N* real numbers:
  - Greater than or equal to 0
  - Less than or equal to (*gamma*+1)/*gamma* (as Mach number approaches infinity)

  If *rayleigh_flow* and *gamma* are both arrays, they must be the same size.

  Use *rayleigh_flow* with *mtype* value 'velo'.

- Scalar value of total temperature ratio. The total temperature ratio is the local stagnation temperature over the reference stagnation temperature for sonic flow. In subsonic mode, *rayleigh_flow* must be a real scalar:
  - Greater than or equal to 0 (at the Mach number equal 0)
  - Less than or equal to 1 (at the Mach number equal 1)

  In supersonic mode, *rayleigh_flow* must be a real scalar:
  - Greater than or equal to (*gamma*+1)^2*(*gamma*-1)/2/(*gamma*^2*(1+(*gamma*-1)/2))) (as Mach number approaches infinity)
  - Less than or equal to 1 (at the Mach number equal 1)

  Use *rayleigh_flow* with the *mtype* values 'totaltsub' and 'totaltsup'.

- Scalar value of total pressure ratio. The total pressure ratio is the local stagnation pressure over the reference stagnation pressure for sonic flow. In subsonic mode, *rayleigh_flow* must be a real scalar.
  - Greater than or equal to 1 (at the Mach number equal 1)

- Less than or equal to (1+*gamma*)*(1+(*gamma*-1)/2)^(-*gamma*/(*gamma*-1)) (at Mach number equal 0)

In supersonic mode, *rayleigh_flow* must be a real scalar greater than or equal to 1.

Use *rayleigh_flow* with *mtype* values 'totalpsub' and 'totalpsup'.

mtype

A string that defines the input mode for the Rayleigh flow in *rayleigh_flow*.

Type	Description
'mach'	Default. Mach number.
'templo'	Low speed static temperature ratio. The low speed temperature ratio is the local static temperature over the reference sonic temperature. This ratio for when the Mach number of the upstream flow is less than the critical Mach number of 1/sqrt(*gamma*).
'temphi'	High speed static temperature ratio. The high speed temperature ratio is the local static temperature over the reference sonic temperature. This ratio is for when the Mach number of the upstream flow is greater than the critical Mach number of 1/sqrt(*gamma*).
'pres'	Pressure ratio.
'dens'	Density ratio.
'velo'	Velocity ratio.
'totaltsub'	Subsonic total temperature ratio.
'totaltsup'	Supersonic total temperature ratio.

Type	Description
'totalpsub'	Subsonic total pressure ratio.
'totalpsup'	Supersonic total pressure ratio.

Output Arguments

All output ratios are static conditions over the sonic conditions. All outputs are the same size as the array inputs. If there are no array inputs, all outputs are scalars.

`mach`

Array of Mach numbers.

`T`

Array of temperature ratios. The temperature ratio is the local static temperature over the reference static temperature for sonic flow.

`P`

Array of pressure ratios. The pressure ratio is the local static pressure over the reference static pressure for sonic flow.

`rho`

Array of density ratio. The density ratio is the local density over the reference density for sonic flow.

`velocity`

Array of velocity ratios. The velocity ratio is the local velocity over the reference velocity for sonic flow.

`T0`

Array of total temperature ratios. The temperature ratio is the local static temperature over the reference static temperature for sonic flow.

`P0`

Array of total pressure ratios. The total pressure ratio is the local stagnation pressure over the reference stagnation pressure for sonic flow.

Examples

Calculate Rayleigh Line Flow Relations Given Air

Calculate the Rayleigh line flow relations for air (*gamma* = 1.4) for supersonic total pressure ratio 1.2.

```
[mach,T,P,rho,velocity,T0,P0] =
flowrayleigh(1.4,1.2,'totalpsup')

mach =

    1.6397

T =

    0.6823

P =

    0.5038

rho =

    0.7383

velocity =

    1.3545

T0 =

    0.8744

P0 =
```

```
    1.2000
```

This example returns scalar values for *mach*, *T*, *P*, *rho*, *velocity*, *T0*, and *P0*.

Calculate Rayleigh Line Flow Relations for Specific Heat Ratios in Array

Calculate the Rayleigh line flow relations for gases with specific heat ratios given in the following 1 x 4 row array for the Mach number 0.5.

```
gamma = [1.3,1.33,1.4,1.67];
[mach,T,P,rho,velocity,T0,P0] = flowrayleigh(gamma,0.5)

mach =

    0.5000    0.5000    0.5000    0.5000

T =

    0.7533    0.7644    0.7901    0.8870

P =

    1.7358    1.7486    1.7778    1.8836

rho =

    2.3043    2.2876    2.2500    2.1236

velocity =

    0.4340    0.4371    0.4444    0.4709

T0 =

    0.6796    0.6832    0.6914    0.7201
```

```
P0 =

    1.1111    1.1121    1.1141    1.1202
```

This example returns a 1 x 4 row array for *mach*, *T*, *P*, *rho*, *velocity*, *T0*, and *P0*.

Calculate Rayleigh Line Flow Relations for Specific Heat Ratios and High Speed Temperature

Calculate the Rayleigh line flow relations for a specific heat ratio of 1.4 and high speed temperature ratio 0.70.

```
[mach,T,P,rho,velocity,T0,P0] =
flowrayleigh(1.4,0.70,'temphi')

mach =

    1.6035

T =

    0.7000

P =

    0.5218

rho =

    0.7454

velocity =

    1.3416

T0 =
```

```
    0.8833

P0 =

    1.1777
```

This example returns scalar values for *mach*, *T*, *P*, *rho*, *velocity*, *T0*, and *P0*.

Calculate Rayleigh Line Flow Relations for Gases with Specific Heat Ratio and Static Pressure

Calculate the Rayleigh line flow relations for gases with specific heat ratio and static pressure ratio combinations as shown.

```
gamma = [1.3,1.4];
P = [0.13,1.7778];
[mach,T,P,rho,velocity,T0,P0] =
flowrayleigh(gamma,P,'pres')

mach =

    3.5833    0.5000

T =

    0.2170    0.7901

P =

    0.1300    1.7778

rho =

    0.5991    2.2501

velocity =
```

```
    1.6692    0.4444

T0 =

    0.5521    0.6913

P0 =

    7.4381    1.1141
```

This example returns a 1 x 2 array for *mach*, *T*, *P*, *rho*, *velocity*, *T0*, and *P0* each. The elements of each array correspond to the inputs element-wise.

References

1. James, J. E. A., *Gas Dynamics, Second Edition*, Allyn and Bacon, Inc, Boston, 1984.

2. *NACA Technical Report 1135*, 1953, National Advisory Committee on Aeronautics, Ames Research Staff, Moffett Field, Calif. Pages 667–671.

See Also

`flowisentropic` | `flownormalshock` | `flowprandtlmeyer` | `flowfanno`

Purpose

Generate patches for body with loaded face, vertex, and color data

Syntax

```
generatePatches(h, ax)
h.generatePatches(ax)
```

Description

`generatePatches(h, ax)` and `h.generatePatches(ax)` generate patches for the animation body object `h` using the loaded face, vertex, and color data in `ax`.

Examples

Generate patches for `b` using the axes, *ax*.

```
b=Aero.Body;
b.load('pa24-250_orange.ac','Ac3d');
f = figure;
ax = axes;
b.generatePatches(ax);
```

See Also

`load`

GenerateRunScript (Aero.FlightGearAnimation)

Purpose

Generate run script for FlightGear flight simulator

Syntax

```
GenerateRunScript(h)
h.GenerateRunScript
```

Description

`GenerateRunScript(h)` and `h.GenerateRunScript` generate a run script for FlightGear flight simulator using the following FlightGear animation object properties:

`OutputFileName`	Specify the name of the output file. The file name is the name of the command you will use to start FlightGear with these initial parameters. The default value is `'runfg.bat'`.
`FlightGearBaseDirectory`	Specify the name of your FlightGear installation folder. The default value is `'D:\Applications\FlightGear'`.
`GeometryModelName`	Specify the name of the folder containing the desired model geometry in the *`FlightGear`*`\data\Aircraft` folder. The default value is `'HL20'`.
`DestinationIpAddress`	Specify your destination IP address. The default value is `'127.0.0.1'`.
`DestinationPort`	Specify your network flight dynamics model (fdm) port. This destination port should be an unused port that you can use when you launch FlightGear. The default value is `'5502'`.

AirportId	Specify the airport ID. The list of supported airports is available in the FlightGear interface, under **Location**. The default value is 'KSFO'.
RunwayId	Specify the runway ID. The default value is '10L'.
InitialAltitude	Specify the initial altitude of the aircraft, in feet. The default value is 7224 feet.
InitialHeading	Specify the initial heading of the aircraft, in degrees. The default value is 113 degrees.
OffsetDistance	Specify the offset distance of the aircraft from the airport, in miles. The default value is 4.72 miles.
OffsetAzimuth	Specify the offset azimuth of the aircraft, in degrees. The default value is 0 degrees.

Examples

Create a run script, `runfg.bat`, to start FlightGear flight simulator using the default object settings:

```
h = fganimation
GenerateRunScript(h)
```

Create a run script, `myscript.bat`, to start FlightGear flight simulator using the default object settings:

```
h = fganimation
h.OutputFileName = 'myscript.bat'
GenerateRunScript(h)
```

See Also

`initialize` | `play` | `update`

geoc2geod

Purpose

Convert geocentric latitude to geodetic latitude

Syntax

```
geodeticLatitude = geoc2geod(geocentricLatitude, radii)
geodeticLatitude = geoc2geod(geocentricLatitude, radii,
   model)
geodeticLatitude = geoc2geod(geocentricLatitude, radii,
   flattening, equatorialRadius)
```

Description

`geodeticLatitude = geoc2geod(geocentricLatitude, radii)` converts an array of *m*-by-1 geocentric latitudes and an array of radii from the center of the planet into an array of *m*-by-1 geodetic latitudes.

`geodeticLatitude = geoc2geod(geocentricLatitude, radii, model)` converts for a specific ellipsoid planet.

`geodeticLatitude = geoc2geod(geocentricLatitude, radii, flattening, equatorialRadius)` converts for a custom ellipsoid planet defined by flattening and the equatorial radius.

The function uses geometric relationships to calculate the geodetic latitude in this noniterative method.

This function has the limitation that this implementation generates a geodetic latitude that lies between ±90 degrees.

Input Arguments

`geocentricLatitude`

Array of *m*-by-1 geocentric latitudes, in degrees.

`radii`

Array of radii from the center of the planet, in meters.

`model`

Specific ellipsoid planet specified as a string. This function supports only `'WGS84'`.

`flattening`

Custom ellipsoid planet defined by flattening.

`equatorialRadius`

Equatorial radius, in meters.

Output Arguments

`geodeticLatitude`

Array of *m*-by-1 geodetic latitudes, in degrees.

Examples

Determine geodetic latitude given a geocentric latitude and radius:

```
gd = geoc2geod(45, 6379136)


gd =

   45.1921
```

Determine geodetic latitude at multiple geocentric latitudes, given a radius, and specifying WGS84 ellipsoid model:

```
gd = geoc2geod([0 45 90], 6379136, 'WGS84')


gd =

         0   45.1921   90.0000
```

Determine geodetic latitude at multiple geocentric latitudes, given a radius, and specifying custom ellipsoid model:

```
f = 1/196.877360;
Re = 3397000;
gd = geoc2geod([0 45 90], 6379136, f, Re)


gd =
```

```
0   45.1550   90.0000
```

References

Jackson, E.B., *Manual for a Workstation-based Generic Flight Simulation Program (LaRCsim) Version 1.4*, NASA TM 110164, April 1995

Hedgley, D. R., Jr., *An Exact Transformation from Geocentric to Geodetic Coordinates for Nonzero Altitudes*, NASA TR R-458, March, 1976

Clynch, J. R., *Radius of the Earth — Radii Used in Geodesy*, Naval Postgraduate School, 2002, `http://www.oc.nps.navy.mil/oc2902w/geodesy/radiigeo.pdf`

Stevens, B. L., and F. L. Lewis, *Aircraft Control and Simulation*, John Wiley & Sons, New York, NY, 1992

Edwards, C. H., and D. E. Penny, *Calculus and Analytical Geometry*, 2nd Edition, Prentice-Hall, Englewood Cliffs, NJ, 1986

See Also

`geod2geoc` | `ecef2lla` | `lla2ecef`

Purpose

Estimate radius of ellipsoid planet at geocentric latitude

Syntax

```
r = geocradius(lambda)
r = geocradius(lambda, model)
r = geocradius(lambda, f, Re)
```

Description

`r = geocradius(lambda)` estimates the radius, `r`, of an ellipsoid planet at a particular geocentric latitude, `lambda`. `lambda` is in degrees. `r` is in meters. The default ellipsoid planet is WGS84.

`r = geocradius(lambda, model)` is an alternate method for estimating the radius for a specific ellipsoid planet. Currently only `'WGS84'` is supported for `model`.

`r = geocradius(lambda, f, Re)` is another alternate method for estimating the radius for a custom ellipsoid planet defined by flattening, `f`, and the equatorial radius, `Re`, in meters.

Examples

Determine radius at 45 degrees latitude:

```
r = geocradius(45)


r =

  6.3674e+006
```

Determine radius at multiple latitudes:

```
r = geocradius([0 45 90])


r =

  1.0e+006 *

    6.3781    6.3674    6.3568
```

Determine radius at multiple latitudes, specifying WGS84 ellipsoid model:

```
r = geocradius([0 45 90], 'WGS84')


r =

  1.0e+006 *

    6.3781    6.3674    6.3568
```

Determine radius at multiple latitudes, specifying custom ellipsoid model:

```
f = 1/196.877360;
Re = 3397000;
r = geocradius([0 45 90], f, Re)


r =

  1.0e+006 *

    3.3970    3.3883    3.3797
```

References

Stevens, B. L., and F. L. Lewis, *Aircraft Control and Simulation*, John Wiley & Sons, New York, NY, 1992

Zipfel, P. H., and D. E. Penny, *Modeling and Simulation of Aerospace Vehicle Dynamics*, AIAA Education Series, Reston, VA, 2000

See Also

`geoc2geod` | `geod2geoc`

Purpose

Convert geodetic latitude to geocentric latitude

Syntax

```
gc = geod2geoc(gd, h)
gc = geod2geoc(gd, h, model)
gc = geod2geoc(gd, h, f, Re)
```

Description

`gc = geod2geoc(gd, h)` converts an array of `m` geodetic latitudes, `gd`, and an array of mean sea level altitudes, `h`, into an array of `m` geocentric latitudes, `gc`. Both `gc` and `gd` are in degrees. `h` is in meters.

`gc = geod2geoc(gd, h, model)` is an alternate method for converting from geodetic to geocentric latitude for a specific ellipsoid planet. Currently only `'WGS84'` is supported for `model`.

`gc = geod2geoc(gd, h, f, Re)` is another alternate method for converting from geodetic to geocentric latitude for a custom ellipsoid planet defined by flattening, `f`, and the equatorial radius, `Re`, in meters.

Examples

Determine geocentric latitude given a geodetic latitude and altitude:

```
gc = geod2geoc(45, 1000)


gc =

   44.8076
```

Determine geocentric latitude at multiple geodetic latitudes and altitudes, specifying WGS84 ellipsoid model:

```
gc = geod2geoc([0 45 90], [1000 0 2000], 'WGS84')


gc =

         0
   44.8076
   90.0000
```

Determine geocentric latitude at multiple geodetic latitudes, given an altitude and specifying custom ellipsoid model:

```
f = 1/196.877360;
Re = 3397000;
gc = geod2geoc([0 45 90], 2000, f, Re)


gc =

         0
   44.7084
   90.0000
```

Assumptions and Limitations

This implementation generates a geocentric latitude that lies between ±90 degrees.

References

Stevens, B. L., and F. L. Lewis, *Aircraft Control and Simulation*, John Wiley & Sons, New York, NY, 1992

See Also

`geoc2geod` | `ecef2lla` | `lla2ecef`

Purpose

Calculate geoid height as determined from EGM96 Geopotential Model

---

Note `geoidegm96` will be removed in a future version. Use `geoidheight` instead.

Syntax

```
N = geoidegm96(lat, long)
N = geoidegm96(lat, long, action)
```

Description

`N = geoidegm96(lat, long)` calculates the geoid height as determined from the EGM96 Geopotential Model. It calculates geoid heights to 0.01 meters. This function interpolates geoid heights from a 15-minute grid of point values in the tide-free system, using the EGM96 Geopotential Model to the degree and order 360. The geoid undulations are relative to the WGS84 ellipsoid.

`N = geoidegm96(lat, long, action)` calculates the geoid height as determined from the EGM96 Geopotential Model. This function performs `action` if `latitude` or `longitude` are out of range.

Inputs required by `geoidegm96`:

`lat`	An array of `m` geocentric latitudes, in degrees, where north latitude is positive and south latitude is negative. `lat` must be of type single or double. If `lat` is not within the range -90 to 90, inclusive, this function wraps the value to be within the range.
`long`	An array of `m` geocentric longitudes, in degrees, where east longitude is positive and west longitude is negative. `long` must be of type single or double. If `long` is not within the range 0 to 360 inclusive, this function

	wraps the value to be within the range.
`action`	A string to determine action for out-of-range input. Specify if out-of-range input invokes a `'Warning'`, `'Error'`, or no action (`'None'`). The default is `'Warning'`.

Examples

Calculate the geoid height at 42.4 degrees N latitude and 71.0 degrees E longitude.

```
N = geoidegm96( 42.4, 71.0)
```

Calculate the geoid height at two different locations, with out-of-range actions generating warnings.

```
N = geoidegm96( [39.3,33.4], [-77.2, 36.5])
```

Calculate the geoid height with latitude wrapping, with out-of-range actions displaying no warnings.

```
N = geoidegm96(100,150,'None')
```

Limitations

This function has the limitations of the 1996 Earth Geopotential Model. For more information, see `http://earth-info.nga.mil/GandG/wgs84/gravitymod/egm96/egm96.html`.

The WGS84 EGM96 geoid undulations have an error range of +/-0.5 to +/-1.0 meters worldwide.

References

NIMA TR8350.2: "Department of Defense World Geodetic System 1984, Its Definition and Relationship with Local Geodetic Systems."

NASA/TP-1998-206861: "The Development of the Joint NASA GSFC and NIMA Geopotential Model EGM96"

National Geospatial-Intelligence Agency Website: `http://earth-info.nga.mil/GandG/wgs84/gravitymod/egm96/egm96.html`

See Also

`gravitywgs84`

geoidheight

Purpose

Calculate geoid height

Syntax

```
N = geoidheight(latitude,longitude)
N = geoidheight(latitude, longitude, modelname)
N = geoidheight(latitude, longitude, action)
N = geoidheight(latitude, longitude, modelname, action)
N = geoidheight(latitude, longitude, 'Custom', datafile)
N = geoidheight(latitude, longitude, 'Custom', datafile,
   action)
```

Description

`N = geoidheight(latitude,longitude)` calculates the geoid height using the EGM96 Geopotential Model. For this model, it calculates these geoid heights to an accuracy of 0.01 m. It interpolates an array of *m* geoid heights at *m* geocentric latitudes, *latitude*, and *m* geocentric longitudes, *longitude*.

`N = geoidheight(latitude, longitude, modelname)` calculates the geoid height using the model, *modelname*.

`N = geoidheight(latitude, longitude, action)` calculates the geoid height using the EGM96 Geopotential Model. This function performs *action* if *latitude* or *longitude* are out of range.

`N = geoidheight(latitude, longitude, modelname, action)` calculates the geoid height using *modelname*.

`N = geoidheight(latitude, longitude, 'Custom', datafile)` calculates the geoid height using a custom model that *datafile* defines.

`N = geoidheight(latitude, longitude, 'Custom', datafile, action)` calculates the geoid height using the custom model. This function performs *action* if *latitude* or `longitude` are out of range.

Tips

- This function interpolates geoid heights from a grid of point values in the tide-free system.
- When using the EGM96 Model, this function has the limitations of the 1996 Earth Geopotential Model.

- When using the EGM2008 Model, this function has the limitations of the 2008 Earth Geopotential Model.
- The interpolation scheme wraps over the poles to allow for geoid height calculations at and near pole locations.
- The geoid undulations for the EGM96 and EGM2008 models are relative to the WGS84 ellipsoid.
- The WGS84 EGM96 geoid undulations have an error range of +/– 0.5 to +/– 1.0 m worldwide.

Input Arguments

`latitude`

An array of *m* geocentric latitudes, in degrees, where north latitude is positive and south latitude is negative. *latitude* must be of type single or double. If *latitude* is not within the range –90 to 90, inclusive, this function wraps the value to be within the range.

`longitude`

An array of *m* geocentric longitudes, in degrees, where east longitude is positive and west longitude is negative. *longitude* must be of type single or double. If *longitude* is not within the range 0 to 360 inclusive, this function wraps the value to be within the range.

`model`

String that specifies the geopotential model.

Geopotential Model	Description
'EGM96'	EGM96 Geopotential Model to degree and order 360. This model uses a 15-minute grid of point values in the tide-free system. This function calculates geoid heights to an accuracy of 0.01 m for this model.
'EGM2008'	EGM2008 Geopotential Model to degree and order 2159. This model uses a 2.5-minute grid of point values in the tide-free system. This function calculates geoid heights to an accuracy of 0.001 m for this model.

'Custom'	Custom geopotential model that you define in *datafile*. This function calculates geoid heights to an accuracy of 0.01 m for custom models.
	
	Note To deploy a custom geopotential model, explicitly include the custom data and reader files to the MATLAB® Compiler™ (mcc) command at compilation. For example:
	
	`mcc -m mycustomsgeoidheightfunction...`
	`-a customDataFile -a customReaderFile`
	
	For other geopotential models, use the MATLAB Compiler as usual.

Default: EGM96

`datafile`

Optional file that contains definitions for a custom geopotential model. Provide this file only if you specify `'Custom'` for the `model` argument. For an example of file content, see `aerogmm2b.mat`.

This file must contain the following variables.

Variable	Description
`'latbp'`	Array of geocentric latitude breakpoints.
`'lonbp'`	Array of geocentric longitude breakpoints.
`'grid'`	Table of geoid height values.
`'windowSize'`	Even integer scalar greater than 2 for the number of interpolation points.

`action`

String that defines action for out-of-range input. Specify one:

`'Error'`
`'Warning'`
`'None'`

Default: `Warning`

Output Arguments

`N`

An array of *M* geoid heights in meters. The values in this array have the same data type as *latitude*.

Examples

Calculate the EGM96 geoid height at 42.4 degrees N latitude and 71.0 degrees W longitude with warning actions:

```
N = geoidheight( 42.4, -71.0 )
```

Calculate the EGM2008 geoid height at two different locations with error actions.

```
N = geoidheight( [39.3, 33.4], [77.2, 36.5], 'egm2008', ...
'error')
```

Calculate a custom geoid height at two different locations with no actions.

```
N = geoidheight( [39.3, 33.4], [-77.2, 36.5], 'custom', ...
'geoidegm96grid','none')
```

References

Vallado, D. A. “Fundamentals of Astrodynamics and Applications.” McGraw-Hill, New York, 1997.

NIMA TR8350.2: "Department of Defense World Geodetic System 1984, Its Definition and Relationship with Local Geodetic Systems."

See Also

`gravitywgs84` | `gravitysphericalharmonic`

Related Links

- National Geospatial-Intelligence Agency Web site: http://earth-info.nga.mil/GandG/publications/vertdatum.html

Purpose

Construct 3-D geometry for use with animation object

Syntax

```
h = Aero.Geometry
```

Description

`h = Aero.Geometry` defines a 3-D geometry for use with an animation object.

See `Aero.Geometry` for further details.

See Also

`Aero.Geometry`

gravitycentrifugal

Purpose

Implement centrifugal effect of planetary gravity

Syntax

```
[gx gy gz] = gravitycentrifugal(planet_coordinates)
[gx gy gz] = gravitycentrifugal(planet_coordinates, model )
[gx gy gz] = gravitycentrifugal(planet_coordinates,
'Custom',
   rotational_rate)
```

Description

`[gx gy gz] = gravitycentrifugal(planet_coordinates)` implements the mathematical representation of centrifugal effect for planetary gravity based on planetary rotation rate. This function calculates arrays of *N* gravity values in the *x*-axis, *y*-axis, and *z*-axis of the Planet-Centered Planet-Fixed coordinates for the planet. It performs these calculations using *planet_coordinates*, an *M*-by-3 array of Planet-Centered Planet-Fixed coordinates. You use centrifugal force in rotating or noninertial coordinate systems. Gravity centrifugal effect values are greatest at the equator of a planet.

`[gx gy gz] = gravitycentrifugal(planet_coordinates, model )` implements the mathematical representation of centrifugal effect based on planetary gravitational potential for the planetary model, *model*.

`[gx gy gz] = gravitycentrifugal(planet_coordinates, 'Custom', rotational_rate)` implements the mathematical representation of centrifugal effect based on planetary gravitational potential using the custom rotational rate, *rotational_rate*.

Input Arguments

`planet_coordinates`

M-by-3 array of Planet-Centered Planet-Fixed coordinates in meters. The *z*-axis is positive toward the North Pole. If *model* is `'Earth'`, the planet coordinates are ECEF coordinates.

`model`

String that specifies the planetary model. Default is `'Earth'`. Specify one:

- `'Mercury'`

- 'Venus'
- 'Earth'
- 'Moon'
- 'Mars'
- 'Jupiter'
- 'Saturn'
- 'Uranus'
- 'Neptune'
- 'Custom'

'Custom' requires that you specify your own planetary model using the *rotational_rate* parameter.

rotational_rate

Scalar value that specifies the planetary rotational rate in radians per second. Specify this parameter only if *model* has the value 'Custom'.

Output Arguments

gx

Array of *M* gravity values in the *x*-axis of the Planet-Centered Planet-Fixed coordinates in meters per second squared (m/s^2).

gy

Array of *M* gravity values in the *y*-axis of the Planet-Centered Planet-Fixed coordinates in meters per second squared (m/s^2).

gz

Array of *M* gravity values in the *z*-axis of the Planet-Centered Planet-Fixed coordinates in meters per second squared (m/s^2).

Examples

Calculate the centrifugal effect of Earth gravity in the *x*-axis at the equator on the surface of Earth:

```
gx = gravitycentrifugal( [-6378.1363e3 0 0] )
```

Calculate the centrifugal effect of Mars gravity at 15000 m over the equator and 11000 m over the North Pole:

```
p  = [2412.648e3 -2412.648e3 0; 0 0 3376.2e3]
[gx, gy, gz] = gravitycentrifugal( p, 'Mars' )
```

Calculate the precessing centrifugal effect of gravity for Earth at 15000 m over the equator and 11000 m over the North Pole. This example uses a custom planetary model at Julian date 2451545:

```
p       = [2412.648e3 -2412.648e3 0; 0 0 3376e3]
% Set julian date to January 1, 2000 at noon GMT
JD      = 2451545
% Calculate precession rate in right ascension in meters
pres_RA = 7.086e-12 + 4.3e-15*(JD - 2451545)/36525
% Calculate the rotational rate in a precessing reference
% frame
Omega   = 7.2921151467e-5 + pres_RA
[gx, gy, gz] = gravitycentrifugal( p, 'custom', Omega )
```

See Also

gravitywgs84 | gravitysphericalharmonic | gravityzonal

Purpose

Implement spherical harmonic representation of planetary gravity

Syntax

```
[gx gy gz] = gravitysphericalharmonic(planet_coordinates)
[gx gy gz] = gravitysphericalharmonic(planet_coordinates,
   model)
[gx gy gz] = gravitysphericalharmonic(planet_coordinates,
   degree)
[gx gy gz] = gravitysphericalharmonic(planet_coordinates,
   model, degree)
[gx gy gz] = gravitysphericalharmonic(planet_coordinates,
   model, degree, action)
[gx gy gz] = gravitysphericalharmonic(planet_coordinates,
   'Custom', degree, {datafile dfreader}, action)
```

Description

`[gx gy gz] = gravitysphericalharmonic(planet_coordinates)` implements the mathematical representation of spherical harmonic planetary gravity based on planetary gravitational potential. This function calculates arrays of *N* gravity values in the *x*-axis, *y*-axis, and *z*-axis of the Planet-Centered Planet-Fixed coordinates for the planet. It performs these calculations using *planet_coordinates*, an *M*-by-3 array of Planet-Centered Planet-Fixed coordinates. By default, this function assumes 120th degree and order spherical coefficients for the `'EGM2008'` (Earth) planetary model.

`[gx gy gz] = gravitysphericalharmonic(planet_coordinates, model)` implements the mathematical representation for the planetary model, *model*.

`[gx gy gz] = gravitysphericalharmonic(planet_coordinates, degree)` uses the degree and order that *degree* specifies.

`[gx gy gz] = gravitysphericalharmonic(planet_coordinates, model, degree)` uses the degree and order that *degree* specifies. *model* specifies the planetary model.

`[gx gy gz] = gravitysphericalharmonic(planet_coordinates, model, degree, action)` uses the specified *action* when input is out of range.

gravitysphericalharmonic

[*gx gy gz*] = gravitysphericalharmonic(*planet_coordinates*, 'Custom', *degree*, {*datafile dfreader*}, *action*) implements the mathematical representation for a custom model planet. *datafile* defines the planetary model. *dfreader* specifies the reader for *datafile*.

This function has the following limitations:

- The function excludes the centrifugal effects of planetary rotation, and the effects of a precessing reference frame.
- Spherical harmonic gravity model is valid for radial positions greater than the planet equatorial radius. Minor errors might occur for radial positions near or at the planetary surface. The spherical harmonic gravity model is not valid for radial positions less than planetary surface.

Tips

- When inputting a large PCPF array and a high degree value, you might receive an out-of-memory error. For more information about avoiding out-of-memory errors in the MATLAB environment, see:
- http://www.mathworks.com/support/tech-notes/1100/1107.html

  When inputting a large PCPF array, you might receive a maximum matrix size limitation. To determine the largest matrix or array that you can create in the MATLAB environment for your platform, see:

  http://www.mathworks.com/support/tech-notes/1100/1110.html

Input Arguments

planet_coordinates

M-by-3 array of Planet-Centered Planet-Fixed coordinates in meters. The *z*-axis is positive toward the North Pole. If *model* is 'EGM2008' or 'EGM96' (Earth), the planet coordinates are ECEF coordinates.

model

String that specifies the planetary model. Default is 'EGM2008'. Specify one:

Planetary Model	Planet
`'EGM2008'`	Earth Gravitational Model 2008
`'EGM96'`	Earth Gravitational Model 1996
`'LP100K'`	100th degree Moon model
`'LP165P'`	165th degree Moon model
`'GMM2B'`	Goddard Mars model 2B

`'Custom'`	Custom planetary model that you define in *`datafile`*
	
	Note To deploy a custom planetary model, explicitly include the custom data and reader files to the MATLAB Compiler (`mcc`) command at compilation. For example:
	
	`mcc -m`
	`mycustomsphericalgravityfunction...`
	`-a customDataFile -a customReaderFile`
	
	For other planetary models, use the MATLAB Compiler as usual.

`'EIGENGL04C'`	Combined Earth gravity field model EIGEN-GL04C.

When inputting a large PCPF array and a high degree value, you might receive an out-of-memory error. For more information about avoiding out-of-memory errors in the MATLAB environment, see:

`http://www.mathworks.com/support/tech-notes/1100/1107.html`

When inputting a large PCPF array, you might receive a maximum matrix size limitation. To determine the largest matrix or array that you can create in the MATLAB environment for your platform, see:

`http://www.mathworks.com/support/tech-notes/1100/1110.html`

`degree`

Scalar value that specifies the degree and order of the harmonic gravity model.

Planetary Model	Degree and Order
`'EGM2008'`	Maximum degree and order is 2159. Default degree and order are 120.
`'EGM96'`	Maximum degree and order is 360. Default degree and order are 70.
`'LP100K'`	Maximum degree and order is 100. Default degree and order are 60.
`'LP165P'`	Maximum degree and order is 165. Default degree and order are 60.
`'GMM2B'`	Maximum degree and order is 80. Default degree and order are 60.
`'Custom'`	Maximum degree is default degree and order.
`'EIGENGL04C'`	Maximum degree and order is 360. Default degree and order are 70.

When inputting a large PCPF array and a high degree value, you might receive an out-of-memory error. For more information about avoiding out-of-memory errors in the MATLAB environment, see:

`http://www.mathworks.com/support/tech-notes/1100/1107.html`

When inputting a large PCPF array, you might receive a maximum matrix size limitation. To determine the largest matrix or array that you can create in the MATLAB environment for your platform, see:

`http://www.mathworks.com/support/tech-notes/1100/1110.html`

`action`

String that defines action for out-of-range input. Specify one:

`'Error'`
`'Warning'` (default)
`'None'`

`'Custom'`

String that specifies that *`datafile`* contains definitions for a custom planetary model.

`datafile`

File that contains definitions for a custom planetary model. For an example of file content, see `aerogmm2b.mat`.

This file must contain the following variables.

Variable	Description
Re	Scalar of planet equatorial radius in meters (m)
GM	Scalar of planetary gravitational parameter in meters cubed per second squared (m^3/s^2)
degree	Scalar of maximum degree
C	(*degree*+1)-by-(*degree*+1) matrix containing normalized spherical harmonic coefficients matrix, *C*
S	(*degree*+1)-by-(*degree*+1) matrix containing normalized spherical harmonic coefficients matrix, *S*

This parameter requires that you specify a program in the *dfreader* parameter to read the data file.

`dfreader`

Specify a MATLAB function to read `datafile`. The reader file that you specify depends on the file type of `datafile`.

Data File Type	Description
MATLAB file	Specify the MATLAB `load` function, for example, `@load`.
Other file type	Specify a custom MATLAB reader function. For examples of custom reader functions, see `astReadSHAFile.m` and `astReadEGMFile.m`. Note the output variable order in these files.

Output Arguments

`gx`

Array of *N* gravity values in the *x*-axis of the Planet-Centered Planet-Fixed coordinates in meters per second squared (m/s^2).

`gy`

Array of *N* gravity values in the *y*-axis of the Planet-Centered Planet-Fixed coordinates in meters per second squared (m/s^2).

`gz`

Array of *N* gravity values in the *z*-axis of the Planet-Centered Planet-Fixed coordinates in meters per second squared (m/s^2).

Examples

Calculate the gravity in the *x*-axis at the equator on the surface of Earth. This example uses the default 120 degree model of EGM2008 with default warning actions:

```
gx = gravitysphericalharmonic( [-6378.1363e3 0 0] )
```

Calculate the gravity at 25000 m over the south pole of Earth. This example uses the 70 degree model of EGM96 with error actions:

```
[gx, gy, gz] = gravitysphericalharmonic( [0 0 -6381.751e3], 'EGM96', 'Error' )
```

Calculate the gravity at 15000 m over the equator and 11000 m over the North Pole. This example uses a 30th order GMM2B Mars model with warning actions:

```
p  = [2412.648e3 -2412.648e3 0; 0 0 3376.2e3]
[gx, gy, gz] = gravitysphericalharmonic( p, 'GMM2B', 30, 'Warning' )
```

Calculate the gravity at 15000 m over the equator and 11000 m over the North Pole. This example uses a 60th degree custom planetary model with no actions:

```
p      = [2412.648e3 -2412.648e3 0; 0 0 3376e3]
[gx, gy, gz] = gravitysphericalharmonic( p, 'custom', 60, ...
{'GMM2BC80_SHA.txt' @astReadSHAFile}, 'None' )
```

Calculate the gravity at 25000 meters over the south pole of Earth using a 120th order EIGEN-GL04C Earth model with warning actions:

```
p  = [0 0 -6381.751e3]
[gx, gy, gz] = gravitysphericalharmonic( p, 'EIGENGL04C', ...
120, 'Warning' )
```

See Also

gravitywgs84 | gravitycentrifugal | gravityzonal | geoidegm96

gravitywgs84

Purpose

Implement 1984 World Geodetic System (WGS84) representation of Earth's gravity

Syntax

```
g = gravitywgs84(h, lat)
g = gravitywgs84(h, lat, lon, method, [noatm, nocent, prec,
   jd], action)
gt = gravitywgs84(h, lat, lon, 'Exact', [noatm, nocent, prec,
   jd], action)
[g gn] = gravitywgs84(h, lat, lon, 'Exact', [noatm, nocent,
   prec, jd], action)
```

Description

`g = gravitywgs84(h, lat)` implements the mathematical representation of the geocentric equipotential ellipsoid of WGS84. Using `h`, an array of `m` altitudes in meters, and `lat`, an array of `m` geodetic latitudes in degrees, calculates `g`, an array of `m` gravity values in the direction normal to the Earth's surface at a specific location. The default calculation method is Taylor Series. Gravity precision is controlled via the `method` parameter.

`g = gravitywgs84(h, lat, lon, method, [noatm, nocent, prec, jd], action)` lets you specify both latitude and longitude, as well as other optional inputs, when calculating gravity values in the direction normal to the Earth's surface. In this format, `method` can be either `'CloseApprox'`or`'Exact'`.

`gt = gravitywgs84(h, lat, lon, 'Exact', [noatm, nocent, prec, jd], action)` calculates an array of total gravity values in the direction normal to the Earth's surface.

`[g gn] = gravitywgs84(h, lat, lon, 'Exact', [noatm, nocent, prec, jd], action)` calculates gravity values in the direction both normal and tangential to the Earth's surface.

Inputs for `gravitywgs84` are:

`h`	An array of `m` altitudes, in meters
`lat`	An array of `m` geodetic latitudes, in degrees, where north latitude is positive, and south latitude is negative
`lon`	An array of `m` geodetic longitudes, in degrees, where east longitude is positive, and west longitude is negative. This input is available only with `method` specified as `'CloseApprox'`or`'Exact'`.
`method`	A string specifying the method to calculate gravity: `'TaylorSeries'`, `'CloseApprox'`, or `'Exact'`. The default is `'TaylorSeries'`.
`noatm`	A logical value specifying the exclusion of Earth's atmosphere. Set to `true` for the Earth's gravitational field to exclude the mass of the atmosphere. Set to `false` for the value for the Earth's gravitational field to include the mass of the atmosphere. This option is available only with `method` specified as `'CloseApprox'`or`'Exact'`. The default is `false`.
`nocent`	A logical value specifying the removal of centrifugal effects. Set to `true` to calculate gravity based on pure attraction resulting from the normal gravitational potential. Set to `false` to calculate gravity including the centrifugal force resulting from the Earth's angular velocity. This option is available only with `method` specified as `'CloseApprox'`or`'Exact'`. The default is `false`.

`prec`	A logical value specifying the presence of a precessing reference frame. Set to `true` for the angular velocity of the Earth to be calculated using the International Astronomical Union (IAU) value of the Earth's angular velocity and the precession rate in right ascension. To obtain the precession rate in right ascension, Julian Centuries from Epoch J2000.0 is calculated using the Julian date, `jd`. If set to `false`, the angular velocity of the Earth used is the value of the standard Earth rotating at a constant angular velocity. This option is available only with `method` specified as `'CloseApprox'`or`'Exact'`. The default is `false`.
`jd`	A scalar value specifying Julian date used to calculate Julian Centuries from Epoch J2000.0. This input is available only with `method` specified as `'CloseApprox'`or`'Exact'`.
`action`	A string to determine action for out-of-range input. Specify if out-of-range input invokes a `'Warning'`, `'Error'`, or no action (`'None'`). The default is `'Warning'`.

Outputs calculated for the Earth's gravity include:

`g`	An array of `m` gravity values in the direction normal to the Earth's surface at a specific `lat lon` location. A positive value indicates a downward direction.
`gt`	An array of `m` total gravity values in the direction normal to the Earth's surface at a specific `lat lon` location. A positive value indicates a downward direction. This option is available only with `method` specified as`'Exact'`.
`gn`	An array of `m` gravity values in the direction tangential to the Earth's surface at a specific `lat lon` location. A positive value indicates a northward direction. This option is available only with `method` specified as`'Exact'`.

Examples

Calculate the normal gravity at 5000 meters and 55 degrees latitude using the Taylor Series approximation method with errors for out-of-range inputs:

```
g = gravitywgs84( 5000, 55, 'TaylorSeries', 'Error' )


g =

    9.7997
```

Calculate the normal gravity at 15,000 meters, 45 degrees latitude, and 120 degrees longitude using the Close Approximation method with atmosphere, centrifugal effects, and no precessing, with warnings for out-of-range inputs:

```
g = gravitywgs84( 15000, 45, 120, 'CloseApprox' )


g =
```

```
    9.7601
```

Calculate the normal and tangential gravity at 1000 meters, 0 degrees latitude, and 20 degrees longitude using the Exact method with atmosphere, centrifugal effects, and no precessing, with warnings for out-of-range inputs:

```
[g, gt] = gravitywgs84( 1000, 0, 20, 'Exact' )


g =

    9.7772


gt =

     0
```

Calculate the normal and tangential gravity at 1000 meters, 0 degrees latitude, and 20 degrees longitude and 11,000 meters, 30 degrees latitude, and 50 degrees longitude using the Exact method with atmosphere, centrifugal effects, and no precessing, with no actions for out-of-range inputs:

```
h = [1000; 11000];
lat = [0; 30];
lon = [20; 50];
[g, gt] = gravitywgs84( h, lat, lon, 'Exact', 'None' )


g =

    9.7772
    9.7594
```

```
gt =

  1.0e-004 *

         0
   -0.7751
```

Calculate the normal gravity at 15,000 meters, 45 degrees latitude, and 120 degrees longitude and 5000 meters, 55 degrees latitude, and 100 degrees longitude using the Close Approximation method with atmosphere, no centrifugal effects, and no precessing, with warnings for out-of-range inputs:

```
h = [15000 5000];
lat = [45 55];
lon = [120 100];
g = gravitywgs84( h, lat, lon, 'CloseApprox', [false true false 0] )


g =

    9.7771    9.8109
```

Calculate the normal and tangential gravity at 1000 meters, 0 degrees latitude, and 20 degrees longitude using the Exact method with atmosphere, centrifugal effects, and precessing at Julian date 2451545, with warnings for out-of-range inputs:

```
[g, gt] = gravitywgs84( 1000, 0, 20, 'Exact', ...
              [ false false true 2451545 ], 'Warning' )


g =

    9.7772
```

```
gt =

     0
```

Calculate the normal gravity at 15,000 meters, 45 degrees latitude, and 120 degrees longitude using the Close Approximation method with no atmosphere, with centrifugal effects, and with precessing at Julian date 2451545, with errors for out-of-range inputs:

```
g = gravitywgs84( 15000, 45, 120, 'CloseApprox', ...
        [ true false true 2451545 ], 'Error'  )


g =

    9.7601
```

Calculate the total normal gravity at 15,000 meters, 45 degrees latitude, and 120 degrees longitude using the Exact method with no atmosphere, with centrifugal effects, and with precessing at Julian date 2451545, with errors for out-of-range inputs:

```
g = gravitywgs84( 15000, 45, 120, 'Exact', ...
        [ true false true 2451545 ], 'Error'  )


g =

    9.7601
```

Assumptions and Limitations

The WGS84 gravity calculations are based on the assumption of a geocentric equipotential ellipsoid of revolution. Since the gravity potential is assumed to be the same everywhere on the ellipsoid, there must be a specific theoretical gravity potential that can be uniquely determined from the four independent constants defining the ellipsoid.

Use of the WGS84 Taylor Series model should be limited to low geodetic heights. It is sufficient near the surface when submicrogal precision is not necessary. At medium and high geodetic heights, it is less accurate.

Use of the WGS84 Close Approximation model should be limited to a geodetic height of 20,000.0 meters (approximately 65,620.0 feet). Below this height, it gives results with submicrogal precision.

To predict and determine a satellite orbit with high accuracy, use the EGM96 through degree and order 70.

References

NIMA TR8350.2: “Department of Defense World Geodetic System 1984, Its Definition and Relationship with Local Geodetic Systems.”

gravityzonal

Purpose

Implement zonal harmonic representation of planetary gravity

Syntax

```
[gravityXcoord gravityYcoord,
   gravityZcoord] = gravityzonal(planetCoord)
[gravityXcoord gravityYcoord,
   gravityZcoord] = gravityzonal(planetCoord,
   degreeGravityModel)
[gravityXcoord gravityYcoord,
   gravityZcoord] = gravityzonal(planetCoord,
   planetModel)
[gravityXcoord gravityYcoord,
   gravityZcoord] = gravityzonal(planetCoord,
   planetModel,
   degreeGravityModel)
[gravityXcoord gravityYcoord,
   gravityZcoord] = gravityzonal(planetCoord,
   planetModel,
   degreeGravityModel, action)
[gravityXcoord gravityYcoord,
   gravityZcoord] = gravityzonal(planetCoord,
   'Custom', equatorialRadius, planetaryGravitional,
   zonalHarmonicCoeff, action)
```

Description

`[gravityXcoord gravityYcoord, gravityZcoord] = gravityzonal(planetCoord)` implements the mathematical representation of zonal harmonic planetary gravity based on planetary gravitational potential. For input, it takes an m-by-3 matrix that contains planet-centered planet-fixed coordinates from the center of the planet in meters. This function calculates the arrays of m gravity values in the *x*-, *y*-, and *z*-axes of the planet-centered planet-fixed coordinates. It uses the fourth order zonal coefficients for Earth by default.

`[gravityXcoord gravityYcoord, gravityZcoord] = gravityzonal(planetCoord, degreeGravityModel)` uses the degree of harmonic model.

`[gravityXcoord gravityYcoord, gravityZcoord] = gravityzonal(planetCoord, planetModel)` uses the planetary model.

`[gravityXcoord gravityYcoord, gravityZcoord] = gravityzonal(planetCoord, planetModel, degreeGravityModel)` uses the degree of harmonic model and planetary model.

`[gravityXcoord gravityYcoord, gravityZcoord] = gravityzonal(planetCoord, planetModel, degreeGravityModel, action)` specifies the action for out-of-range input.

`[gravityXcoord gravityYcoord, gravityZcoord] = gravityzonal(planetCoord, 'Custom', equatorialRadius, planetaryGravitional, zonalHarmonicCoeff, action)` uses the equatorial radius, planetary gravitational parameter, and zonal harmonic coefficients for the custom planetary model.

This function does not include the potential due planet rotation, which excludes the centrifugal effects of planetary rotation and the effects of a precessing reference frame.

Input Arguments

`planetCoord`

m-by-3 matrix that contains planet-centered planet-fixed coordinates from the center of the planet in meters. If `planetModel` has a value of `'Earth'`, this matrix contains Earth-centered Earth-fixed (ECEF) coordinates.

`planetModel`

String that specifies the planetary model. Enter one:

- `'Mercury'`
- `'Venus'`
- `'Earth'`
- `'Moon'`
- `'Mars'`
- `'Jupiter'`
- `'Saturn'`

- 'Uranus'
- 'Neptune'
- 'Custom'

'Custom' requires you to specify your own planetary model using the equatorialRadius, planetaryGravitional, and zonalHarmonicCoeff parameters.

Default: 'Earth'

degreeGravityModel

Degree of harmonic model.

- 2 — Second degree, J2. Most significant or largest spherical harmonic term, which accounts for the oblateness of a planet. 2 is default if planetModel is 'Mercury', 'Venus', 'Moon', 'Uranus', or 'Neptune'.
- 3 — Third degree, J3. 3 is default if planetModel is 'Mars'.
- 4 — Fourth degree, J4 (default). Default is 4 if planetModel is 'Earth, 'Jupiter', 'Saturn' or 'Custom'.

Default:

equatorialRadius

Planetary equatorial radius in meters. Use this parameter only if you specify planetModel as 'Custom'.

planetaryGravitional

Planetary gravitational parameter in meters cubed per second squared. Use this parameter only if you specify planetModel as 'Custom'.

zonalHarmonicCoeff

3-element array defining the zonal harmonic coefficients that the function uses to calculate zonal harmonics planetary gravity. Use this parameter only if you specify `planetModel` as `'Custom'`.

`action`

String that defines action for out-of-range input. Specify one:

`'Error'`
`'Warning'`
`'None'` (default)

Output Arguments

`gravityXcoord`

Array of m gravity values in the *x*-axis of the planet-centered planet-fixed coordinates in meters per second squared.

`gravityYcoord`

Array of m gravity values in the *y*-axis of the planet-centered planet-fixed coordinates in meters per second squared.

`gravityZcoord`

Array of m gravity values in the *z*-axis of the planet-centered planet-fixed coordinates in meters per second squared.

Examples

Calculate the gravity in the *x*-axis at the equator on the surface of Earth using the fourth degree model with no warning actions:

```
gx = gravityzonal( [-6378.1363e3 0 0] )

gx =

9.8142
```

Calculate the gravity using the close approximation method at 100 m over the geographic South Pole of Earth with error actions:

```
[gx, gy, gz] = gravityzonal( [0 0 -6356.851e3], 'Error' )
```

```
gx =

     0

gy =

     0

gz =

    9.8317
```

Calculate the gravity at 15000 m over the equator and 11000 m over the geographic North Pole using a second order Mars model with warning actions:

```
p  = [2412.648e3 -2412.648e3 0; 0 0 3376.2e3]
[gx, gy, gz] = gravityzonal( p, 'Mars', 2, 'Warning' )
p =

     2412648    -2412648           0
           0           0     3376200

gx =

   -2.6224
         0

gy =

    2.6224
         0

gz =
```

```
         0
   -3.7542
```

Calculate the gravity at 15000 m over the equator and 11000 m over the geographic North Pole using a custom planetary model with no actions:

```
p= [2412.648e3 -2412.648e3 0; 0 0 3376e3]
GM      = 42828.371901e9  % m^3/s^2
Re      = 3397e3          % m
Jvalues = [1.95545367944545e-3 3.14498094262035e-5 ...
-1.53773961526397e-5]
[gx, gy, gz] = gravityzonal( p, 'custom', Re, GM, ...
Jvalues, 'None' )
```

Algorithms

`gravityzonal` is implemented using the following planetary parameter values for each planet:

Planet	Equatorial Radius (Re) in Meters	Gravitational Parameter (GM) in m^3/s^2	Zonal Harmonic Coefficients (J Values)
Earth	6378.1363e3	3.986004415e14	[0.0010826269 -0.0000025323 -0.0000016204]
Jupiter	71492.e3	1.268e17	[0.01475 0 -0.00058]
Mars	3397.2e3	4.305e13	[0.001964 0.000036]
Mercury	2439.0e3	2.2032e13	0.00006
Moon	1738.0e3	4902.799e9	0.0002027
Neptune	24764e3	6.809e15	0.004
Saturn	60268.e3	3.794e16	[0.01645 0 -0.001]
Uranus	25559.e3	5.794e15	0.012
Venus	6052.0e3	3.257e14	0.000027

References

Vallado, D. A., *Fundamentals of Astrodynamics and Applications*, McGraw-Hill, New York, 1997.

Fortescue, P., J. Stark, G. Swinerd, (Eds.). *Spacecraft Systems Engineering*, Third Edition, Wiley & Sons, West Sussex, 2003.

Tewari, A., *Atmospheric and Space Flight Dynamics Modeling and Simulation with MATLAB and Simulink*, Birkhäuser, Boston, 2007.

Alternatives

Zonal Harmonic Gravity Model block

See Also

`gravitywgs84` | `geoidegm96`

Purpose

Hide animation figure

Syntax

```
hide(h)
h.hide
```

Description

`hide(h)` and `h.hide` hide (close) the figure for the animation object `h`. Use `Aero.Animation.show` to redisplay the animation object figure.

Input Arguments

`h`	Animation object.

Examples

Hide the animation object figure that the `Aero.Animation.show` method displays.

```
h=Aero.Animation;
h.show;
h.hide;
```

igrf11magm

Purpose

Calculate Earth's magnetic field using 11th generation of International Geomagnetic Reference Field

Syntax

```
[mag_field_vector, hor_intensity, declination, inclination,
   total_intensity, mag_field_sec_variation,
   sec_variation_horizontal, sec_variation_declination,
   sec_variation_inclination,
   sec_variation_total] = igrf11magm(height, latitude,
   longitude, decimal_year)
```

Description

`[mag_field_vector, hor_intensity, declination, inclination, total_intensity, mag_field_sec_variation, sec_variation_horizontal, sec_variation_declination, sec_variation_inclination, sec_variation_total] = igrf11magm(height, latitude, longitude, decimal_year)` calculates the Earth's magnetic field and the secular variation at a specific location and time. This function uses the 11th generation of the International Geomagnetic Reference Field (IGRF-11).

Tips

- The `igrf11magm` function is valid between the heights of –1000 meters to 600000 meters.
- The `igrf11magm` function is valid between the years of 1900 and 2015.
- This function has the limitations of the International Geomagnetic Reference Field (IGRF).

Input Arguments

`height`

Scalar distance, in meters, from the surface of the Earth.

`latitude`

Scalar geodetic latitude, in degrees. North latitude is positive, south latitude is negative.

`longitude`

Scalar geodetic longitude, in degrees. East longitude is positive, west longitude is negative.

`decimal_year`

Scalar year, in decimal format. This value is the desired year to include any fraction of the year that has already passed.

Output Arguments

`mag_field_vector`

Magnetic field vector, in nanotesla (nT). Z is the vertical component (+ve down).

`hor_intensity`

Horizontal intensity, in nanotesla (nT).

`declination`

Declination, in degrees (+ve east).

`inclination`

Inclination, in degrees (+ve down).

`total_intensity`

Total intensity, in nanotesla (nT).

`mag_field_sec_variation`

Secular variation in magnetic field vector, in nT/year. Z is the vertical component (+ve down).

`sec_variation_horizontal`

Secular variation in horizontal intensity, in nT/year.

`sec_variation_declination`

Secular variation in declination, in minutes/year (+ve east).

`sec_variation_inclination`

Secular variation in inclination, in minutes/year (+ve down).

`sec_variation_total`

Secular variation in total intensity, in nT/year.

Examples

Calculate the magnetic model 1000 meters over Natick, Massachusetts on July 4, 2005 using IGRF-11:

```
[XYZ, H, DEC, DIP, F] = igrf11magm(1000, 42.283, -71.35, ...
decyear(2005,7,4))

XYZ =

  1.0e+004 *

    1.8982   -0.5176    4.9558

H =

  1.9675e+004

DEC =

  -15.2524

DIP =

   68.3467

F =

  5.3320e+004
```

References

Lowes, F. J. “The International Geomagnetic Reference Field: A ’Health’ Warning.” January, 2010. http://www.ngdc.noaa.gov/IAGA/vmod/igrfhw.html

Blakely, R. J. *Potential Theory in Gravity & Magnetic Applications*, Cambridge, UK: Cambridge University Press, 1996.

Purpose

Create animation object figure and axes and build patches for bodies

Syntax

```
initialize(h)
h.initialize
```

Description

`initialize(h)` and `h.initialize` create a figure and axes for the animation object `h`, and builds patches for the bodies associated with the animation object. If there is an existing figure, this function

1. Clears out the old figure and its patches.
2. Creates a new figure and axes with default values.
3. Repopulates the axes with new patches using the surface to patch data from each body.

Input Arguments

`h`	Animation object.

Examples

Initialize the animation object, `h`.

```
h = Aero.Animation;
h.initialize();
```

initialize (Aero.FlightGearAnimation)

Purpose Set up FlightGear animation object

Syntax

```
initialize(h)
h.initialize
```

Description `initialize(h)` and `h.initialize` set up the FlightGear version, IP address, and socket for the FlightGear animation object `h`.

Examples Initialize the animation object, `h`.

```
h = Aero.FlightGearAnimation;
h.initialize();
```

See Also `delete` | `play` | `GenerateRunScript` | `update`

Purpose Create and populate virtual reality animation object

Syntax

```
initialize(h)
h.initialize
```

Description `initialize(h)` and `h.initialize` create a virtual reality animation world and populate the virtual reality animation object `h`. If a previously initialized virtual reality animation object existgs, and that object has user-specified data, this function saves the previous object to be reset after the initialization.

Examples Initialize the virtual reality animation object, h.

```
h = Aero.VirtualRealityAnimation;
h.VRWorldFilename = [matlabroot,'/toolbox/aero/astdemos/asttkoff.wrl'];
copyfile(h.VRWorldFilename,[tempdir,'asttkoff.wrl'],'f');
h.VRWorldFilename = [tempdir,'asttkoff.wrl'];
h.initialize();
```

See Also `delete` | `play`

Aero.Animation.initIfNeeded

Purpose

Initialize animation graphics if needed

Syntax

```
initIfNeeded(h)
h.initIfNeeded
```

Description

`initIfNeeded(h)` and `h.initIfNeeded` initialize animation object graphics if necessary.

Input Arguments

`h`	Animation object.

Examples

Initialize the animation object graphics of `h` as needed.

```
h=Aero.Animation;
h.initIfNeeded;
```

Purpose

Calculate Julian date

Syntax

```
jd = juliandate(v)
jd = juliandate(s,f)
jd = juliandate(y,mo,d)
jd = juliandate([y,mo,d])
jd = juliandate(y,mo,d,h,mi,s)
jd = juliandate([y,mo,d,h,mi,s])
```

Description

`jd = juliandate(v)` converts one or more date vectors, `v`, into Julian date, `jd`. Input `v` can be an `m`-by-6 or `m`-by-3 matrix containing `m` full or partial date vectors, respectively. `juliandate` returns a column vector of `m` Julian dates, which are the number of days and fractions since noon Universal Time on January 1, 4713 BCE.

A date vector contains six elements, specifying year, month, day, hour, minute, and second. A partial date vector has three elements, specifying year, month, and day. Each element of `v` must be a positive double-precision number.

`jd = juliandate(s,f)` converts one or more date strings, `s`, into Julian date, `jd`, using format string `f`. `s` can be a character array where each row corresponds to one date string, or a one-dimensional cell array of strings. `juliandate` returns a column vector of `m` Julian dates, where `m` is the number of strings in `s`.

All of the date strings in `s` must have the same format `f`, which must be composed of date format symbols listed in the `datestr` function reference page. Formats containing the letter `Q` are not accepted by `juliandate`.

Certain formats may not contain enough information to compute a date number. In those cases, hours, minutes, and seconds default to 0, days default to 1, months default to January, and years default to the current year. Date strings with two-character years are interpreted to be within the 100 years centered around the current year.

`jd = juliandate(y,mo,d)` and `jd = juliandate([y,mo,d])` return the decimal year for corresponding elements of the `y,mo,d` (year,month,day) arrays. `y`, `mo`, and `d` must be arrays of the same size (or any of them can be a scalar).

`jd = juliandate(y,mo,d,h,mi,s)` and `jd = juliandate([y,mo,d,h,mi,s])` return the Julian dates for corresponding elements of the `y,mo,d,h,mi,s` (year,month,day,hour,minute,second) arrays. The six arguments must be arrays of the same size (or any of them can be a scalar).

Examples

Calculate Julian date for May 24, 2005:

```
jd = juliandate('24-May-2005','dd-mmm-yyyy')

jd =

  2.4535e+006
```

Calculate Julian date for December 19, 2006:

```
jd = juliandate(2006,12,19)

jd =

  2.4541e+006
```

Calculate Julian date for October 10, 2004, at 12:21:00 p.m.:

```
jd = juliandate(2004,10,10,12,21,0)

jd =

  2.4533e+006
```

Assumptions and Limitations

This function is valid for all common era (CE) dates in the Gregorian calendar.

The calculation of Julian date does not take into account leap seconds.

See Also

`decyear` | `leapyear` | `mjuliandate`

Purpose

Determine leap year

Syntax

```
ly = leapyear(year)
```

Description

`ly = leapyear(year)` determines whether one or more years are leap years or not. The output, `ly`, is a logical array. `year` should be numeric.

Examples

Determine whether 2005 is a leap year:

```
ly = leapyear(2005)

ly =

  0
```

Determine whether 2000, 2005, and 2020 are leap years:

```
ly = leapyear([2000 2005 2020])

ly =

  1    0    1
```

Assumptions and Limitations

The determination of leap years is done by Gregorian calendar rules.

See Also

`decyear` | `juliandate` | `mjuliandate`

Purpose

Convert geodetic coordinates to Earth-centered Earth-fixed (ECEF) coordinates

Syntax

```
p = lla2ecef(lla)
p = lla2ecef(lla, model)
p = lla2ecef(lla, f, Re)
```

Description

`p = lla2ecef(lla)` converts an `m`-by-3 array of geodetic coordinates (latitude, longitude and altitude), `lla`, to an `m`-by-3 array of ECEF coordinates, `p`. `lla` is in [degrees degrees meters]. `p` is in meters. The default ellipsoid planet is WGS84.

`p = lla2ecef(lla, model)` is an alternate method for converting the coordinates for a specific ellipsoid planet. Currently only `'WGS84'` is supported for `model`.

`p = lla2ecef(lla, f, Re)` is another alternate method for converting the coordinates for a custom ellipsoid planet defined by flattening, `f`, and the equatorial radius, `Re`, in meters.

Examples

Determine ECEF coordinates at a latitude, longitude, and altitude:

```
p = lla2ecef([0 45 1000])


p =

   1.0e+006 *

     4.5107    4.5107         0
```

Determine ECEF coordinates at multiple latitudes, longitudes, and altitudes, specifying WGS84 ellipsoid model:

```
p = lla2ecef([0 45 1000; 45 90 2000], 'WGS84')


p =
```

```
  1.0e+006 *

    4.5107    4.5107         0
    0.0000    4.5190    4.4888
```

Determine ECEF coordinates at multiple latitudes, longitudes, and altitudes, specifying custom ellipsoid model:

```
f = 1/196.877360;
Re = 3397000;
p = lla2ecef([0 45 1000; 45 90 2000], f, Re)


p =

  1.0e+006 *

    2.4027    2.4027         0
    0.0000    2.4096    2.3852
```

See Also

ecef2lla | geoc2geod | geod2geoc

lla2flat

Purpose

Estimate flat Earth position from geodetic latitude, longitude, and altitude

Syntax

```
flatearth_pos = lla2flat(lla, llo, psio, href)
flatearth_pos = lla2flat(lla, llo, psio, href,
   ellipsoidModel)
flatearth_pos = lla2flat(lla, llo, psio, href, flattening,
   equatorialRadius)
```

Description

`flatearth_pos = lla2flat(lla, llo, psio, href)` estimates an array of flat Earth coordinates, *`flatearth_pos`*, from an array of geodetic coordinates, *`lla`*. This function estimates the `flatearth_pos` value with respect to a reference location that `llo`, `psio`, and `href` define.

`flatearth_pos = lla2flat(lla, llo, psio, href, ellipsoidModel)` estimates the coordinates for a specific ellipsoid planet.

`flatearth_pos = lla2flat(lla, llo, psio, href, flattening, equatorialRadius)` estimates the coordinates for a custom ellipsoid planet defined by `flattening` and `equatorialRadius`.

Tips

- This function assumes that the flight path and bank angle are zero.
- This function assumes that the flat Earth *z*-axis is normal to the Earth only at the initial geodetic latitude and longitude. This function has higher accuracy over small distances from the initial geodetic latitude and longitude. It also has higher accuracy at distances closer to the equator. The function calculates a longitude with higher accuracy when the variations in latitude are smaller. Additionally, longitude is singular at the poles.

Input Arguments

`lla`

m-by-3 array of geodetic coordinates (latitude, longitude, and altitude), in [degrees, degrees, meters].

`llo`

Reference location, in degrees, of latitude and longitude, for the origin of the estimation and the origin of the flat Earth coordinate system.

`psio`

Angular direction of flat Earth *x*-axis (degrees clockwise from north), which is the angle in degrees used for converting flat Earth *x* and *y* coordinates to the North and East coordinates.

`href`

Reference height from the surface of the Earth to the flat Earth frame with regard to the flat Earth frame, in meters.

`ellipsoidModel`

String that specifies the specific ellipsoid planet model. This function supports only `'WGS84'`.

Default: WGS84

`flattening`

Custom ellipsoid planet defined by flattening.

`equatorialRadius`

Planetary equatorial radius, in meters.

Output Arguments

`flatearth_pos`

Flat Earth position coordinates, in meters.

Examples

Estimate coordinates at latitude, longitude, and altitude:

```
p = lla2flat( [ 0.1 44.95 1000 ], [0 45], 5, -100 )

p =

  1.0e+004 *
```

```
1.0530   -0.6509   -0.0900
```

Estimate coordinates at multiple latitudes, longitudes, and altitudes, specifying the WGS84 ellipsoid model:

```
p = lla2flat( [ 0.1 44.95 1000; -0.05 45.3 2000 ], [0 45], 5, -100, 'WGS84' )

p =

  1.0e+004 *

    1.0530   -0.6509   -0.0900
   -0.2597    3.3751   -0.1900
```

Estimate coordinates at multiple latitudes, longitudes, and altitudes, specifying a custom ellipsoid model:

```
f = 1/196.877360;
Re = 3397000;
p = lla2flat( [ 0.1 44.95 1000; -0.05 45.3 2000 ], [0 45], 5, -100,  f, Re )

p =

  1.0e+004 *

    0.5588   -0.3465   -0.0900
   -0.1373    1.7975   -0.1900
```

Algorithms

The estimation begins by finding the small changes in latitude and longitude from the output latitude and longitude minus the initial latitude and longitude.

$$d\mu = \mu - \mu_0$$
$$d_\iota = \iota - \iota_0$$

To convert geodetic latitude and longitude to the North and East coordinates, the estimation uses the radius of curvature in the prime vertical (R_N) and the radius of curvature in the meridian (R_M). R_N and R_M are defined by the following relationships:

$$R_N = \frac{R}{\sqrt{1-(2f-f^2)\sin^2\mu_0}}$$

$$R_M = R_N \frac{1-(2f-f^2)}{1-(2f-f^2)\sin^2\mu_0}$$

where (R) is the equatorial radius of the planet and f is the flattening of the planet.

Small changes in the North (dN) and East (dE) positions are approximated from small changes in the North and East positions by

$$dN = \frac{d\mu}{\operatorname{atan}\left(\frac{1}{R_M}\right)}$$

$$dE = \frac{d\iota}{\operatorname{atan}\left(\frac{1}{R_N \cos\mu_0}\right)}$$

With the conversion of the North and East coordinates to the flat Earth x and y coordinates, the transformation has the form of

$$\begin{bmatrix} p_x \\ p_y \end{bmatrix} = \begin{bmatrix} \cos\psi & \sin\psi \\ -\sin\psi & \cos\psi \end{bmatrix} \begin{bmatrix} N \\ E \end{bmatrix}$$

where

$$(\psi)$$

is the angle in degrees clockwise between the x-axis and north.

The flat Earth z-axis value is the negative altitude minus the reference height (h_{ref}).

$$p_z = -h - h_{ref}$$

References

Etkin, B., *Dynamics of Atmospheric Flight*. NewYork: John Wiley & Sons, 1972.

Stevens, B. L., and F. L. Lewis, *Aircraft Control and Simulation*, 2nd ed. New York: John Wiley & Sons, 2003.

See Also

`flat2lla`

Purpose

Get geometry data from source

Syntax

```
load(h, bodyDataSrc)
h.load(bodyDataSrc)
load(h, bodyDataSrc, geometrysource)
h.load(bodyDataSrc, geometrysource)
```

Description

`load(h, bodyDataSrc)` and `h.load(bodyDataSrc)` load the graphics data from the body graphics file. This command assumes a default geometry source type set to `Auto`.

`load(h, bodyDataSrc, geometrysource)` and `h.load(bodyDataSrc, geometrysource)` load the graphics data from the body graphics file, `bodyDataSrc`, into the face, vertex, and color data of the animation body object `h`. Then, when axes `ax` is available, you can use this data to generate patches with `generatePatches`. `geometrysource` is the geometry source type for the body.

By default *`geometrysource`* is set to `Auto`, which recognizes `.mat` extensions as MAT-files, `.ac` extensions as Ac3d files, and structures containing fields of `name`, `faces`, `vertices`, and `cdata` as MATLAB variables. If you want to use alternate file extensions or file types, enter one of the following:

- `Auto`
- `Variable`
- `MatFile`
- `Ac3d`
- `Custom`

Examples

Load the graphic data from the graphic data file, `pa24-250_orange.ac`, into `b`.

```
b=Aero.Body;
b.load('pa24-250_orange.ac','Ac3d');
```

See Also

generatePatches | move | update

Purpose

Compute Mach number using velocity and speed of sound

Syntax

```
mach = machnumber(v, a)
```

Description

`mach = machnumber(v, a)` computes `m` Mach numbers, `mach`, from an `m`-by-3 array of velocities, `v`, and an array of `m` speeds of sound, `a`. `v` and `a` must have the same length units.

Examples

Determine the Mach number for velocity and speed of sound in feet per second:

```
mach = machnumber([84.3905 33.7562 10.1269], 1116.4505)


mach =

    0.0819
```

Determine the Mach number for velocity and speed of sound in meters per second:

```
mach = machnumber([25.7222 10.2889 3.0867], [340.2941 295.0696])


mach =

    0.0819    0.0945
```

Determine the Mach number for velocity and speed of sound in knots:

```
mach = machnumber([50 20 6; 5 0.5 2], [661.4789 573.5694])


mach =

    0.0819
    0.0094
```

See Also

airspeed | alphabeta | dpressure

Purpose

Calculate modified Julian date

Syntax

```
mjd = mjuliandate(v)
mjd = mjuliandate(s,f)
mjd = mjuliandate(y,mo,d)
mjd = mjuliandate([y,mo,d])
mjd = mjuliandate(y,mo,d,h,mi,s)
mjd = mjuliandate([y,mo,d,h,mi,s])
```

Description

`mjd = mjuliandate(v)` converts one or more date vectors, `v`, into modified Julian date, `mjd`. Input `v` can be an `m`-by-6 or `m`-by-3 matrix containing `m` full or partial date vectors, respectively. `mjuliandate` returns a column vector of `m` modified Julian dates. Modified Julian dates begin at midnight rather than noon and have the first two digits of the corresponding Julian date removed.

A date vector contains six elements, specifying year, month, day, hour, minute, and second. A partial date vector has three elements, specifying year, month, and day. Each element of `v` must be a positive double-precision number.

`mjd = mjuliandate(s,f)` converts one or more date strings, `s`, into modified Julian date, `mjd`, using format string `f`. `s` can be a character array where each row corresponds to one date string, or a one-dimensional cell array of strings. `mjuliandate` returns a column vector of `m` modified Julian dates, where `m` is the number of strings in `s`.

All of the date strings in `s` must have the same format `f`, which must be composed of date format symbols listed in the `datestr` function reference page. Formats containing the letter `Q` are not accepted by `mjuliandate`.

Certain formats may not contain enough information to compute a date number. In those cases, hours, minutes, and seconds default to 0, days default to 1, months default to January, and years default to the current year. Date strings with two-character years are interpreted to be within the 100 years centered around the current year.

`mjd = mjuliandate(y,mo,d)` and `mjd = mjuliandate([y,mo,d])` return the decimal year for corresponding elements of the `y,mo,d` (year,month,day) arrays. `y`, `mo`, and `d` must be arrays of the same size (or any of them can be a scalar).

`mjd = mjuliandate(y,mo,d,h,mi,s)` and `mjd = mjuliandate([y,mo,d,h,mi,s])` return the modified Julian dates for corresponding elements of the `y,mo,d,h,mi,s` (year,month,day,hour,minute,second) arrays. The six arguments must be arrays of the same size (or any of them can be a scalar).

Examples

Calculate the modified Julian date for May 24, 2005:

```
mjd = mjuliandate('24-May-2005','dd-mmm-yyyy')

mjd =

  53514
```

Calculate the modified Julian date for December 19, 2006:

```
mjd = mjuliandate(2006,12,19)

mjd =

  54088
```

Calculate the modified Julian date for October 10, 2004, at 12:21:00 p.m.:

```
mjd = mjuliandate(2004,10,10,12,21,0)

mjd =

  5.3289e+004
```

Assumptions and Limitations

This function is valid for all common era (CE) dates in the Gregorian calendar.

The calculation of modified Julian date does not take into account leap seconds.

See Also

`decyear` | `juliandate` | `leapyear`

move (Aero.Body)

Purpose Change animation body position and orientation

Syntax

```
move(h, translation, rotation)
h.move(translation,rotation)
```

Description `move(h, translation, rotation)` and `h.move(translation,rotation)` set a new position and orientation for the body object `h`. `translation` is a 1-by-3 matrix in the aerospace body *x*-*y*-*z* coordinate system. `rotation` is a 1-by-3 matrix, in radians, that specifies the rotations about the right-hand *x*-*y*-*z* sequence of coordinate axes. The order of application of the rotation is *z*-*y*-*x* (*r*-*q*-*p*).

Examples Change animation body position to *newpos* and *newrot*.

```
h = Aero.Body;
h.load('ac3d_xyzisrgb.ac','Ac3d');
newpos = h.Position + 1.00;
newrot = h.Rotation + 0.01;
h.move(newpos,newrot);
```

See Also `load`

Purpose

Change node translation and rotation

Syntax

```
move(h,translation,rotation)
h.move(translation,rotation)
```

Description

`move(h,translation,rotation)` and `h.move(translation,rotation)` set a new position and orientation for the node object `h`. `translation` is a 1-by-3 matrix in the aerospace body *x*-*y*-*z* coordinate system or another coordinate system. In the latter case, you can use the `CoordTransformFcn` function to move it into an aerospace body. `rotation` is a 1-by-3 matrix, in radians, that specifies the rotations about the right-hand *x*-*y*-*z* sequence of coordinate axes. The order of application of the rotation is *z*-*y*-*x* (*r*-*q*-*p*). This function uses the `CoordTransformFcn` to apply the translation and rotation from the input coordinate system to the aerospace body. The function then moves the translation and rotation from the aerospace body to the VRML *x*-*y*-*z* coordinates.

Examples

Move the Lynx body. This example uses the Simulink 3D Animation `vrnode/getfield` function to retrieve the translation and rotation. These coordinates are those used in the Simulink 3D Animation software.

```
h = Aero.VirtualRealityAnimation;
h.VRWorldFilename = [matlabroot,'/toolbox/aero/astdemos/asttkoff.wrl'];
copyfile(h.VRWorldFilename,[tempdir,'asttkoff.wrl'],'f');
h.VRWorldFilename = [tempdir,'asttkoff.wrl'];
h.initialize();
newtrans = getfield(h.Nodes{4}.VRNode,'translation') + 1.0;
newrot = getfield(h.Nodes{4}.VRNode,'rotation') + [.2 0.01 0.01 0.01];
h.Nodes{4}.move(newtrans,newrot);
```

Limitations

This function cannot get the node position in aerospace body coordinates; it needs to use the `CoordTransformFcn` to do so.

This function cannot set a viewpoint position or orientation (see `addViewpoint`).

See Also

`addNode`

Purpose

Move body in animation object

Syntax

```
moveBody(h,idx,translation,rotation)
h.moveBody(idx,translation,rotation)
```

Description

`moveBody(h,idx,translation,rotation)` and `h.moveBody(idx,translation,rotation)` set a new position and attitude for the body specified with the index `idx` in the animation object `h`. `translation` is a 1-by-3 matrix in the aerospace body coordinate system. `rotation` is a 1-by-3 matrix, in radians, that specifies the rotations about the right-hand *x-y-z* sequence of coordinate axes. The order of application of the rotation is *z-y-x (R-Q-P)*.

Input Arguments

`h`	Animation object.
`translation`	1-by-3 matrix in the aerospace body coordinate system.
`rotation`	1-by-3 matrix, in radians, that specifies the rotations about the right-hand *x-y-z* sequence of coordinate axes.
`idx`	Body specified with this index.

Examples

Move the body with the index 1 to position offset from the original by `+ [0 0 -3]` and rotation, *rot1*.

```
h = Aero.Animation;
idx1 = h.createBody('pa24-250_orange.ac','Ac3d');
pos1 = h.Bodies{1}.Position;
rot1 = h.Bodies{1}.Rotation;
h.moveBody(1,pos1 + [0 0 -3],rot1);
```

Node (Aero.Node)

Purpose

Create node object for use with virtual reality animation

Syntax

```
h = Aero.Node
```

Description

`h = Aero.Node` creates a node object for use with virtual reality animation.

See `Aero.Node` for further details.

See Also

`Aero.Node`

nodeInfo (Aero.VirtualRealityAnimation)

Purpose

Create list of nodes associated with virtual reality animation object

Syntax

```
nodeInfo(h)
h.nodeInfo
n = nodeInfo(h)
n = h.nodeInfo
```

Description

`nodeInfo(h)` and `h.nodeInfo` create a list of nodes associated with the virtual reality animation object, `h`.

`n = nodeInfo(h)` and `n = h.nodeInfo` create a cell array (`n`) that contains the node information. The function stores the information in a cell array as follows:

```
N{1,n} = Node Index
N{2,n} = Node Name
N{3,n} = Node Type
```

where `n` is the number of nodes. You might want to use this function to find an existing node by name and then perform a certain action on it using the node index.

Examples

Create list of nodes associated with virtual reality animation object, `h`.

```
h = Aero.VirtualRealityAnimation;
h.VRWorldFilename = [matlabroot,'/toolbox/aero/astdemos/asttkoff.wrl'];
h.initialize();
h.nodeInfo;
```

See Also

`addNode`

Aero.Animation.play

Purpose Animate `Aero.Animation` object given position/angle time series

Syntax

```
play(h)
play.h
```

Description `play(h)` and `play.h` animate the loaded geometry in `h` for the current `TimeseriesDataSource` at the specified rate given by the `'TimeScaling'` property (in seconds of animation data per second of wall-clock time) and animated at a certain number of frames per second using the `'FramesPerSecond'` property.

The time series data is interpreted according to the `'TimeseriesSourceType'` property, which can be one of:

`'Timeseries'`	MATLAB time series data with six values per time: `x y z phi theta psi` The values are resampled.

`'Simulink.Timeseries'`	Simulink.Timeseries (Simulink signal logging):
	• First data item
	`x y z`
	• Second data item
	`phi theta psi`

`'StructureWithTime'`	Simulink struct with time (for example, Simulink root outport logging `'Structure with time'`): • `signals(1).values:  x y z` • `signals(2).values:  phi theta psi` Signals are linearly interpolated vs. time using `interp1`.
`'Array6DoF'`	A double-precision array in `n` rows and 7 columns for 6-DoF data: `time x y z phi theta psi`. If a double-precision array of 8 or more columns is in `'TimeseriesSource'`, the first 7 columns are used as 6-DoF data.
`'Array3DoF'`	A double-precision array in `n` rows and 4 columns for 3-DoF data: `time x z theta`. If a double-precision array of 5 or more columns is in `'TimeseriesSource'`, the first 4 columns are used as 3-DoF data.
`'Custom'`	Position and angle data is retrieved from `'TimeseriesSource'` by the currently registered `'TimeseriesReadFcn'`.

The following are limitations for the `TStart` and `TFinal` values:

- `TStart` and `TFinal` must be numeric.
- `TStart` and `TFinal` cannot be Inf or NaN.
- `TFinal` must be greater than or equal to `TStart`.

- `TFinal` cannot be greater than the maximum `Timeseries` time.
- `TStart` cannot be less than the minimum `Timeseries` time.

The time advancement algorithm used by `play` is based on animation frames counted by ticks:

```
ticks = ticks + 1;
time  = tstart + ticks*FramesPerSecond*TimeScaling;
```

where

`TimeScaling`	Specify the seconds of animation data per second of wall-clock time.
`FramesPerSecond`	Specify the number of frames per second used to animate the `'TimeseriesSource'`.

For default `'TimeseriesReadFcn'` methods, the last frame played is the last time value.

Time is in seconds, position values are in the same units as the geometry data loaded into the animation object, and all angles are in radians.

Note If there is a 15% difference between the expected time advance and the actual time advance, this method will generate the following warning:

```
TimerPeriod has been set to <value>. You may wish to modify the animation
TimeScaling and FramesPerSecond properties to compensate for the
millisecond limit of the TimerPeriod.  See documentation for details.
```

Input Arguments

`h`	Animation object.

Examples

Animate the body, `idx1`, for the duration of the time series data.

```
h = Aero.Animation;
h.FramesPerSecond = 10;
h.TimeScaling = 5;
idx1 = h.createBody('pa24-250_orange.ac','Ac3d');
load simdata;
h.Bodies{1}.TimeSeriesSource = simdata;
h.show();
h.play();
```

play (Aero.FlightGearAnimation)

Purpose

Animate FlightGear flight simulator using given position/angle time series

Syntax

```
play(h)
h.play
```

Description

`play(h)` and `h.play` animate FlightGear flight simulator using specified time series data in `h`. The time series data can be set in `h` by using the property `'TimeseriesSource'`.

The time series data, stored in the property `'TimeseriesSource'`, is interpreted according to the `'TimeseriesSourceType'` property, which can be one of:

`'Timeseries'`	MATLAB time series data with six values per time: `latitude longitude altitude phi theta psi` The values are resampled.
`'StructureWithTime'`	Simulink struct with time (for example, Simulink root outport logging `'Structure with time'`): • `signals(1).values:  latitude longitude altitude` • `signals(2).values:  phi theta psi` Signals are linearly interpolated vs. time using `interp1`.

'Array6DoF'	A double-precision array in n rows and 7 columns for 6-DoF data: time latitude longitude altitude phi theta psi. If a double-precision array of 8 or more columns is in 'TimeseriesSource', the first 7 columns are used as 6-DoF data.
'Array3DoF'	A double-precision array in n rows and 4 columns for 3-DoF data: time latitude altitude theta. If a double-precision array of 5 or more columns is in 'TimeseriesSource', the first 4 columns are used as 3-DoF data.
'Custom'	Position and angle data is retrieved from 'TimeseriesSource' by the currently registered 'TimeseriesReadFcn'.

The time advancement algorithm used by play is based on animation frames counted by ticks:

```
ticks = ticks + 1;
time  = tstart + ticks*FramesPerSecond*TimeScaling;
```

where

TimeScaling	Specify the seconds of animation data per second of wall-clock time.
FramesPerSecond	Specify the number of frames per second used to animate the 'TimeseriesSource'.

For default 'TimeseriesReadFcn' methods, the last frame played is the last time value.

Time is in seconds, position values are in the same units as the geometry model to be used by FlightGear (see the property 'GeometryModelName'), and all angles are in radians. A possible result of using incorrect units is the early termination of the FlightGear flight simulator.

Note If there is a 15% difference between the expected time advance and the actual time advance, this method will generate the following warning:

```
TimerPeriod has been set to <value>. You may wish to modify the animation
TimeScaling and FramesPerSecond properties to compensate for the
millisecond limit of the TimerPeriod.  See documentation for details.
```

The play method supports FlightGear animation objects with custom timers.

Limitations

The following are limitations for the TStart and TFinal values:

- TStart and TFinal must be numeric.
- TStart and TFinal cannot be Inf or NaN.
- TFinal must be greater than or equal to TStart.
- TFinal cannot be greater than the maximum Timeseries time.
- TStart cannot be less than the minimum Timeseries time.

Examples

Animate FlightGear flight simulator using the given 'Array3DoF' position/angle time series data:

```
data = [86.2667 -2.13757034184404 7050.896596 -0.135186746141248;...
        87.2833 -2.13753906554384 6872.545051 -0.117321084678936;...
        88.2583 -2.13751089592972 6719.405713 -0.145815609299676;...
        89.275  -2.13747984652232 6550.117118 -0.150635248762596;...
```

```
            90.2667 -2.13744993157894 6385.05883  -0.143124782831999;...
            91.275  -2.13742019116849 6220.358163 -0.147946202530756;...
            92.275  -2.13739055547779 6056.906647 -0.167529704309343;...
            93.2667 -2.13736104196014 5892.356118 -0.152547361677911;...
            94.2583 -2.13733161570895 5728.201718 -0.161979312941906;...
            95.2583 -2.13730231163081 5562.923808 -0.122276929636682;...
            96.2583 -2.13727405475022 5406.736322 -0.160421658944379;...
            97.2667 -2.1372440001805  5239.138477 -0.150591353731908;...
            98.2583 -2.13721598764601 5082.78798  -0.147737722951605];
h = fganimation
h.TimeseriesSource = data
h.TimeseriesSourceType = 'Array3DoF'
play(h)
```

Animate FlightGear flight simulator using the custom timer, `MyFGTimer`.

```
h.SetTimer('MyFGTimer')
h.play('MyFGTimer')
```

See Also

`GenerateRunScript` | `initialize` | `update`

play (Aero.VirtualRealityAnimation)

Purpose

Animate virtual reality world for given position and angle in time series data

Syntax

```
play(h)
h.play
```

Description

`play(h)` and `h.play` animate the virtual reality world in `h` for the current `TimeseriesDataSource` at the specified rate given by the `'TimeScaling'` property (in seconds of animation data per second of wall-clock time) and animated at a certain number of frames per second using the `'FramesPerSecond'` property.

The time series data is interpreted according to the `'TimeseriesSourceType'` property, which can be one of:

`'timeseries'`	MATLAB time series data with six values per time: `x y z phi theta psi` The values are resampled.

`'Simulink.Timeseries'`	Simulink.Timeseries (Simulink signal logging):
	• First data item
	`x y z`
	• Second data item
	`phi theta psi`

`'StructureWithTime'`	Simulink struct with time (for example, Simulink root outport logging `'Structure with time'`): • `signals(1).values:  x y z` • `signals(2).values:  phi theta psi` Signals are linearly interpolated vs. time using `interp1`.
`'Array6DoF'`	A double-precision array in `n` rows and 7 columns for 6-DoF data: `time x y z phi theta psi`. If a double-precision array of 8 or more columns is in `'TimeseriesSource'`, the first 7 columns are used as 6-DoF data.
`'Array3DoF'`	A double-precision array in `n` rows and 4 columns for 3-DoF data: `time x z theta`. If a double-precision array of 5 or more columns is in `'TimeseriesSource'`, the first 4 columns are used as 3-DoF data.
`'Custom'`	Position and angle data is retrieved from `'TimeseriesSource'` by the currently registered `'TimeseriesReadFcn'`.

The time advancement algorithm used by `play` is based on animation frames counted by ticks:

```
ticks = ticks + 1;
time  = tstart + ticks*FramesPerSecond*TimeScaling;
```

where

TimeScaling	Specify the seconds of animation data per second of wall-clock time.
FramesPerSecond	Specify the number of frames per second used to animate the 'TimeseriesSource'.

For default 'TimeseriesReadFcn' methods, the last frame played is the last time value.

Time is in seconds, position values are in the same units as the geometry data loaded into the animation object, and all angles are in radians.

Examples

Animate virtual reality world, asttkoff.

```
h = Aero.VirtualRealityAnimation;
h.FramesPerSecond = 10;
h.TimeScaling = 5;
h.VRWorldFilename = [matlabroot,'/toolbox/aero/astdemos/asttkoff.wrl'];
h.initialize();
load takeoffData
h.Nodes{7}.TimeseriesSource = takeoffData;
h.Nodes{7}.TimeseriesSourceType = 'StructureWithTime';
h.Nodes{7}.CoordTransformFcn = @vranimCustomTransform;
h.play();
```

See Also

initialize

Purpose

Convert quaternion to rotation angles

Syntax

```
[r1 r2 r3] = quat2angle(q)
[r1 r2 r3] = quat2angle(q, s)
```

Description

`[r1 r2 r3] = quat2angle(q)` calculates the set of rotation angles, `r1`, `r2`, `r3`, for a given quaternion, `q`. `q` is an `m`-by-4 matrix containing `m` quaternions. Each element of `q` must be a real number. `q` has its scalar number as the first column.

Rotation angles are output in radians.

`r1`
: Returns an `m` array of first rotation angles.

`r2`
: Returns an `m` array of second rotation angles.

`r3`
: Returns an `m` array of third rotation angles.

`[r1 r2 r3] = quat2angle(q, s)` calculates the set of rotation angles, `r1`, `r2`, `r3`, for a given quaternion, `q`, and a specified rotation sequence, `s`.

The default rotation sequence is `'ZYX'`, where `r1` is *z*-axis rotation, `r2` is *y*-axis rotation, and `r3` is *x*-axis rotation.

Supported rotation sequence strings are `'ZYX'`, `'ZYZ'`, `'ZXY'`, `'ZXZ'`, `'YXZ'`, `'YXY'`, `'YZX'`, `'YZY'`, `'XYZ'`, `'XYX'`, `'XZY'`, and `'XZX'`.

Examples

Determine the rotation angles from q = [1 0 1 0].

```
[yaw, pitch, roll] = quat2angle([1 0 1 0])
yaw =
     0
pitch =
    1.5708
roll =
     0
```

Determine the rotation angles from multiple quaternions.

```
q = [1 0 1 0; 1 0.5 0.3 0.1];
 [pitch, roll, yaw] = quat2angle(q, 'YXZ')
pitch =
    1.5708
    0.8073
roll =
         0
    0.7702
yaw =
         0
    0.5422
```

Assumptions and Limitations

The limitations for the 'ZYX', 'ZXY', 'YXZ', 'YZX', 'XYZ', and 'XZY' implementations generate an r2 angle that lies between ±90 degrees, and r1 and r3 angles that lie between ±180 degrees.

The limitations for the 'ZYZ', 'ZXZ', 'YXY', 'YZY', 'XYX', and 'XZX' implementations generate an r2 angle that lies between 0 and 180 degrees, and r1 and r3 angles that lie between ±180 degrees.

See Also

angle2dcm | angle2quat | dcm2angle | dcm2quat | quat2dcm

Purpose

Convert quaternion to direction cosine matrix

Syntax

```
n = quat2dcm(q)
```

Description

`n = quat2dcm(q)` calculates the direction cosine matrix, `n`, for a given quaternion, `q`. Input `q` is an `m`-by-4 matrix containing `m` quaternions. `n` returns a 3-by-3-by-`m` matrix of direction cosine matrices. The direction cosine matrix performs the coordinate transformation of a vector in inertial axes to a vector in body axes. Each element of `q` must be a real number. Additionally, `q` has its scalar number as the first column.

Examples

Determine the direction cosine matrix from `q = [1 0 1 0]`:

```
dcm = quat2dcm([1 0 1 0])


dcm =

         0         0   -1.0000
         0    1.0000         0
    1.0000         0         0
```

Determine the direction cosine matrices from multiple quaternions:

```
q = [1 0 1 0; 1 0.5 0.3 0.1];
dcm = quat2dcm(q)


dcm(:,:,1) =

         0         0   -1.0000
         0    1.0000         0
    1.0000         0         0


dcm(:,:,2) =
```

```
0.8519    0.3704   -0.3704
0.0741    0.6148    0.7852
0.5185   -0.6963    0.4963
```

See Also

angle2dcm | dcm2angle | dcm2quat | angle2quat | quat2angle | quatrotate

Purpose Calculate conjugate of quaternion

Syntax

```
n = quatconj(q)
```

Description

`n = quatconj(q)` calculates the conjugate, `n`, for a given quaternion, `q`. Input `q` is an `m`-by-4 matrix containing `m` quaternions. `n` returns an `m`-by-4 matrix of conjugates. Each element of `q` must be a real number. Additionally, `q` has its scalar number as the first column.

Examples

Determine the conjugate of `q = [1 0 1 0]`:

```
conj = quatconj([1 0 1 0])


conj =

     1     0    -1     0
```

See Also

`quatdivide` | `quatinv` | `quatmod` | `quatmultiply` | `quatnorm` | `quatnormalize` | `quatrotate`

quatdivide

Purpose

Divide quaternion by another quaternion

Syntax

```
n = quatdivide(q,r)
```

Description

`n = quatdivide(q,r)` calculates the result of quaternion division, `n`, for two given quaternions, `q` and `r`. Inputs `q` and `r` can each be either an `m`-by-4 matrix containing `m` quaternions, or a single 1-by-4 quaternion. `n` returns an `m`-by-4 matrix of quaternion quotients. Each element of `q` and `r` must be a real number. Additionally, `q` and `r` have their scalar number as the first column.

Examples

Determine the division of two 1-by-4 quaternions:

```
q = [1 0 1 0];
r = [1 0.5 0.5 0.75];
d = quatdivide(q, r)


d =

    0.7273    0.1212    0.2424   -0.6061
```

Determine the division of a 2-by-4 quaternion by a 1-by-4 quaternion:

```
q = [1 0 1 0; 2 1 0.1 0.1];
r = [1 0.5 0.5 0.75];
d = quatdivide(q, r)


d =

    0.7273    0.1212    0.2424   -0.6061
    1.2727    0.0121   -0.7758   -0.4606
```

See Also

`quatconj` | `quatinv` | `quatmod` | `quatmultiply` | `quatnorm` | `quatnormalize` | `quatrotate`

Purpose

Calculate inverse of quaternion

Syntax

```
n = quatinv(q)
```

Description

`n = quatinv(q)` calculates the inverse, `n`, for a given quaternion, `q`. Input `q` is an `m`-by-4 matrix containing `m` quaternions. `n` returns an `m`-by-4 matrix of inverses. Each element of `q` must be a real number. Additionally, `q` has its scalar number as the first column.

Examples

Determine the inverse of `q = [1 0 1 0]`:

```
qinv = quatinv([1 0 1 0])


qinv =

    0.5000         0   -0.5000         0
```

See Also

`quatconj` | `quatdivide` | `quatmod` | `quatmultiply` | `quatnorm` | `quatnormalize` | `quatrotate`

quatmod

Purpose

Calculate modulus of quaternion

Syntax

```
n = quatmod(q)
```

Description

`n = quatmod(q)` calculates the modulus, `n`, for a given quaternion, `q`. Input `q` is an `m`-by-4 matrix containing `m` quaternions. `n` returns a column vector of `m` moduli. Each element of `q` must be a real number. Additionally, `q` has its scalar number as the first column.

Examples

Determine the modulus of `q = [1 0 0 0]`:

```
mod = quatmod([1 0 0 0])


mod =

     1
```

See Also

`quatconj` | `quatdivide` | `quatinv` | `quatmultiply` | `quatnorm` | `quatnormalize` | `quatrotate`

Purpose

Calculate product of two quaternions

Syntax

```
n = quatmultiply(q,r)
```

Description

`n = quatmultiply(q,r)` calculates the quaternion product, `n`, for two given quaternions, `q` and `r`. Inputs `q` and `r` can each be either an `m`-by-4 matrix containing `m` quaternions, or a single 1-by-4 quaternion. `n` returns an `m`-by-4 matrix of quaternion products. Each element of `q` and `r` must be a real number. Additionally, `q` and `r` have their scalar number as the first column.

Note Quaternion multiplication is not commutative.

Examples

Determine the product of two 1-by-4 quaternions:

```
q = [1 0 1 0];
r = [1 0.5 0.5 0.75];
mult = quatmultiply(q, r)


mult =

    0.5000    1.2500    1.5000    0.2500
```

Determine the product of a 1-by-4 quaternion with itself:

```
q = [1 0 1 0];
mult = quatmultiply(q)


mult =

     0     0     2     0
```

Determine the product of 1-by-4 and 2-by-4 quaternions:

```
q = [1 0 1 0];
r = [1 0.5 0.5 0.75; 2 1 0.1 0.1];
mult = quatmultiply(q, r)


mult =

    0.5000    1.2500    1.5000    0.2500
    1.9000    1.1000    2.1000   -0.9000
```

See Also

quatconj | quatdivide | quatinv | quatmod | quatnorm | quatnormalize | quatrotate

Purpose Calculate norm of quaternion

Syntax

```
n = quatnorm(q)
```

Description `n = quatnorm(q)` calculates the norm, `n`, for a given quaternion, `q`. Input `q` is an `m`-by-4 matrix containing `m` quaternions. `n` returns a column vector of `m` norms. Each element of `q` must be a real number. Additionally, `q` has its scalar number as the first column.

Examples Determine the norm of `q = [1 0 0 0]`:

```
norm = quatnorm([1 0 0 0])


norm =

     1
```

See Also `quatconj` | `quatdivide` | `quatinv` | `quatmod` | `quatmultiply` | `quatnormalize` | `quatrotate`

quatnormalize

Purpose

Normalize quaternion

Syntax

```
n = quatnormalize(q)
```

Description

`n = quatnormalize(q)` calculates the normalized quaternion, `n`, for a given quaternion, `q`. Input `q` is an `m`-by-4 matrix containing `m` quaternions. `n` returns an `m`-by-4 matrix of normalized quaternions. Each element of `q` must be a real number. Additionally, `q` has its scalar number as the first column.

Examples

Normalize `q = [1 0 1 0]`:

```
normal = quatnormalize([1 0 1 0])


normal =

    0.7071         0    0.7071         0
```

See Also

`quatconj` | `quatdivide` | `quatinv` | `quatmod` | `quatmultiply` | `quatnorm` | `quatrotate`

Purpose

Rotate vector by quaternion

Syntax

```
n = quatrotate(q,r)
```

Description

`n = quatrotate(q,r)` calculates the rotated vector, `n`, for a quaternion, `q`, and a vector, `r`. `q` is either an `m`-by-4 matrix containing `m` quaternions, or a single 1-by-4 quaternion. `r` is either an `m`-by-3 matrix, or a single 1-by-3 vector. `n` returns an `m`-by-3 matrix of rotated vectors. Each element of `q` and `r` must be a real number. Additionally, `q` has its scalar number as the first column.

Examples

Rotate a 1-by-3 vector by a 1-by-4 quaternion:

```
q = [1 0 1 0];
r = [1 1 1];
n = quatrotate(q, r)


n =

   -1.0000    1.0000    1.0000
```

Rotate a 1-by-3 vector by a 2-by-4 quaternion:

```
q = [1 0 1 0; 1 0.5 0.3 0.1];
r = [1 1 1];
n = quatrotate(q, r)


n =

   -1.0000    1.0000    1.0000
    0.8519    1.4741    0.3185
```

Rotate a 2-by-3 vector by a 1-by-4 quaternion:

```
q = [1 0 1 0];
r = [1 1 1; 2 3 4];
```

```
n = quatrotate(q, r)


n =

   -1.0000    1.0000    1.0000
   -4.0000    3.0000    2.0000
```

Rotate a 2-by-3 vector by a 2-by-4 quaternion:

```
q = [1 0 1 0; 1 0.5 0.3 0.1];
r = [1 1 1; 2 3 4];
n = quatrotate(q, r)


n =

   -1.0000    1.0000    1.0000
    1.3333    5.1333    0.9333
```

See Also

quatconj | quatinv | quatmod | quatmultiply | quatnorm | quatnormalize

read (Aero.Geometry)

Purpose

Read geometry data using current reader

Syntax

```
read(h, source)
```

Description

`read(h, source)` reads the geometry data of the geometry object `h`. `source` can be:

- `'Auto'`

  Selects default reader.

- `'Variable'`

  Selects MATLAB variable of type structure structures that contains the fields`name`, `faces`, `vertices`, and `cdata` that define the geometry in the Handle Graphics patches.

- `'MatFile'`

  Selects MAT-file reader.

- `'Ac3dFile'`

  Selects Ac3d file reader.

- `'Custom'`

  Selects a custom reader.

Examples

Read geometry data from Ac3d file, `pa24-250_orange.ac`.

```
g = Aero.Geometry;
g.Source = 'Ac3d';
g.read('pa24-250_orange.ac');
```

Aero.Animation.removeBody

Purpose

Remove one body from animation

Syntax

```
h = removeBody(h,idx)
h = h.removeBody(idx)
```

Description

`h = removeBody(h,idx)` and `h = h.removeBody(idx)` remove the body specified by the index `idx` from the animation object `h`.

Input Arguments

`h`	Animation object.
`idx`	Body specified with this index.

Examples

Remove the body identified by the index, 1.

```
h = Aero.Animation;
idx1 = h.createBody('pa24-250_orange.ac','Ac3d');
h = removeBody(h,1)
```

Purpose

Remove node from virtual reality animation object

Syntax

```
removeNode(h,node)
h.removeNode(node)
```

Description

`removeNode(h,node)` and `h.removeNode(node)` remove the node specified by `node` from the virtual reality animation object `h`. `node` can be either the node name or the node index. This function can remove only one node at a time.

Note You can use only this function to remove a node added by `addNode`. If you need to remove a node from a previously defined `.wrl` file, use a VRML editor.

Examples

Remove the node, Lynx1.

```
h = Aero.VirtualRealityAnimation;
h.VRWorldFilename = [matlabroot,'/toolbox/aero/astdemos/asttkoff.wrl'];
copyfile(h.VRWorldFilename,[tempdir,'asttkoff.wrl'],'f');
h.VRWorldFilename = [tempdir,'asttkoff.wrl'];
h.initialize();
h.addNode('Lynx1',[matlabroot,'/toolbox/aero/astdemos/chaseHelicopter.wrl']);
h.removeNode('Lynx1');
```

See Also

`addNode`

removeViewpoint (Aero.VirtualRealityAnimation)

Purpose

Remove viewpoint node from virtual reality animation

Syntax

`removeViewpoint(h,viewpoint)`
`h.removeViewpoint(viewpoint)`

Description

`removeViewpoint(h,viewpoint)` and `h.removeViewpoint(viewpoint)` remove the viewpoint specified by `viewpoint` from the virtual reality animation object `h`. `viewpoint` can be either the viewpoint name or the viewpoint index. This function can remove only one viewpoint at a time.

Note You can use this function to remove a viewpoint added by `addViewpoint`. If you need to remove a viewpoint from a previously defined `.wrl` file, use a VRML editor.

Examples

Remove the node, Lynx1.

```
h = Aero.VirtualRealityAnimation;
h.VRWorldFilename = [matlabroot,'/toolbox/aero/astdemos/asttkoff.wrl'];
copyfile(h.VRWorldFilename,[tempdir,'asttkoff.wrl'],'f');
h.VRWorldFilename = [tempdir,'asttkoff.wrl'];
h.initialize();
h.addViewpoint(h.Nodes{2}.VRNode,'children','chaseView','View From Helicopter');
h.removeViewpoint('chaseView');
```

See Also

`addViewpoint`

Purpose

Compute relative pressure ratio

Syntax

```
d = rrdelta(p0, mach, g)
```

Description

`d = rrdelta(p0, mach, g)` computes `m` pressure relative ratios, `d`, from `m` static pressures, `p0`, `m` Mach numbers, `mach`, and `m` specific heat ratios, `g`. `p0` must be in pascals.

Examples

Determine the relative pressure ratio for three pressures:

```
delta = rrdelta([101325 22632.0672 4328.1393], 0.5, 1.4)


delta =

     1.1862    0.2650    0.0507
```

Determine the relative pressure ratio for three pressures and three different heat ratios:

```
delta = rrdelta([101325 22632.0672 4328.1393], 0.5, [1.4 1.35 1.4])


delta =

    1.1862    0.2635    0.0507
```

Determine the relative pressure ratio for three pressures at three different conditions:

```
delta = rrdelta([101325 22632.0672 4328.1393], [0.5 1 2], [1.4 1.35 1.4])


delta =

    1.1862    0.4161    0.3342
```

Assumptions and Limitations

For cases in which total pressure ratio is desired (Mach number is nonzero), the total pressures are calculated assuming perfect gas (with constant molecular weight, constant pressure specific heat, and constant specific heat ratio) and dry air.

References

Aeronautical Vestpocket Handbook, United Technologies Pratt & Whitney, August, 1986

See Also

`rrsigma` | `rrtheta`

Purpose Compute relative density ratio

Syntax

```
s = rrsigma(rho, mach, g)
```

Description

`s = rrsigma(rho, mach, g)` computes `m` density relative ratios, `s`, from `m` static densities, `rho`, `m` Mach numbers, `mach`, and `m` specific heat ratios, `g`. `rho` must be in kilograms per meter cubed.

Examples

Determine the relative density ratio for three densities:

```
sigma = rrsigma([1.225 0.3639 0.0953], 0.5, 1.4)


sigma =

    1.1297    0.3356    0.0879
```

Determine the relative density ratio for three densities and three different heat ratios:

```
sigma = rrsigma([1.225 0.3639 0.0953], 0.5, [1.4 1.35 1.4])


sigma =

    1.1297    0.3357    0.0879
```

Determine the relative density ratio for three densities at three different conditions:

```
sigma = rrsigma([1.225 0.3639 0.0953], [0.5 1 2], [1.4 1.35 1.4])


sigma =

    1.1297    0.4709    0.3382
```

Assumptions and Limitations

For cases in which total density ratio is desired (Mach number is nonzero), the total density is calculated assuming perfect gas (with constant molecular weight, constant pressure specific heat, and constant specific heat ratio) and dry air.

References

Aeronautical Vestpocket Handbook, United Technologies Pratt & Whitney, August, 1986

See Also

`rrdelta` | `rrtheta`

Purpose

Compute relative temperature ratio

Syntax

```
th = rrtheta(t0, mach, g)
```

Description

`th = rrtheta(t0, mach, g)` computes `m` temperature relative ratios, `th`, from `m` static temperatures, `t0`, `m` Mach numbers, `mach`, and `m` specific heat ratios, `g`. `t0` must be in kelvin.

Examples

Determine the relative temperature ratio for three temperatures:

```
th = rrtheta([273.15 310.9278 373.15], 0.5, 1.4)


th =

    0.9953    1.1330    1.3597
```

Determine the relative temperature ratio for three temperatures and three different heat ratios:

```
th = rrtheta([273.15 310.9278 373.15], 0.5, [1.4 1.35 1.4])


th =

    0.9953    1.1263    1.3597
```

Determine the relative temperature ratio for three temperatures at three different conditions:

```
th = rrtheta([273.15 310.9278 373.15], [0.5 1 2], [1.4 1.35 1.4])


th =

    0.9953    1.2679    2.3310
```

Assumptions and Limitations

For cases in which total temperature ratio is desired (Mach number is nonzero), the total temperature is calculated assuming perfect gas (with constant molecular weight, constant pressure specific heat, and constant specific heat ratio) and dry air.

References

Aeronautical Vestpocket Handbook, United Technologies Pratt & Whitney, August, 1986

See Also

`rrdelta` | `rrsigma`

saveas (Aero.VirtualRealityAnimation)

Purpose

Save virtual reality world associated with virtual reality animation object

Syntax

```
saveas(h, filename)
h.saveas(filename)
```

Description

`saveas(h, filename)` and `h.saveas(filename)` save the world associated with the virtual reality animation object, `h`, into the `.wrl` file name specified in the `filename` variable. After saving, this function reinitializes the virtual reality animation object from the saved world.

Examples

Save the world associated with `h`.

```
h = Aero.VirtualRealityAnimation;
h.VRWorldFilename = [matlabroot,'/toolbox/aero/astdemos/asttkoff.wrl'];
copyfile(h.VRWorldFilename,[tempdir,asttkoff.wrl'],'f');
h.VRWorldFilename = [tempdir,asttkoff.wrl'];
h.initialize();
h.saveas([tempdir,'my_asttkoff.wrl']);
```

SetTimer (Aero.FlightGearAnimation)

Purpose Set name of timer for animation of FlightGear flight simulator

Syntax

```
SetTimer(h)
h.SetTimer
SetTimer(h, MyFGTimer)
h.SetTimer('MyFGTimer')
```

Description `SetTimer(h)` and `h.SetTimer` set the name of the MATLAB timer for the animation of the FlightGear flight simulator. `SetTimer(h, MyFGTimer)` and `h.SetTimer('MyFGTimer')` set the name of the MATLAB timer for the animation of the FlightGear flight simulator and assign a custom name to the timer.

You can use this function to customize your FlightGear animation object. This customization allows you to simultaneously run multiple FlightGear objects if you want to use

- Multiple FlightGear sessions
- Different ports to connect to those sessions

Examples Set the MATLAB timer for animation of the FlightGear animation object, `h`:

```
h = Aero.FlightGearAnimation
h.SetTimer
```

Set the MATLAB timer used for animation of the FlightGear animation object, `h`, and assign a custom name, *`MyFGTimer`*, to the timer:

```
h = Aero.FlightGearAnimation
h.SetTimer('MyFGTimer')
```

See Also `ClearTimer`

Purpose

Show animation object figure

Syntax

```
show(h)
h.show
```

Description

`show(h)` and `h.show` create the figure graphics object for the animation object `h`. Use the `Aero.Animation.hide` function to close the figure.

Input Arguments

`h`	Animation object.

Examples

Show the animation object, `h`.

```
h = Aero.Animation;
idx1 = h.createBody('pa24-250_orange.ac','Ac3d');
h.show;
```

update (Aero.Body)

Purpose

Change body position and orientation as function of time

Syntax

```
update(h,t)
h.update(t)
```

Description

`update(h,t)` and `h.update(t)` change body position and orientation of body `h` as a function of time `t`. *t* is a scalar in seconds.

Note This function requires that you load the body geometry and time series data first.

Examples

Update the body `b` with time in seconds of 5.

```
b=Aero.Body;
b.load('pa24-250_orange.ac','Ac3d');
tsdata = [ ...
    0,  1,1,1, 0,0,0; ...
    10  2,2,2, 1,1,1; ];
b.TimeSeriesSource = tsdata;
b.update(5);
```

See Also

`load`

Purpose

Update camera position based on time and position of other Aero.Body objects

Syntax

```
update(h,newtime,bodies)
h.update(newtime,bodies)
```

Description

`update(h,newtime,bodies)` and `h.update(newtime,bodies)` update the camera object, `h`, position and aim point data based on the new time, `newtime`, and position of other `Aero.Body` objects, `bodies`. This function updates the camera object `PrevTime` property to `newtime`.

See Also

`Aero.Animation.play`

update (Aero.FlightGearAnimation)

Purpose Update position data to FlightGear animation object

Syntax

```
update(h,time)
h.update(time)
```

Description `update(h,time)` and `h.update(time)` update the position data to the FlightGear animation object via UDP. It sets the new position and attitude of body `h`. `time` is a scalar in seconds.

Note This function requires that you load the time series data and run FlightGear first.

Examples Configure a body with `TimeSeriesSource` set to `simdata`, then update the body with time *`time`* equal to 0.

```
h = Aero.FlightGearAnimation;
h.FramesPerSecond = 10;
h.TimeScaling = 5;
load simdata;
h.TimeSeriesSource = simdata;
t = 0;
h.update(t);
```

See Also `GenerateRunScript` | `initialize` | `play`

Purpose

Change node position and orientation versus time data

Syntax

```
update(h,t)
h.update(t)
```

Description

`update(h,t)` and `h.update(t)` change node position and orientation of node `h` as a function of time `t`. *t* is a scalar in seconds.

Note This function requires that you load the node and time series data first.

Examples

Move the Lynx body.

```
h = Aero.VirtualRealityAnimation;
h.FramesPerSecond = 10;
h.TimeScaling = 5;
h.VRWorldFilename = [matlabroot,'/toolbox/aero/astdemos/asttkoff.wrl'];
copyfile(h.VRWorldFilename,[tempdir,'asttkoff.wrl'],'f');
h.VRWorldFilename = [tempdir,'asttkoff.wrl'];
h.initialize();
load takeoffData
h.Nodes{7}.TimeseriesSource = takeoffData;
h.Nodes{7}.TimeseriesSourceType = 'StructureWithTime';
h.Nodes{7}.update(5);
```

See Also

`updateNodes`

Aero.Animation.updateBodies

Purpose

Update bodies of animation object

Syntax

```
h = updateBodies(time)
h.updateBodies(time)
```

Description

`h = updateBodies(time)` and `h.updateBodies(time)` set the new position and attitude of movable bodies in the animation object `h`. This function updates the bodies contained in the animation `object h`. `time` is a scalar in seconds.

Examples

Configure a body with `TimeSeriesSource` set to `simdata`, then update the body with time *t* equal to 0.

```
h = Aero.Animation;
h.FramesPerSecond = 10;
h.TimeScaling = 5;
idx1 = h.createBody('pa24-250_orange.ac','Ac3d');
load simdata;
h.Bodies{1}.TimeSeriesSource = simdata;
t = 0;
h.updateBodies(t);
```

Purpose

Update camera in animation object

Syntax

```
updateCamera(h,time)
h.updateCamera(time)
```

Description

`updateCamera(h,time)` and `h.updateCamera(time)` update the camera in the animation object `h`. `time` is a scalar in seconds.

Note The `PositionFcn` property of a camera object controls the camera position relative to the bodies in the animation. The default camera `PositionFcn` follows the path of a first order chase vehicle. Therefore, it takes a few steps for the camera to position itself correctly in the chase plane position.

Input Arguments

`h`	Animation object.
`time`	Scalar in seconds.

Examples

Configure a body with `TimeSeriesSource` set to `simdata`, then update the camera with time *t* equal to 0.

```
h = Aero.Animation;
h.FramesPerSecond = 10;
h.TimeScaling = 5;
idx1 = h.createBody('pa24-250_orange.ac','Ac3d');
load simdata;
h.Bodies{1}.TimeSeriesSource = simdata;
t = 0;
h.updateCamera(t);
```

updateNodes (Aero.VirtualRealityAnimation)

Purpose

Change virtual reality animation node position and orientation as function of time

Syntax

`updateNodes(h,t)`
`h.updateNotes(t)`

Description

`updateNodes(h,t)` and `h.updateNotes(t)` change node position and orientation of body `h` as a function of time `t`. *`t`* is a scalar in seconds.

Note This function requires that you load the node and time series data first.

Examples

Update the node `h` with time in 5 seconds.

```
h = Aero.VirtualRealityAnimation;
h.FramesPerSecond = 10;
h.TimeScaling = 5;
h.VRWorldFilename = [matlabroot,'/toolbox/aero/astdemos/asttkoff.wrl'];
copyfile(h.VRWorldFilename,[tempdir,'asttkoff.wrl'],'f');
h.VRWorldFilename = [tempdir,'asttkoff.wrl'];
h.initialize();
load takeoffData
h.Nodes{7}.TimeseriesSource = takeoffData;
h.Nodes{7}.TimeseriesSourceType = 'StructureWithTime';
h.Nodes{7}.CoordTransformFcn = @vranimCustomTransform;
h.updateNodes(5);
```

See Also

`addNode` | `update`

Purpose Create viewpoint object for use in virtual reality animation

Syntax

```
h = Aero.Viewpoint
```

Description `h = Aero.Viewpoint` creates a viewpoint object for use with virtual reality animation.

See `Aero.Viewpoint` for further details.

VirtualRealityAnimation (Aero.VirtualRealityAnimation)

Purpose

Construct virtual reality animation object

Syntax

`h = Aero.VirtualRealityAnimation`

Description

`h = Aero.VirtualRealityAnimation` constructs a virtual reality animation object. The animation object is returned to `h`.

See `Aero.VirtualRealityAnimation` for further details.

See Also

`Aero.VirtualRealityAnimation`

Purpose

Use World Magnetic Model

Note The '2000' or '2005' epoch year are outdated. For model years between 2000 and the start of 2010, use `igrf11magm`. For model years between 2010 and the start of 2015, use `wrldmagm`.

Syntax

```
[xyz, h, dec, dip, f] = wrldmagm(height, lat, lon, dyear)
[xyz, h, dec, dip, f] = wrldmagm(height, lat, lon, dyear,
   '2010')
[xyz, h, dec, dip, f] = wrldmagm(height, lat, lon, dyear,
   '2005')
[xyz, h, dec, dip, f] = wrldmagm(height, lat, lon, dyear,
   '2000')
```

Description

`[xyz, h, dec, dip, f] = wrldmagm(height, lat, lon, dyear)` calculates the Earth's magnetic field at a specific location and time using the World Magnetic Model (WMM). The default WMM is WMM-2010, which is valid from January 1, 2010, until December 31, 2014.

Inputs required by `wrldmagm` are:

`height`	A scalar value, in meters
`lat`	A scalar geodetic latitude, in degrees, where north latitude is positive, and south latitude is negative
`lon`	A scalar geodetic longitude, in degrees, where east longitude is positive, and west longitude is negative
`dyear`	A scalar decimal year. Decimal year is the desired year in a decimal format to include any fraction of the year that has already passed.

Outputs calculated for the Earth's magnetic field include:

`xyz`	Magnetic field vector in nanotesla (nT)
`h`	Horizontal intensity in nanotesla (nT)
`dec`	Declination in degrees
`dip`	Inclination in degrees
`f`	Total intensity in nanotesla (nT)

`[xyz, h, dec, dip, f] = wrldmagm(height, lat, lon, dyear, '2010')` is an alternate method for calling WMM-2010, or 2010 epoch.

`[xyz, h, dec, dip, f] = wrldmagm(height, lat, lon, dyear, '2005')` is an alternate method for calling WMM-2005, or 2005 epoch.

`[xyz, h, dec, dip, f] = wrldmagm(height, lat, lon, dyear, '2000')` is the method for calling WMM-2000, or 2000 epoch.

Examples

Calculate the magnetic model 1000 meters over Natick, Massachusetts on July 4, 2010, using WMM-2010:

```
[XYZ, H, DEC, DIP, F] = wrldmagm(1000, 42.283, -71.35, decyear(2010,7,4),'2010')
XYZ =

  1.0e+004 *

    1.9229
   -0.5139
    4.8865

H =

  1.9904e+004

DEC =

  -14.9627
```

```
DIP =

   67.8376

F =

  5.2763e+004
```

Assumptions and Limitations

The WMM specification produces data that is reliable five years after the epoch of the model, which begins January 1 of the model year selected. The WMM specification describes only the long-wavelength spatial magnetic fluctuations due to the Earth's core. Intermediate and short-wavelength fluctuations, contributed from the crustal field (the mantle and crust), are not included. Also, the substantial fluctuations of the geomagnetic field, which occur constantly during magnetic storms and almost constantly in the disturbance field (auroral zones), are not included.

References

`http://www.ngdc.noaa.gov/geomag/WMM/DoDWMM.shtml`

"NOAA Technical Report: The US/UK World Magnetic Model for 2005–2010"

See Also

`decyear`

Aero.Animation.Bodies property

Purpose Specify name of animation object

Values

`MATLAB array`

Default: `[ ]`

Description This property specifies the bodies that the animation object contains.

Purpose Specify camera that animation object contains

Values

`handle`

Default: `[ ]`

Description This property specifies the camera that the animation object contains.

Aero.Animation.Figure property

Purpose

Specify name of figure object

Values

```
MATLAB array
```

Default: `[ ]`

Description

This property specifies the name of the figure object.

Purpose Specify figure customization function

Values

`MATLAB array`

Default: `[ ]`

Description This property specifies the figure customization function.

Aero.Animation.FramesPerSecond property

Purpose Animation rate

Values

```
MATLAB array
```

Default: `12`

Description This property specifies rate in frames per second.

Purpose Specify name of animation object

Values

`String`

Default: `' '`

Description This property specifies the name of the animation object.

Aero.Animation.TCurrent property

Purpose Current time

Values

`double`

Default: `0`

Description This property specifies the current time.

Purpose End time

Values

`double`

Default: `NaN`

Description This property specifies the end time.

Aero.Animation.TimeScaling property

Purpose Scaling time

Values

`double`

Default: `1`

Description This property specifies the time, in seconds.

Purpose Start time

Values

`double`

Default: `NaN`

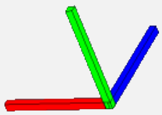
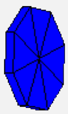
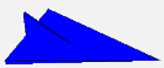
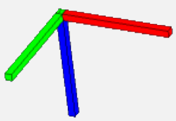
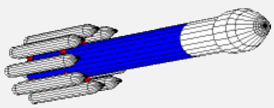
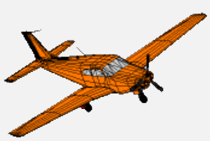
Description This property specifies the start time.

A

AC3D Files and Thumbnails

Overview

Aerospace Toolbox demos use the following AC3D files, located in the `matlabroot\toolbox\aero\astdemos` folder. For other AC3D files, see `http://www.flightgear.org/Downloads/` and click the **Download Aircraft** link.

Thumbnail	AC3D File
	`ac3d_xyzisrgb.ac`
	`blueoctagon.ac`
	`bluewedge.ac`
	`body_xyzisrgb.ac`
	`delta2.ac`
	`greenarrow.ac`
	`pa24 250_blue.ac`
	`pa24 250_orange.ac`

Thumbnail	AC3D File
	`redwedge.ac`
	`testrocket.ac`

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