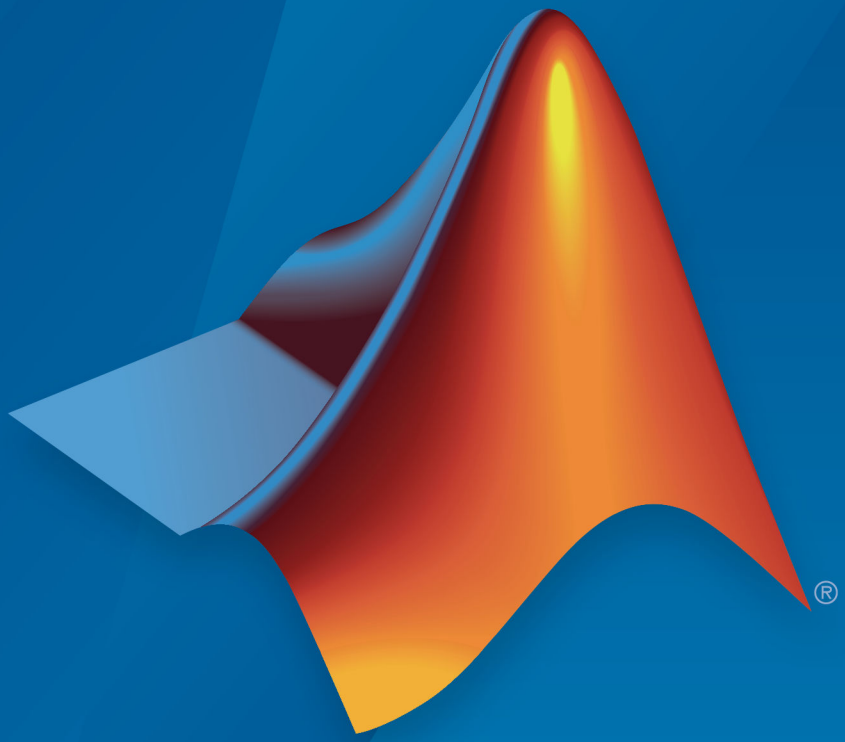
# Aerospace Toolbox

User's Guide



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*Aerospace Toolbox User's Guide*

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**Revision History**

| | | |
|---|---|---|
| September 2006 | Online only | New for Version 1.0 (Release 2006b) |
| March 2007 | Online only | Revised for Version 1.1 (Release 2007a) |
| September 2007 | First printing | Revised for Version 2.0 (Release 2007b) |
| March 2008 | Online only | Revised for Version 2.1 (Release 2008a) |
| October 2008 | Online only | Revised for Version 2.2 (Release 2008b) |
| March 2009 | Online only | Revised for Version 2.3 (Release 2009a) |
| September 2009 | Online only | Revised for Version 2.4 (Release 2009b) |
| March 2010 | Online only | Revised for Version 2.5 (Release 2010a) |
| September 2010 | Online only | Revised for Version 2.6 (Release 2010b) |
| April 2011 | Online only | Revised for Version 2.7 (Release 2011a) |
| September 2011 | Online only | Revised for Version 2.8 (Release 2011b) |
| March 2012 | Online only | Revised for Version 2.9 (Release 2012a) |
| September 2012 | Online only | Revised for Version 2.10 (Release 2012b) |
| March 2013 | Online only | Revised for Version 2.11 (Release 2013a) |
| September 2013 | Online only | Revised for Version 2.12 (Release 2013b) |
| March 2014 | Online only | Revised for Version 2.13 (Release 2014a) |
| October 2014 | Online only | Revised for Version 2.14 (Release 2014b) |
| March 2015 | Online only | Revised for Version 2.15 (Release 2015a) |
| September 2015 | Online only | Revised for Version 2.16 (Release 2015b) |
| March 2016 | Online only | Revised for Version 2.17 (Release 2016a) |
| September 2016 | Online only | Revised for Version 2.18 (Release 2016b) |
| March 2017 | Online only | Revised for Version 2.19 (Release 2017a) |
| September 2017 | Online only | Revised for Version 2.20 (Release 2017b) |
| March 2018 | Online only | Revised for Version 2.21 (Release 2018a) |
| September 2018 | Online only | Revised for Version 3.0 (Release 2018b) |

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# Getting Started


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- “Aerospace Toolbox and Aerospace Blockset” on page 1-3

# Aerospace Toolbox Product Description

**Analyze and visualize aerospace vehicle motion using reference standards and models**

Aerospace Toolbox provides tools and functions for analyzing the navigation and environment of aerospace vehicles and visualizing their flight using standard cockpit instruments or a flight simulator. It lets you import Data Compendium (Datcom) files directly into MATLAB® to represent vehicle aerodynamics and incorporate validated environment models for atmosphere, gravity, wind, geoid height, and magnetic field. You can evaluate vehicle motion and orientation using built-in aerospace math operations and coordinate system and spatial transformations. You can visualize the vehicle in flight directly from MATLAB with standard cockpit instruments and using the pre-built FlightGear Flight Simulator interface.

## Key Features

- Built-in axis transformations for body, wind, and geodetic coordinates, including earth-centered / earth-fixed (ECEF) and earth-centered inertial (ECI)
- Validated environment models, including gravity, atmosphere, wind, geoid height, magnetic field, and planetary ephemerides
- 3D animations and flight instruments for visualizing flight data
- Gas dynamics functions for calculating flow ratios, relations, and Prandtl-Meyer expansion waves
- Aerodynamic coefficients from Data Compendium (Datcom) files

# Aerospace Toolbox and Aerospace Blockset

The Aerospace product family includes the Aerospace Toolbox and Aerospace Blockset products. The toolbox provides static data analysis capabilities, while the 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.

# Using Aerospace Toolbox


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# Fundamental Coordinate System Concepts

Coordinate systems allow you to track an aircraft or spacecraft 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 rightmost 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 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 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 surface. The geographic poles are the intersection of the Earth surface and the geopolar axis. In general, the Earth 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 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 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 rotation about its axis. This is a *rotating*, *geocentric* system. The toolbox ignores the Earth motion around the Sun, the Sun motion in the Galaxy, and the Galaxy's motion through cosmos. In most applications, only the Earth rotation matters.

  This approximation must be changed for spacecraft sent into deep space, that is, 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.

## References

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

Mapping Toolbox™ documentation, The MathWorks, Inc., Natick, Massachusetts. “Mapping Toolbox”.

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`.

# Coordinate Systems for Modeling

Modeling aircraft and spacecraft are 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.

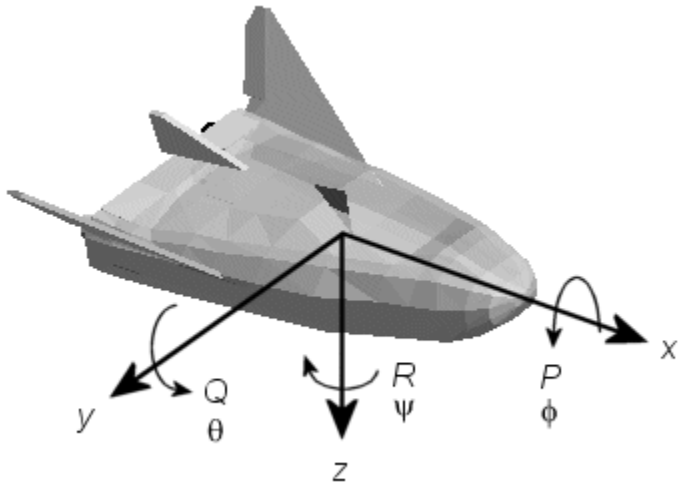
### Translational Degrees of Freedom

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 $\Phi$, $\Theta$, $\Psi$. They are

- $P$ or $\Phi$: Roll about the $x$-axis
- $Q$ or $\Theta$: Pitch about the $y$-axis
- $R$ or $\Psi$: Yaw about the $z$-axis




Unless otherwise specified, by default the software uses ZYX rotation order for Euler angles.

## 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.

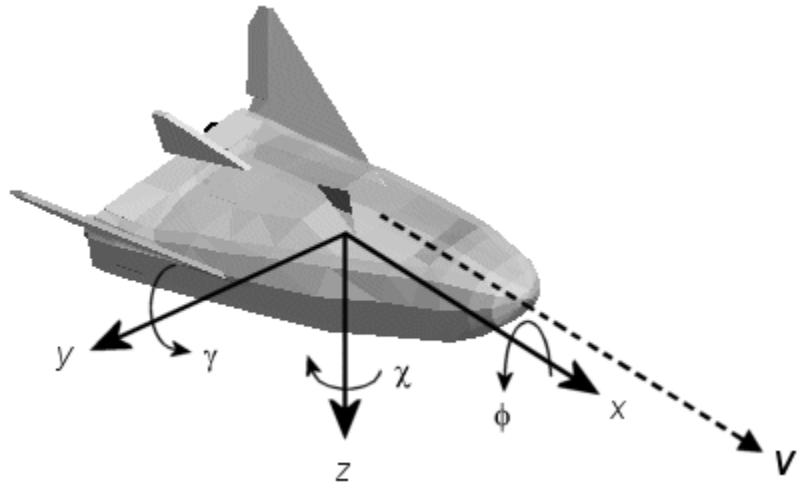
### Translational Degrees of Freedom

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




Unless otherwise specified, by default the software uses ZYX rotation order for Euler angles.

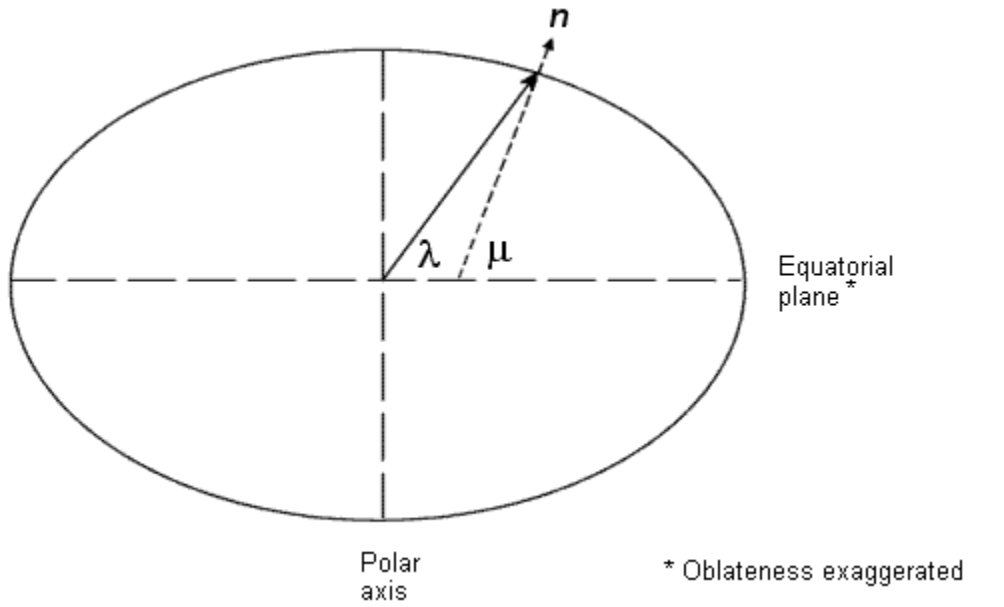
# Coordinate Systems for Navigation

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 surface is defined by the angle subtended by the radius vector from the Earth center to the surface point with the equatorial plane.

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

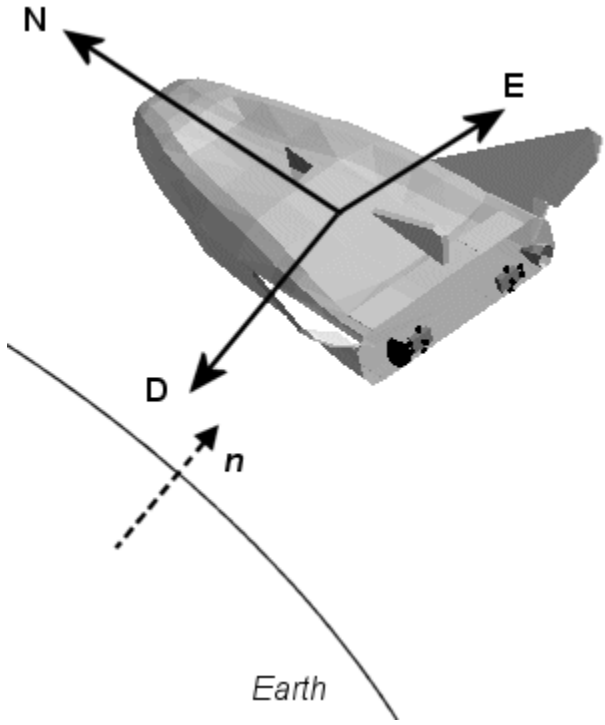



## NED Coordinates

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 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 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.

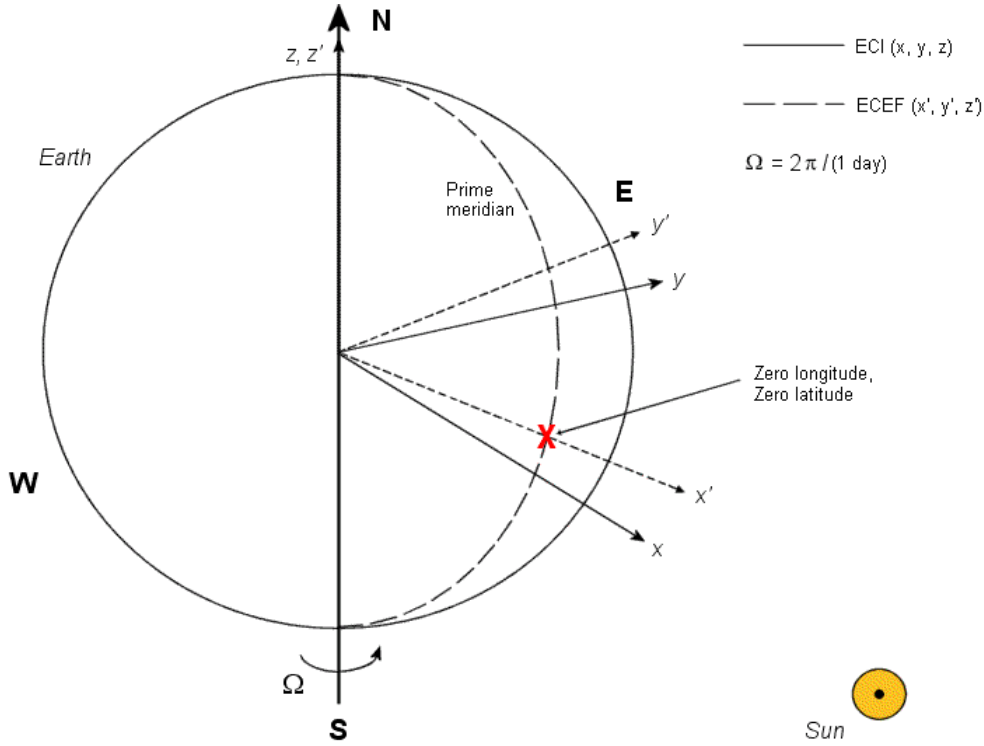



## ECI Coordinates

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

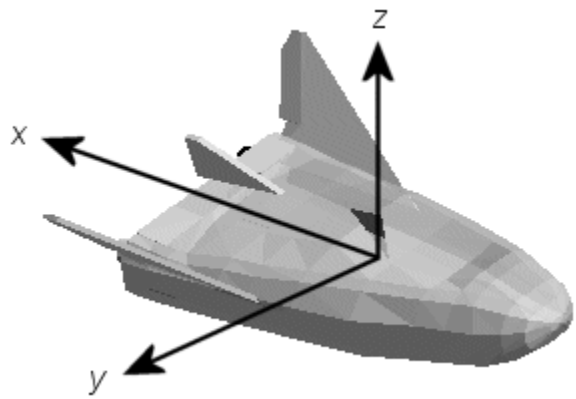
The Aerospace Toolbox software lets you use FlightGear coordinates for rendering motion.

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

- “Flight Simulator Interface Example” on page 2-57 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.



# 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) |
| Length | meter (m) | inch (in), foot (ft), mile (mi), nautical mile (nm) |
| Mass | kilogram (kg) | slug (slug), pound mass (lbm) |
| Pressure | pascal (Pa) | pound/inch$^2$ (psi), pound/foot$^2$ (psf), atmosphere (atm) |
| Temperature | kelvin (K), degrees Celsius ($^o$C) | degrees Fahrenheit ($^o$F), degrees Rankine ($^o$R) |

| Quantity | MKS (SI) | English |
|---|---|---|
| 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 |

# Digital DATCOM Data

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## Digital DATCOM Data 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 example. You can run the example by entering `astimportddatcom` in the MATLAB Command Window.

## 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.

## Data from DATCOM Files

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

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

## 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 =
 struct with fields:

        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]
```

## 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
```

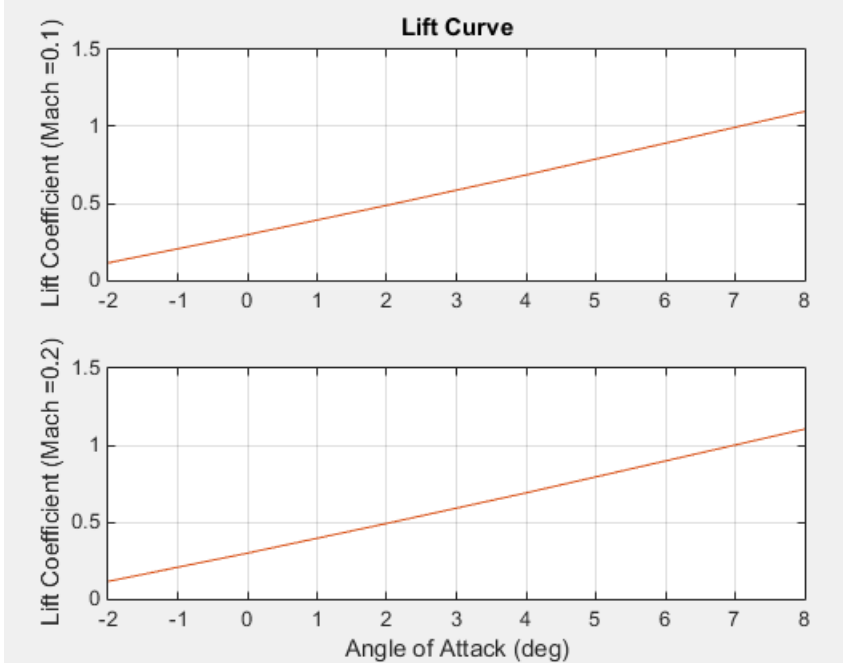
## Aerodynamic Coefficients

You can now plot the aerodynamic coefficients:

- “Plotting Lift Curve Moments” on page 2-20
- “Plotting Drag Polar Moments” on page 2-20
- “Plotting Pitching Moments” on page 2-21

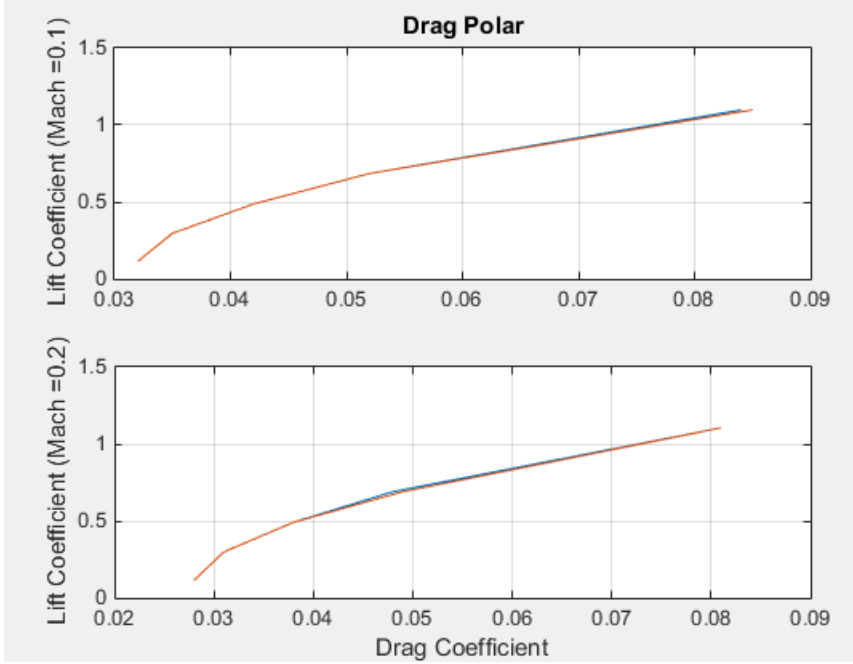
### Plotting Lift Curve Moments

```
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)')
```



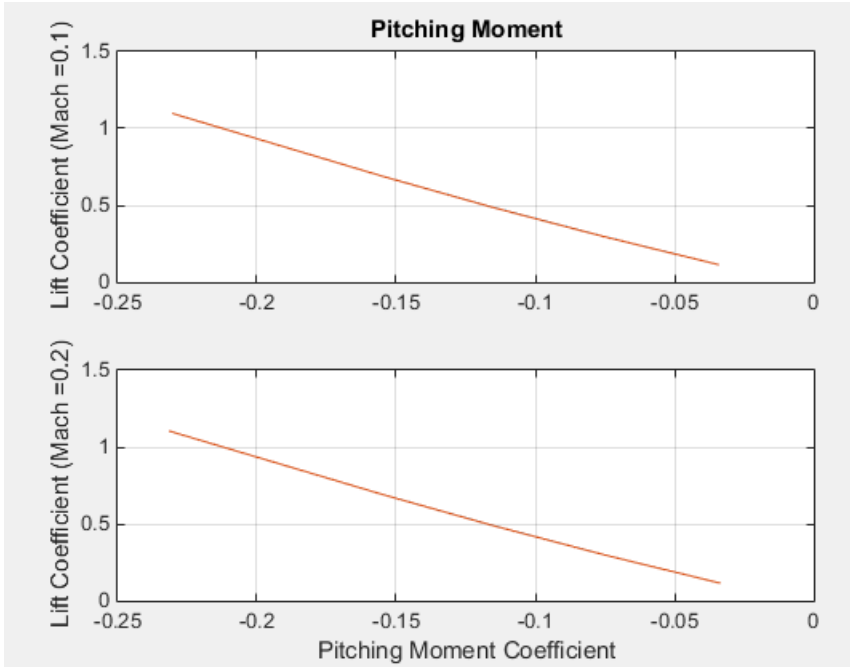

### Plotting Drag Polar Moments

```
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

# 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` — Visualize flight data without any other tool or toolbox. The following objects support this object.
  - `Aero.Body`
  - `Aero.Camera`
  - `Aero.Geometry`

  For more information, see “Aero.Animation Objects” on page 2-24.
- `Aero.VirtualRealityAnimation` — Visualize flight data with the Simulink 3D Animation™ product. The following objects support this object.
  - `Aero.Node`
  - `Aero.Viewpoint`

  For more information, see “Aero.VirtualRealityAnimation Objects” on page 2-34.
- `Aero.FlightGearAnimation` — Visualize flight data with the FlightGear simulator. For more information, see “Aero.FlightGearAnimation Objects” on page 2-53.

# Aero.Animation Objects

The toolbox interface to animation objects uses the Handle Graphics capability. The Overlaying Simulated and Actual Flight Data (`astmlanim`) example visually compares simulated and actual flight trajectory data by creating animation objects, creating bodies for those objects, and loading the flight trajectory data.

- Create and configure an animation object.
- Load recorded data for flight trajectories.
- Display body geometries in a figure window.
- Play back flight trajectories using the animation object.
- Manipulate the camera.
- Move and reposition bodies.
- Create a transparency in the first body.
- Change the color of the second body.
- Turn off the landing gear of the second body.

## Running the Example

1. Start the MATLAB software.
2. Enter `astmlanim` in the MATLAB Command Window.

   While running, the example performs several steps by issuing a series of commands.

# Simulated and Actual Flight Data Using Aero.Animation Objects

## 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 configuration 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. These settings result in a time step of approximately 0.5 s.

4. Create and load bodies for the animation object. This example uses 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 example must set the body object **TimeSeriesSourceType** parameter to `Custom` and 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 example 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();
```

## Recording Animation Files

Enable recording of the playback of flight trajectories using the animation object on page 2-27.

```
h.VideoRecord = 'on';
h.VideoQuality = 50;
h.VideoCompression = 'Motion JPEG AVI'
h.VideoFilename = 'astMotion_JPEG';
```

Enable animation recording at any point that you want to preserve an animation sequence.

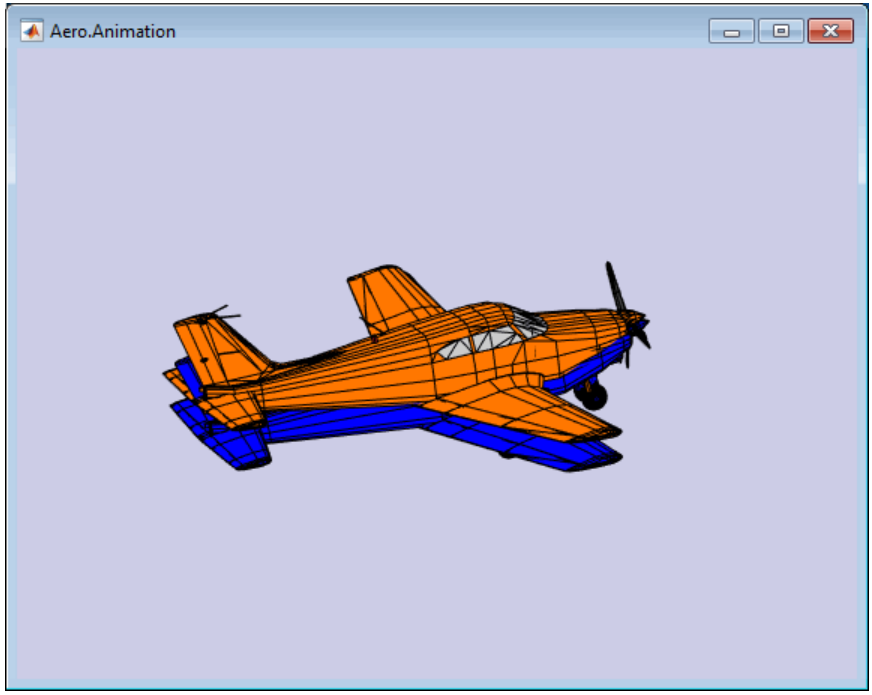
**Note** When choosing the video compression type, keep in mind that you will need the corresponding viewer software. For example, if you create an AVI format, you need a viewer such as Windows Media® Player to view the file.

After you play the animation as described in “Playing Back Flight Trajectories Using the Animation Object” on page 2-27, `astMotion_JPEG` contains a recording of the playback.

## Playing Back Flight Trajectories Using the Animation Object

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

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




If you used the `Video` properties to store the recording, see “Viewing Recorded Animation Files” on page 2-28 for a description of how to view the files.

## Viewing Recorded Animation Files

If you do not have an animation file to view, see “Recording Animation Files” on page 2-26.

1. Open the folder that contains the animation file you want to view.
2. View the animation file with an application of your choice.

   If your animation file is not yet running, start it now from the application.
3. To prevent other `h.play` commands from overwriting the contents of the animation file, disable the recording after you are satisfied with the contents.

   ```
   h.VideoRecord = 'off';
   ```

## Manipulating the Camera

This command series shows 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 “Playing Back Flight Trajectories Using the Animation Object” on page 2-27, the camera object uses a default value for the `PositionFcn` property. In this command series, the example references a custom `PositionFcn` function that uses a static position based on the position of the bodies. No dynamics are involved.

---

**Note** 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();
   ```

## 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);
   ```

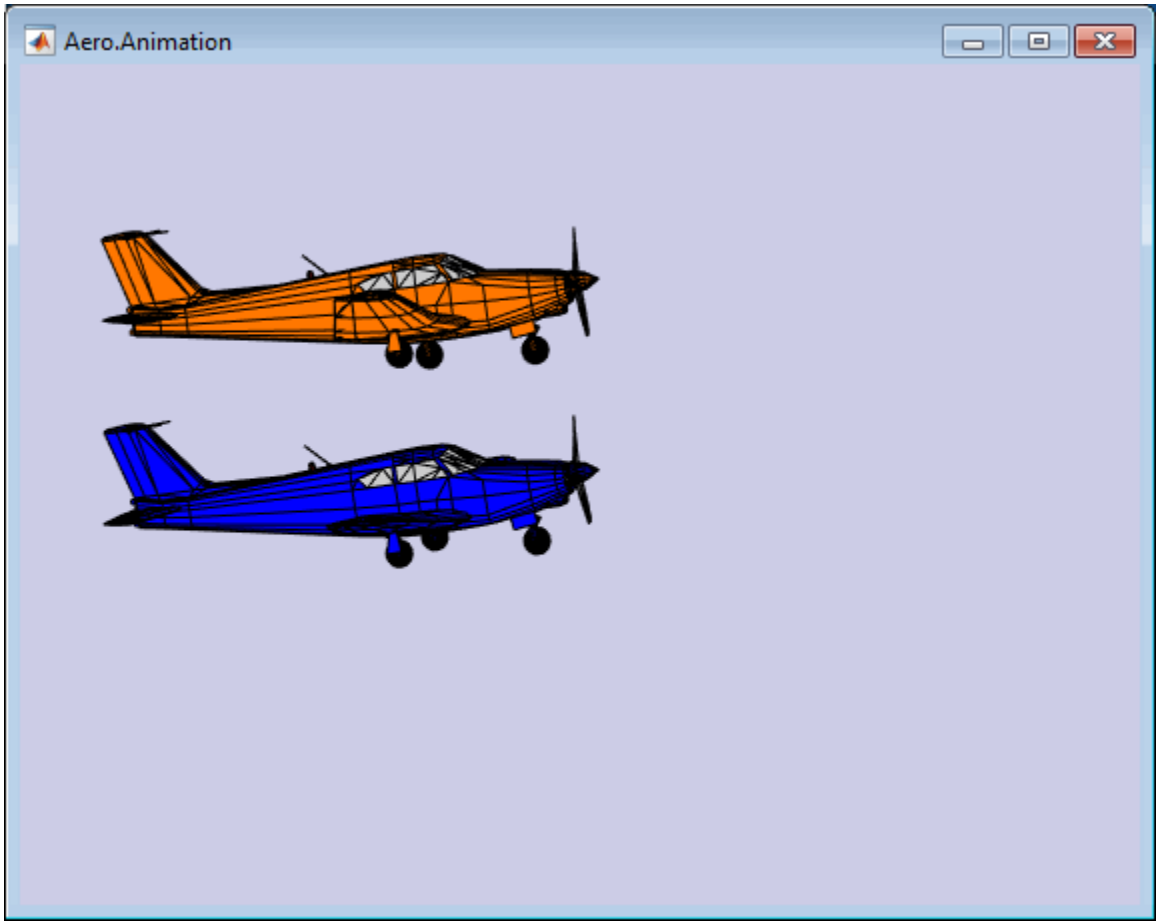
4. Reposition the bodies by first getting the current body position, then separating the bodies.

   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 Patch Properties).

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

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

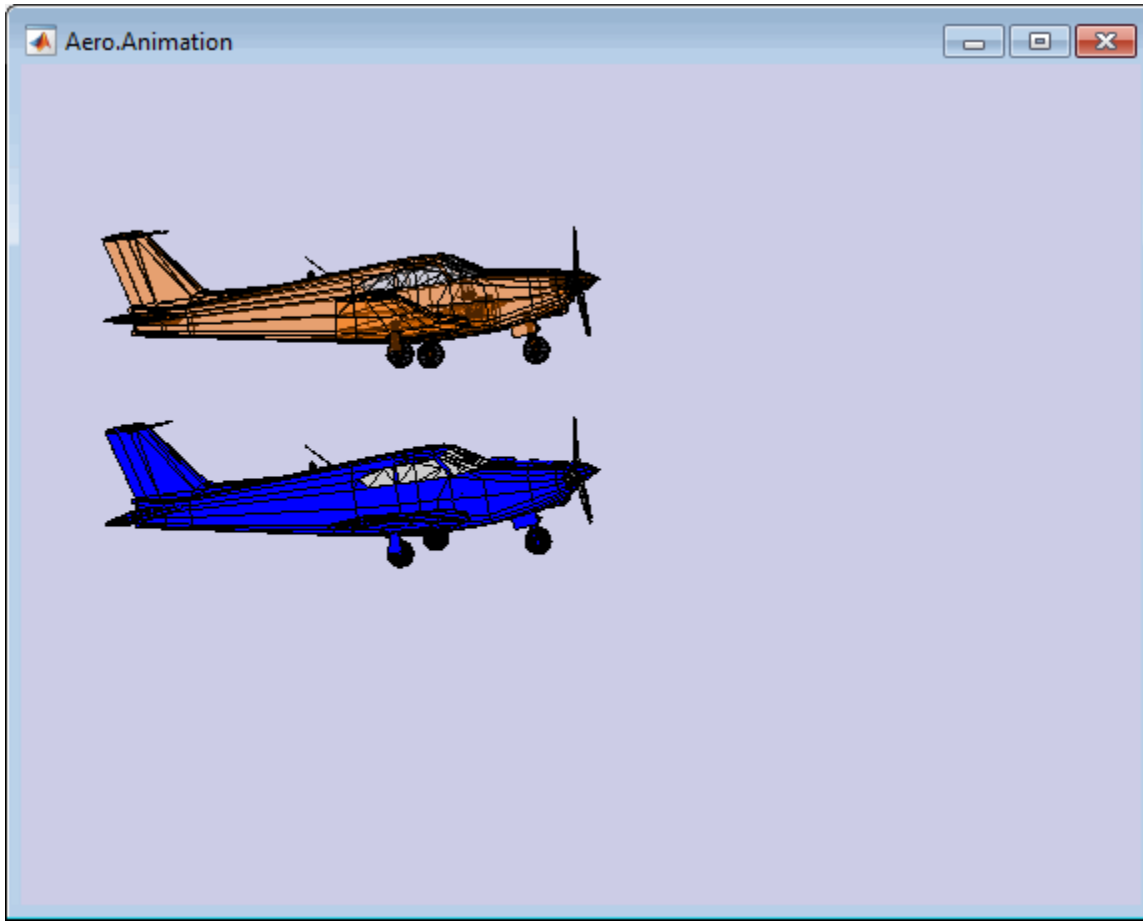
   ```
   patchHandles2 = h.Bodies{1}.PatchHandles;
   ```

2. Set the face and edge alpha values that you want for the transparency.

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

3. Get the current face and edge alpha data and change all values to the alpha values that you want. In the figure, 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 manipulates 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.

- 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
```

# Aero.VirtualRealityAnimation Objects

The Aerospace Toolbox interface to virtual reality animation objects uses the Simulink 3D Animation software. For more information, see `Aero.VirtualRealityAnimation`, `Aero.Node`, and `Aero.Viewpoint`.

- Create, configure, and initialize an animation object.
- Enable the tracking of changes to virtual worlds.
- Load the animation world.
- Load time series data for simulation.
- Set coordination information for the object.
- Add a chase helicopter to the object.
- Load time series data for chase helicopter simulation.
- Set coordination information for the new object.
- Add a new viewpoint for the helicopter.
- Play the animation.
- Create a new viewpoint.
- Add a route.
- Add another helicopter.
- Remove bodies.
- Revert to the original world.

## Running the Example

1. Start the MATLAB software.
2. Enter `astvranim` in the MATLAB Command Window.

   While running, the example performs several steps by issuing a series of commands.

# Example of Visualize Aircraft Takeoff and Chase Helicopter with the Virtual Reality Animation Object

## Visualize Aircraft Takeoff via Virtual Reality Animation Object

This example shows how to visualize aircraft takeoff and chase helicopter with the virtual reality animation object. In this example, you can use the Aero.VirtualRealityAnimation object to set up a virtual reality animation based on the asttkoff.wrl file. The scene simulates an aircraft takeoff. The example adds a chase vehicle to the simulation and a chase viewpoint associated with the new vehicle.

### Create the Animation Object

This code creates an instance of the `Aero.VirtualRealityAnimation` object.

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

### Set the Animation Object Properties

This code sets the number of frames per second and the seconds of animation data per second time scaling. `'FramesPerSecond'` controls the rate at which frames are displayed in the figure window. `'TimeScaling'` is the seconds of animation data per second time scaling.

The `'TimeScaling'` and `'FramesPerSecond'` properties determine the time step of the simulation. The settings in this example result in a time step of approximately 0.5s. The equation is:

(1/FramesPerSecond)*TimeScaling + extra terms to handle for sub-second precision.

```
h.FramesPerSecond = 10;
h.TimeScaling = 5;
```

This code sets the .wrl file to be used in the virtual reality animation.

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

### Change Directory

The VirtualRealityAnimation object methods use temporary .wrl files to keep track of changes to the world. This requires the directory containing the original .wrl file to be

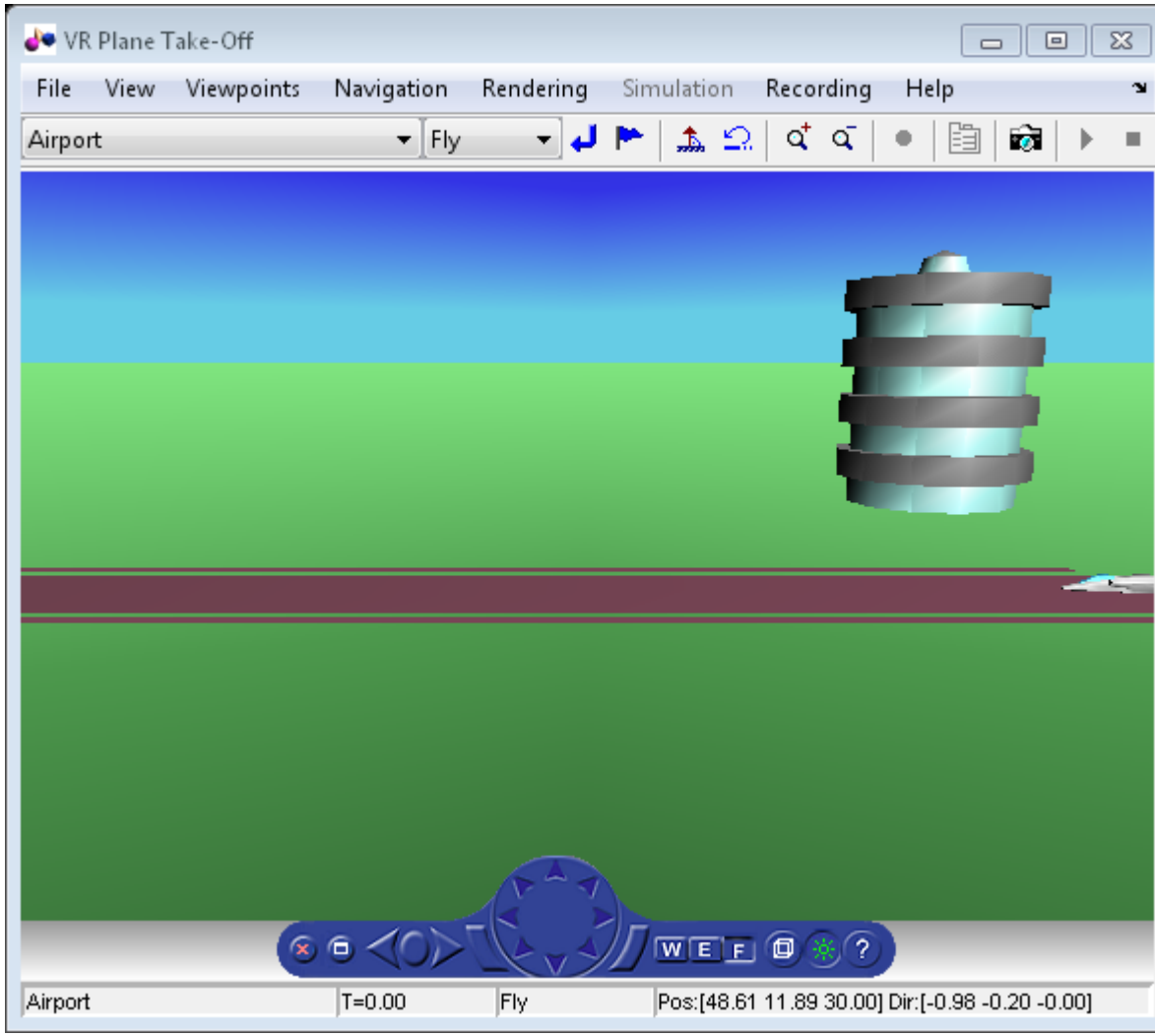
writable. This code runs the example from a temporary directory to ensure there are no issues with directory permissions. Note, a license for Simulink® 3D Animation™ is required to run this example.

```
% Copy file to temporary directory
copyfile(h.VRWorldFilename,[tempdir,'asttkoff.wrl'],'f');
% Set world filename to the copied .wrl file.
h.VRWorldFilename = [tempdir,'asttkoff.wrl'];
```

### Initialize the Virtual Reality Animation Object

The `initialize` method loads the animation world described in the `'VRWorldFilename'` field of the animation object. When parsing the world, node objects are created for existing nodes with DEF names. The `initialize` method also opens the Simulink 3D Animation viewer.

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




### Set Additional Node Information

This code sets simulation timeseries data. `takeoffData.mat` contains logged simulated data. `takeoffData` is set up as a `'StructureWithTime'`, which is one of the default data formats.

```
load takeoffData
[~, idxPlane] = find(strcmp('Plane', h.nodeInfo));
h.Nodes{idxPlane}.TimeseriesSource = takeoffData;
h.Nodes{idxPlane}.TimeseriesSourceType = 'StructureWithTime';
```

### Set Coordinate Transform Function

The virtual reality animation object expects positions and rotations in aerospace body coordinates. If the input data is different, you must create a coordinate transformation function in order to correctly line up the position and rotation data with the surrounding objects in the virtual world. This code sets the coordinate transformation function for the virtual reality animation.

In this particular case, if the input translation coordinates are [x1,y1,z1], they must be adjusted as follows: [X,Y,Z] = -[y1,x1,z1]. The custom transform function can be seen here: `matlabroot/toolbox/aero/astdemos/vranimCustomTransform.m`

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

### Add a Chase Helicopter

This code shows how to add a chase helicopter to the animation object.

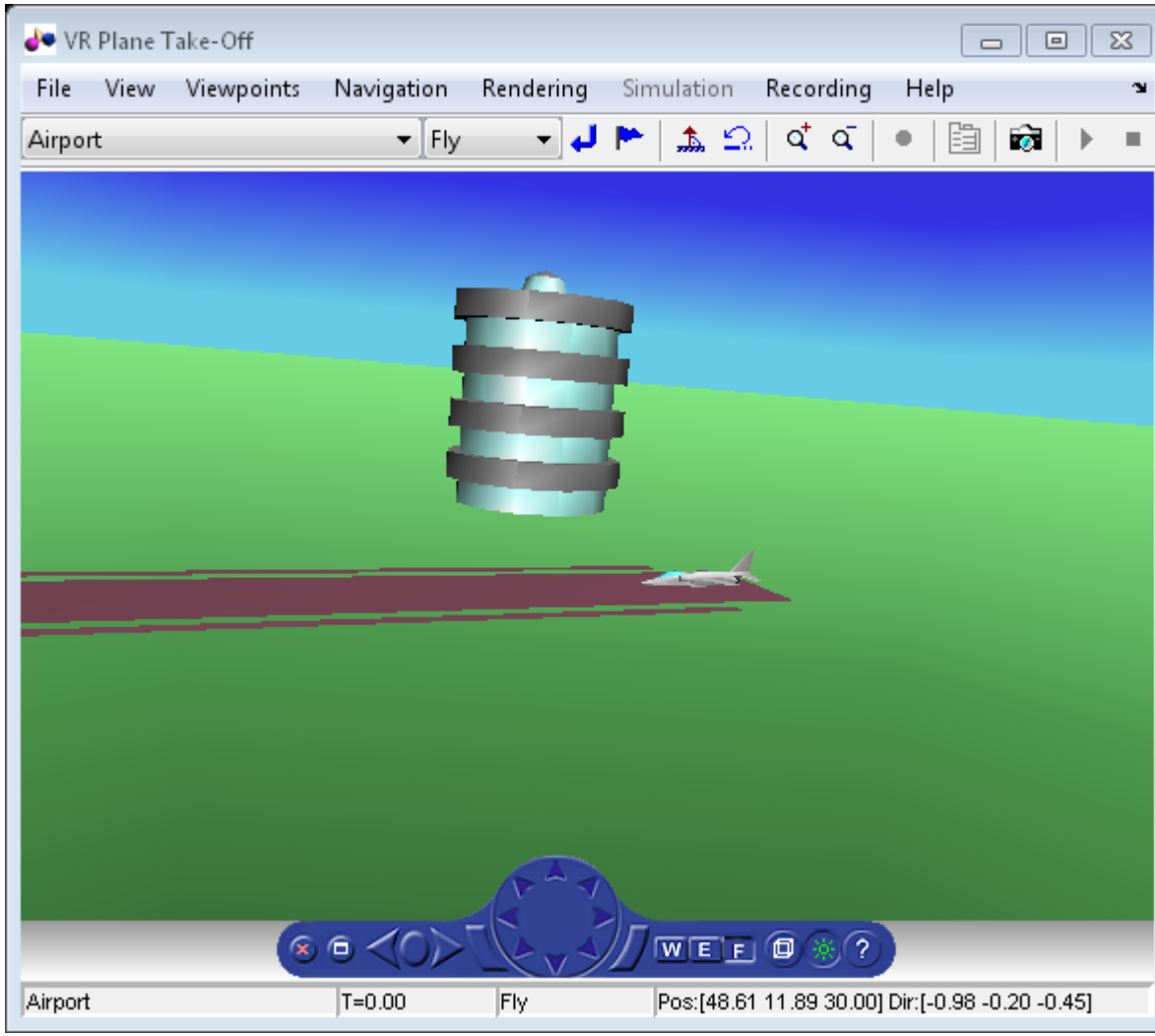
You can view all the nodes currently in the virtual reality animation object by using the `nodeInfo` method. When called with no output argument, this method prints the node information to the command window. With an output argument, the method sets node information to that argument.

```
h.nodeInfo;
```

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

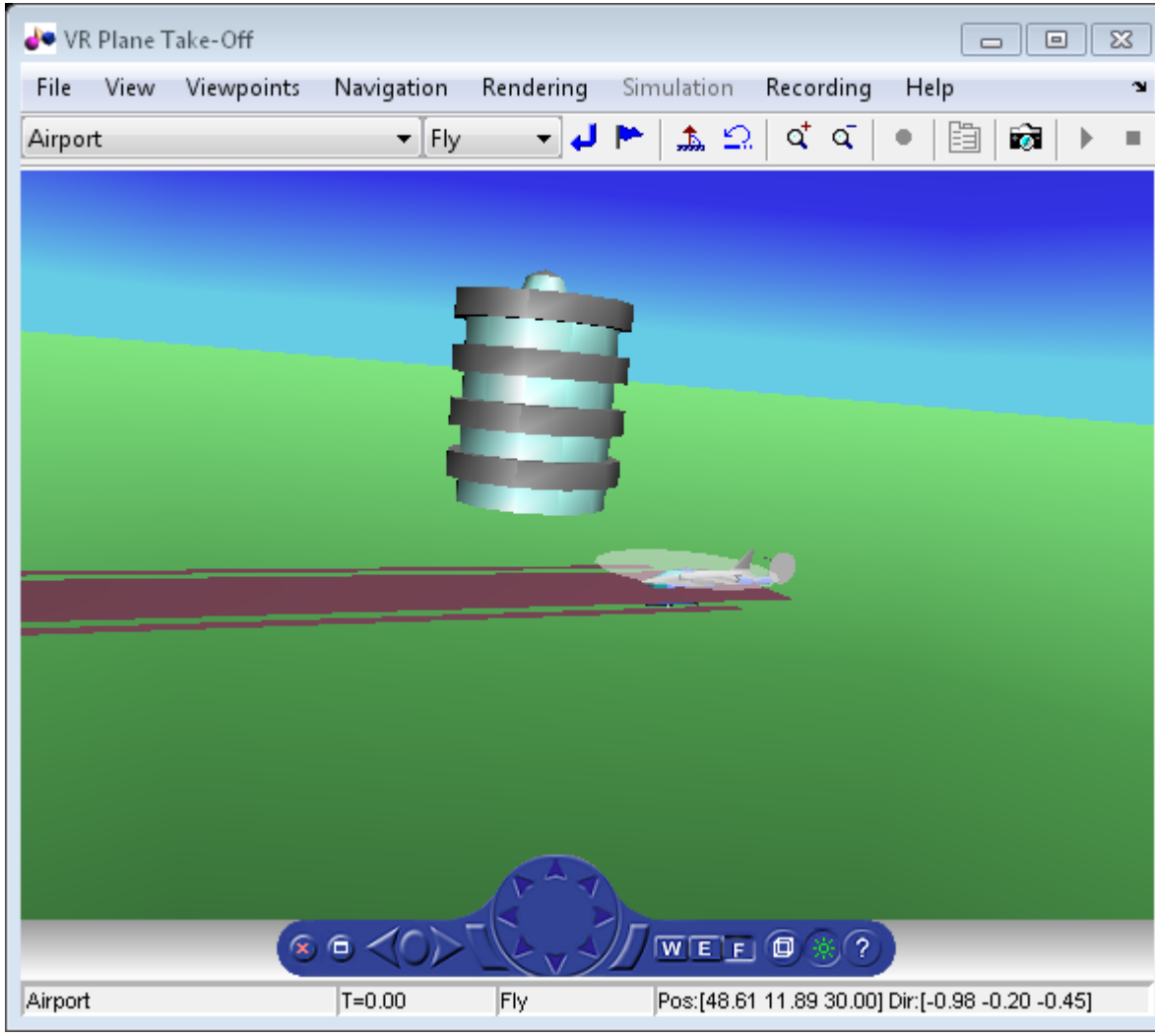
This code moves the camera angle of the virtual reality figure to view the aircraft.

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




Use the `addNode` method to add another node to the object. By default, each time you add or remove a node or route, or when you call the `saveas` method, Aerospace Toolbox displays a message about the current .wrl file location. To disable this message, set the `'ShowSaveWarning'` property in the VirtualRealityAnimation object.

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




Another call to `nodeInfo` shows the newly added Node objects.

```
h.nodeInfo
```

```
Node Information
1    Camera1
```

```
2    Plane
3    _V2
4    Block
5    Terminal
6    _v3
7    Lighthouse
8    _v1
9    Lynx
10    Lynx_Inline
```

Adjust newly added helicopter to sit on runway.

```
[~, idxLynx] = find(strcmp('Lynx',h.nodeInfo));
h.Node{idxLynx}.VRNode.translation = [0 1.5 0];
```

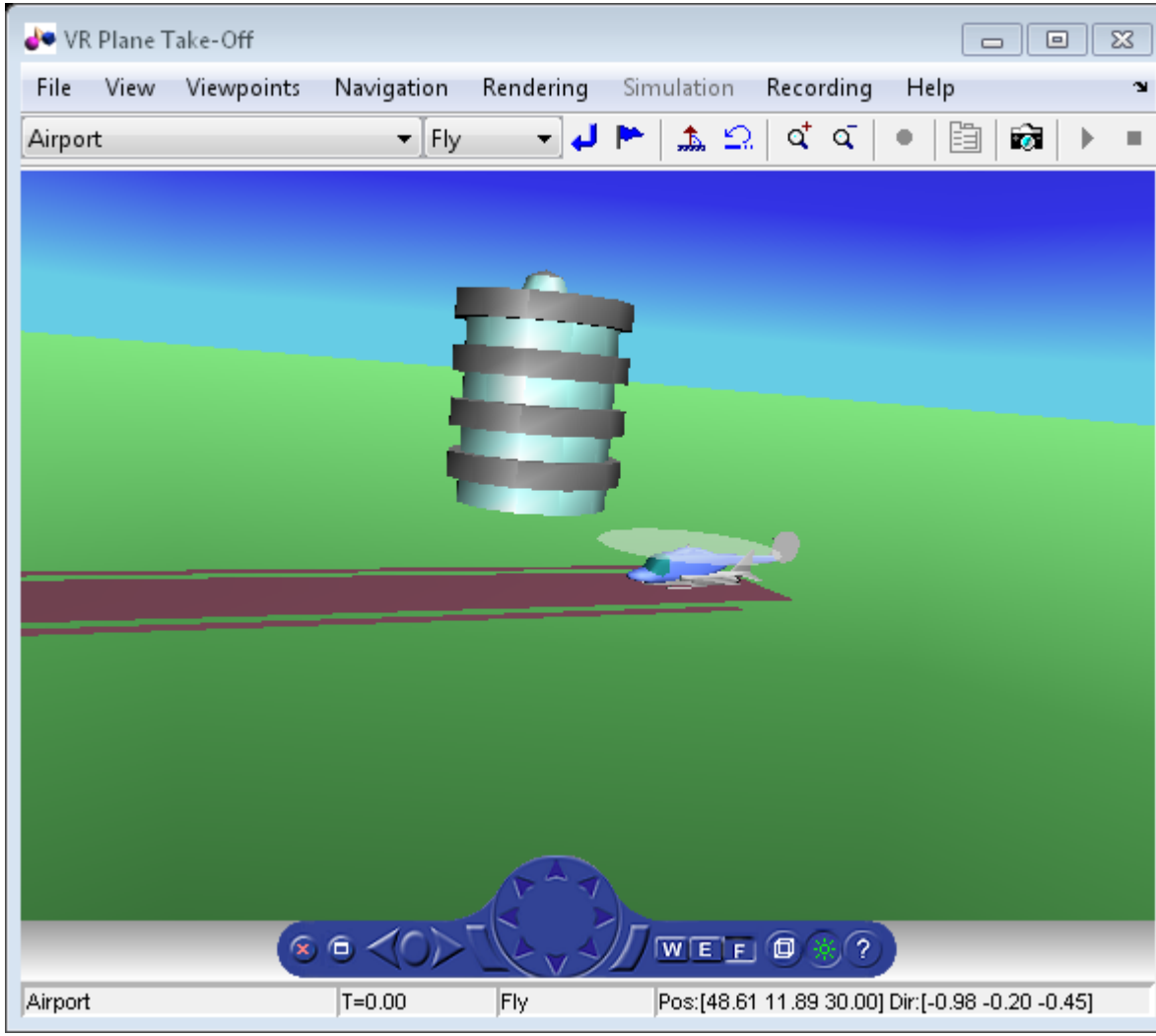
This code sets data properties for the chase helicopter. The `'TimeseriesSourceType'` is the default `'Array6DoF'`, so no additional property changes are needed. The same coordinate transform function (`vranimCustomTransform`) is used for this node as the preceding node. The previous call to `nodeInfo` returned the node index (2).

```
load chaseData
h.Nodes{idxLynx}.TimeseriesSource = chaseData;
h.Nodes{idxLynx}.CoordTransformFcn = @vranimCustomTransform;
```

### Create New Viewpoint

This code uses the `addViewpoint` method to create a new viewpoint named 'chaseView'. The new viewpoint will appear in the viewpoint pulldown menu in the virtual reality window as "View From Helicopter". Another call to `nodeInfo` shows the newly added node objects. The node is created as a child of the chase helicopter.

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




### Play Animation

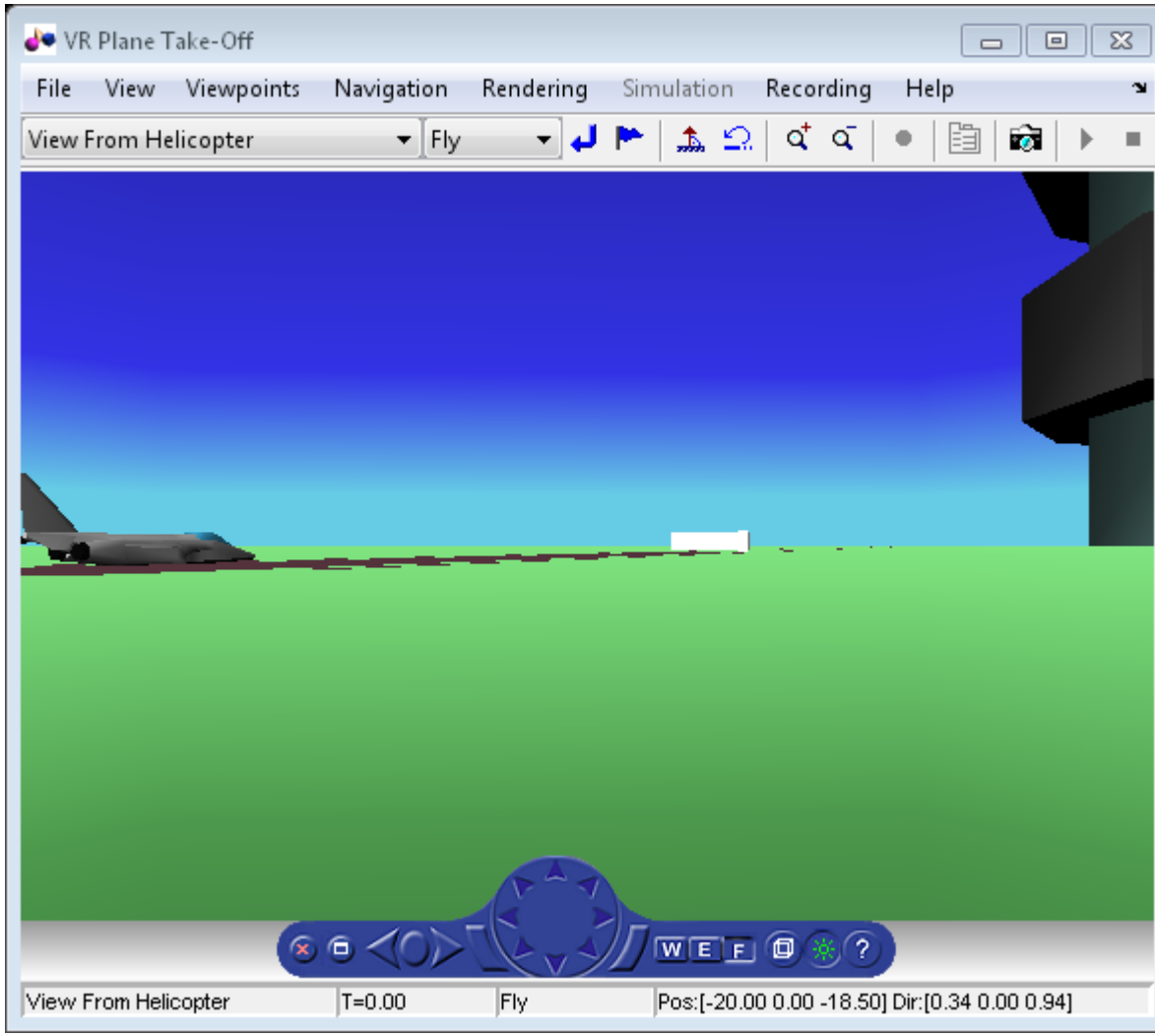
The `play` method runs the simulation for the specified timeseries data.

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

### Play Animation From Helicopter

This code sets the orientation of the viewpoint via the vrnode object associated with the node object for the viewpoint. In this case, it will change the viewpoint to look out the left side of the helicopter at the plane.

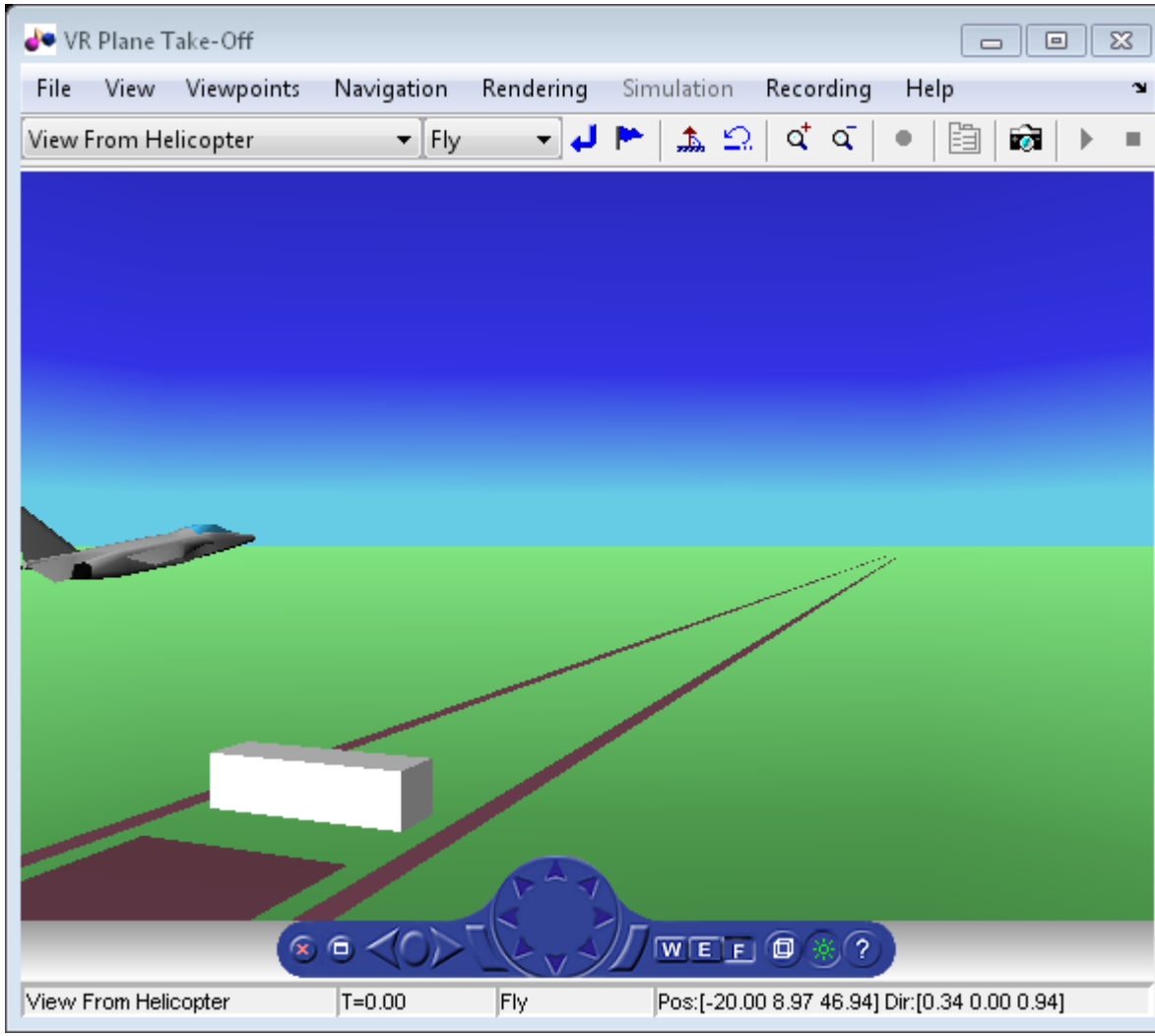
```
[~, idxChaseView] = find(strcmp('chaseView',h.nodeInfo));
h.Nodes{idxChaseView}.VRNode.orientation = [0 1 0 convang(200,'deg','rad')];
set(h.VRFigure,'Viewpoint','View From Helicopter');
```




### Add ROUTE

This code calls the `addRoute` method to add a ROUTE command to connect the plane position to the Camera1 node. This will allow for the "Ride on the Plane" viewpoint to function as intended.

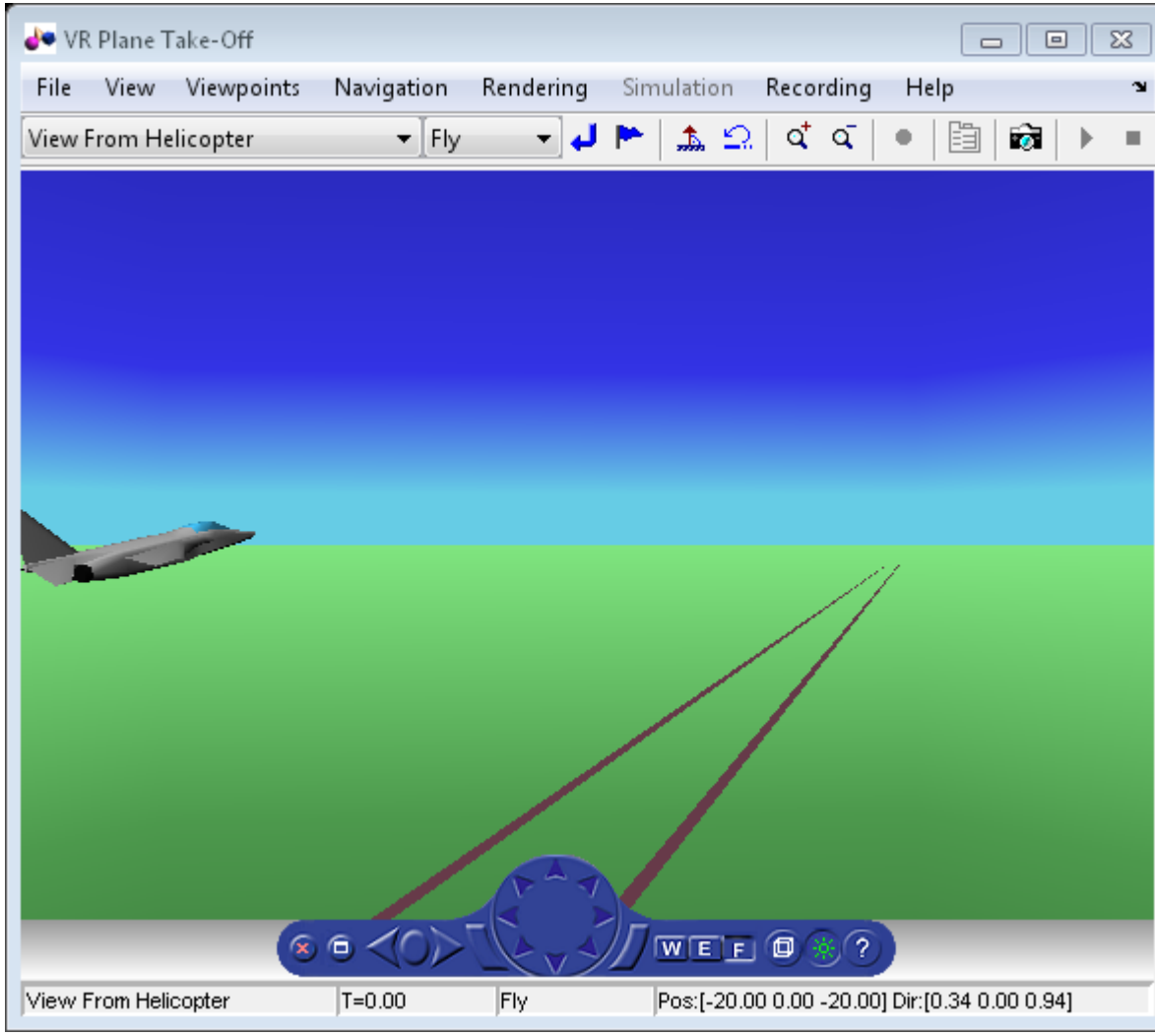
```
h.addRoute('Plane','translation','Camera1','translation');
```




The scene from the helicopter viewpoint

This code plays the animation.

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

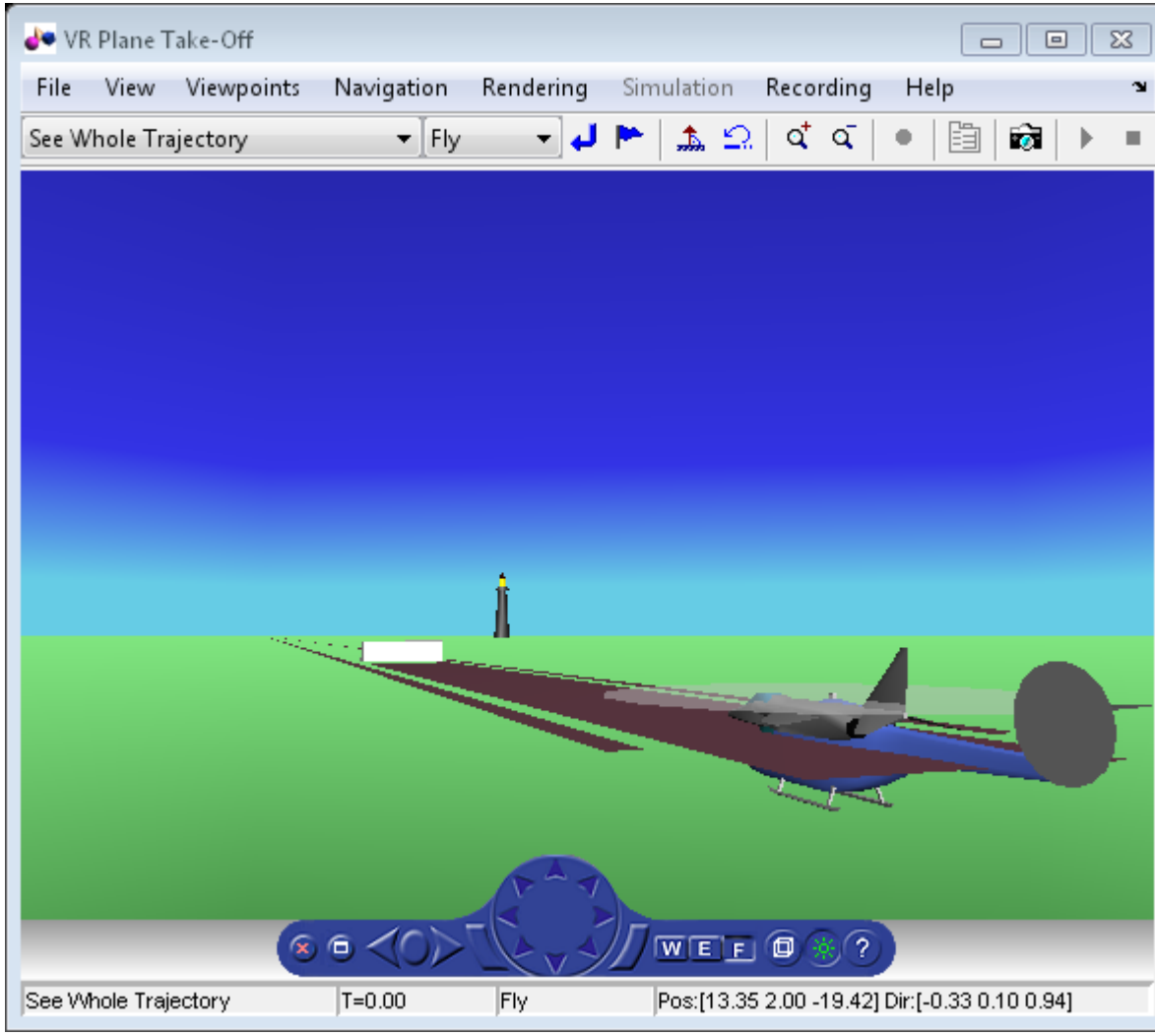



### Add Another Body

This code adds another helicopter to the scene. It also changes to another viewpoint to view all three bodies in the scene at once.

```
set(h.VRFigure,'Viewpoint','See Whole Trajectory');
h.addNode('Lynx1',[matlabroot,'/toolbox/aero/astdemos/chaseHelicopter.wrl']);
h.nodeInfo
```

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




Adjust newly added helicopter to sit above runway.

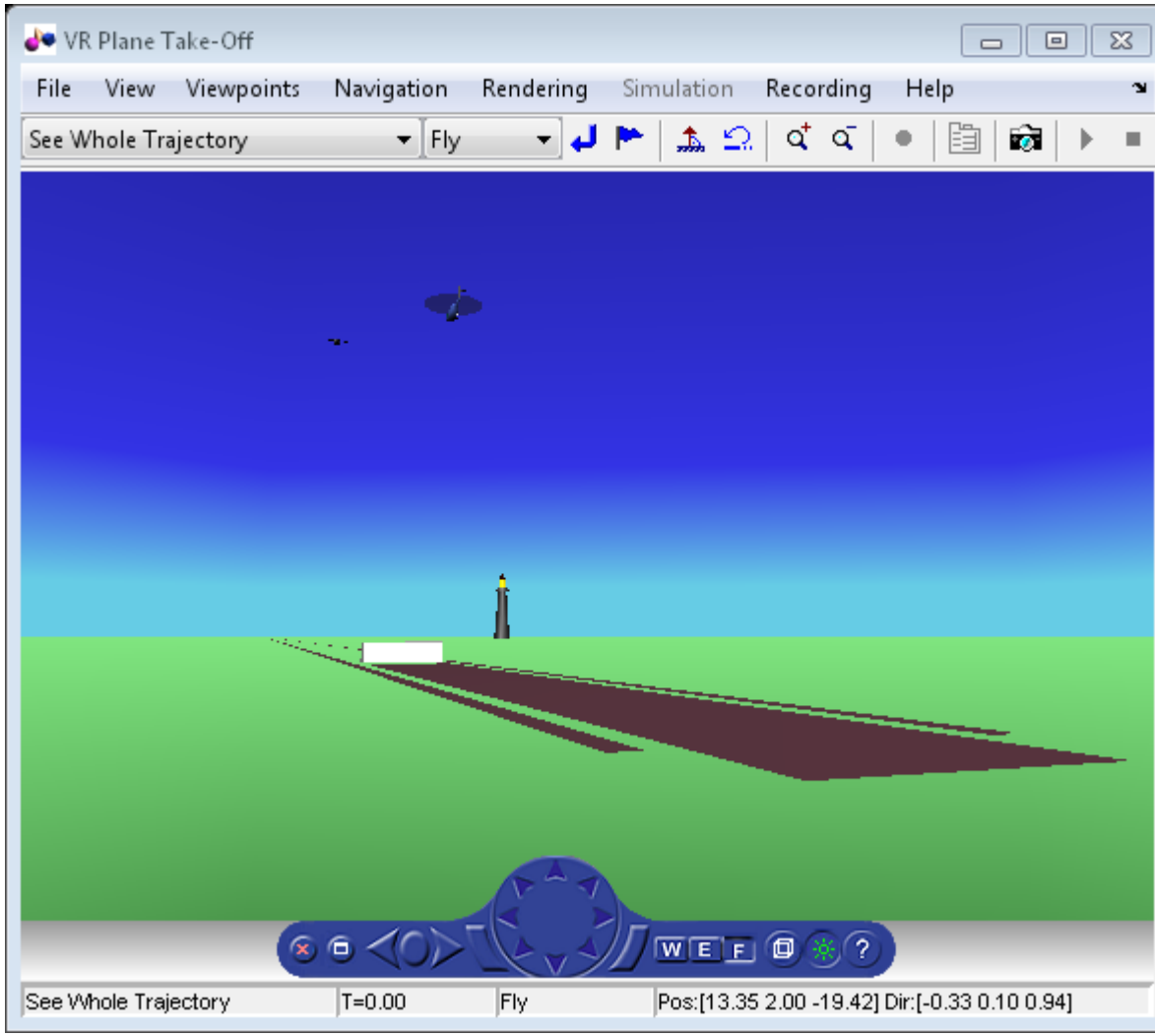
```
[~, idxLynx1] = find(strcmp('Lynx1',h.nodeInfo));
h.Node{idxLynx1}.VRNode.translation = [0 1.3 0];
```

### Remove Body

This code uses the `removeNode` method to remove the second helicopter. `removeNode` takes either the node name or node index (as obtained from `nodeInfo`). The associated inline node is removed as well.

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

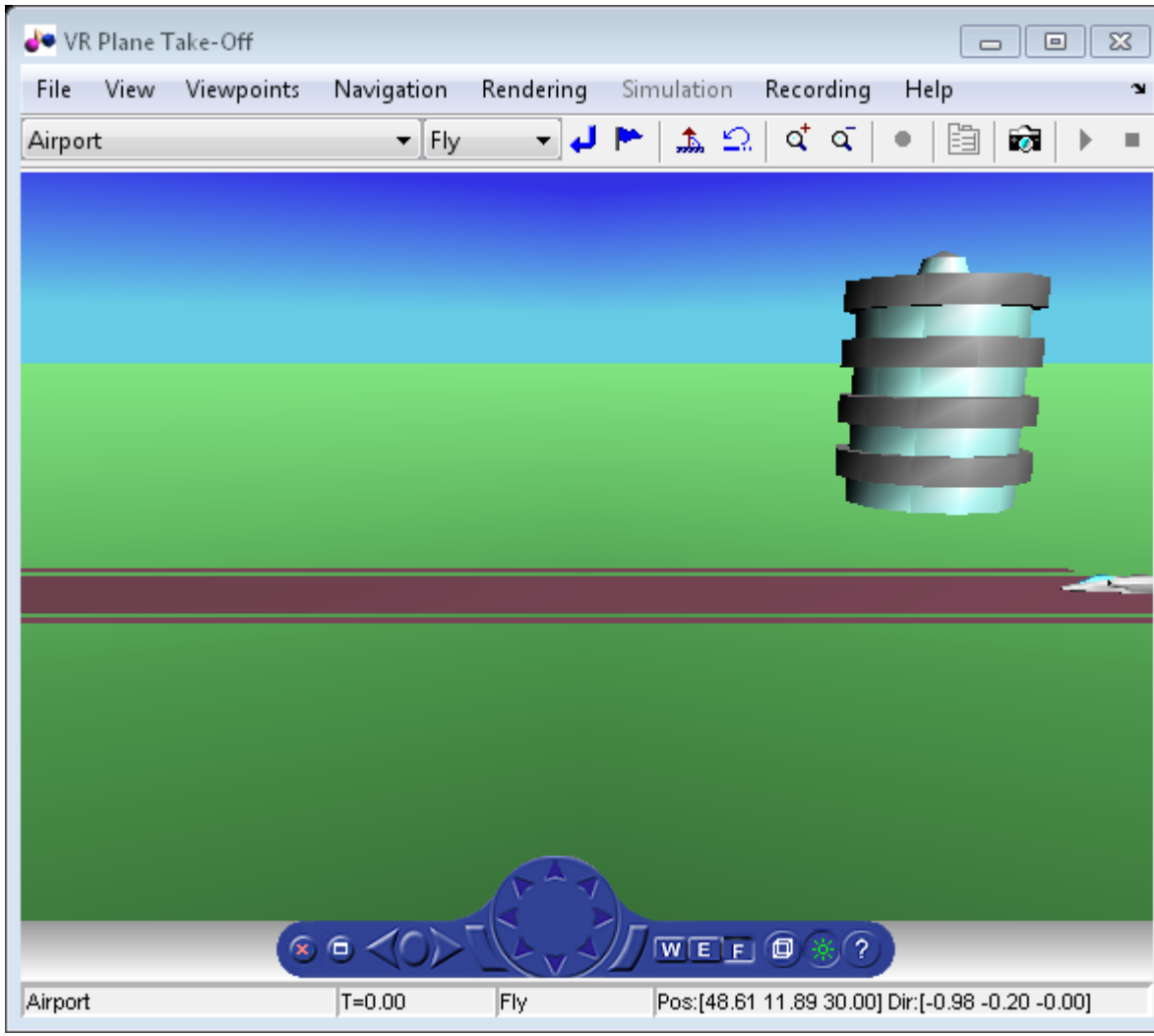
```
Node Information
1    Camera1
2    Plane
3    _V2
4    Block
5    Terminal
6    _v3
7    Lighthouse
8    _v1
9    Lynx
10    Lynx_Inline
11    chaseView
```




### Revert To Original World

The original filename is stored in the `'VRWorldOldFilename'` property of the animation object. To bring up the original world, set `'VRWorldFilename'` to the original name and reinitializing it.

```
h.VRWorldFilename = h.VRWorldOldFilename{1};
h.initialize();
```




### Close and Delete World

To close and `delete`

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

# 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 describes how to obtain and install the third-party FlightGear flight simulator. It also describes how to play back 3-D flight data by using a FlightGear example, provided with your Aerospace Toolbox software.

## 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. It uses 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. For interface details, see “Flight Simulator Interface Example” on page 2-57.

FlightGear is a separate software entity that is not created, owned, or maintained by MathWorks.

- To report bugs in or request enhancements to the Aerospace Toolbox FlightGear interface, contact MathWorks technical support at https://www.mathworks.com/support/.
- To report bugs or request enhancements to FlightGear itself, go to `www.flightgear.org` and use the contact page.

### Supported FlightGear Versions

The Aerospace Toolbox product supports the following FlightGear versions:

- `v2018.1`
- `v2017.3`
- `v2017.1`
- `v2016.3`
- `v2016.1`
- `v3.4`
- `v3.2`

- v3.0
- v2.12
- v2.10
- v2.8
- v2.6
- v2.4
- v2.0

#### Obtaining FlightGear Software

You can obtain FlightGear software 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 website, www.flightgear.org.

#### 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 website, 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 website.

#### FlightGear and Video Cards in Windows Systems

Your computer built-in video card, such as NVIDIA®cards, can have issues working with FlightGear shaders. Consider this workaround:

- Disable the FlightGear shaders by specifying the DisableShaders property of the Aero.FlightGearAnimation object to the GenerateRunScript (Aero.FlightGearAnimation) method.

## Install and Start FlightGear

The extensive FlightGear documentation guides you through the installation. For complete installation instructions, consult the documentation section of the FlightGear website `www.flightgear.org`.

Note:

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

  For more information, see `http://wiki.flightgear.org/Hardware_recommendations`.
- Have sufficient disk space for the FlightGear download and installation.
- Before you install FlightGear, configure your computer graphics card. See the preceding section, “Configuring Your Computer for FlightGear” on page 2-54.
- Before installing FlightGear, shut down all running applications (including the MATLAB software).
- Install FlightGear in a folder path name composed of ASCII characters.
- 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 (System Requirements). The following table lists the properties to be aware of before you start using FlightGear.

| FlightGear Property | Folder Description | Platforms | Typical Location |
|---|---|---|---|
| `FlightGearBase-Directory` | FlightGear installation folder. | Windows | `C:\Program Files\FlightGear` (default) |
| | | Linux | Directory into which you installed FlightGear |

| FlightGear Property | Folder Description | Platforms | Typical Location |
|---|---|---|---|
| | | Mac | `/Applications` (folder into which you dragged the FlightGear icon) |
| `GeometryModelName` | Model geometry folder | Windows | `C:\Program Files\FlightGear\data\Aircraft\HL20` (default) |
| | | Linux | `$FlightGearBaseDirectory/-data/Aircraft/HL20` |
| | | Mac | `$FlightGearBaseDirectory/-FlightGear.app/Contents/-Resources/data/Aircraft/-HL20` |

## Installing Additional FlightGear Scenery

When you install the FlightGear software, the installation provides a basic level of scenery files. The FlightGear documentation 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.

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. For a description of the `FG_SCENERY` variable, see the documentation at `http://www.flightgear.org`.

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

If you do not download scenery, you can direct FlightGear to download it automatically during simulation using the `InstallScenery` property of the `Aero.FlightGearAnimation` object for the `GenerateRunScript (Aero.FlightGearAnimation)` method.

## Flight Simulator Interface Example

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

Before attempting to simulate this model, you must have FlightGear installed and configured. See “About the FlightGear Interface” on page 2-53.

To run the example:

- Import the aircraft geometry into FlightGear.
- Run the example. The example performs the following steps:
  - Loads recorded trajectory data.
  - Creates a time series object from trajectory data.
  - Creates a FlightGearAnimation object.
- Modify the animation object properties, if needed.
- Create a run script for launching the FlightGear flight simulator.
- Start the FlightGear flight simulator.
- Play back the flight trajectory.

### Import the Aircraft Geometry into FlightGear

Before running the example, 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 “Install and Start FlightGear” on page 2-55.

If your platform is Windows:

1. Go to your installed FlightGear folder. Open the `data` folder, and then the `Aircraft` folder: *`FlightGear`*`\data\Aircraft\`.
2. If you have previously run the Aerospace Blockset NASA HL-20 with FlightGear Interface example, you might already have an `HL20` subfolder there.

   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 Linux:

1. Go to your installed FlightGear folder. Open the `data` folder, then the `Aircraft` folder: *`$FlightGearBaseDirectory`*`/data/Aircraft/`.
2. If you have previously run the Aerospace Blockset NASA HL-20 with FlightGear Interface example, you might already have an `HL20` subfolder there. If that is the case, you do not have to do anything, because you can use the existing geometry model.

   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. If you have previously run the Aerospace Blockset NASA HL-20 with FlightGear Interface example, you might already have an `HL20` subfolder there. In this case, you do not have to do anything, because you can use the existing geometry model. Continue to “Running the Example” on page 2-24.

   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 Example

1. Start the MATLAB software.
2. Enter `astfganim` in the MATLAB Command Window.

   While running, the example performs several steps by issuing a series of commands.

# Flight Trajectory Data

## 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 omits 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, Euler angle data, and 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 the network information for the FlightGear flight simulator.

   ```
   h.FlightGearBaseDirectory = 'C:\Program Files\FlightGear20181';
   h.FlightGearVersion = '2018.1';
   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 Set the seconds of animation data per second of wall-clock time.

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

6 Check the FlightGearAnimation object properties and their values.

```
get(h)
```

The example stops running and returns the FlightGearAnimation object, `h`:

```
         TimeseriesSource: [1x1 timeseries]
    TimeseriesSourceType: 'Timeseries'
       TimeseriesReadFcn: @TimeseriesRead
             TimeScaling: 5
          FramesPerSecond: 12
       FlightGearVersion: '2018.1'
          OutputFileName: 'runfg.bat'
FlightGearBaseDirectory: 'C:\Program Files\FlightGear20181'
      GeometryModelName: 'HL20'
   DestinationIpAddress: '127.0.0.1'
        DestinationPort: '5502'
              AirportId: 'KSFO'
               RunwayId: '10L'
        InitialAltitude: 7224
         InitialHeading: 113
         OffsetDistance: 4.7200
          OffsetAzimuth: 0
                 TStart: NaN
                 TFinal: NaN
           Architecture: 'Default'
```

You can now set the object properties for data playback (see “Modifying the FlightGearAnimation Object Properties” on page 2-62).

## Modifying the FlightGearAnimation Object Properties

Modify the FlightGearAnimation object properties as needed. If your FlightGear installation folder is other than the one in the example (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 2-62).

## Generating the Run Script

To start FlightGear with the initial conditions (location, date, time, weather, operating modes) that you want, 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.

You do not need to generate the file each time the data is viewed, only when the initial conditions or FlightGear information changes.

You are now ready to start FlightGear (see “Starting the FlightGear Flight Simulator” on page 2-63).

---

**Note** The `FlightGearBaseDirectory` and `OutputFileName` properties must be composed of ASCII characters.

---

## 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, helicopter, chase, and so on.

---

You are now ready to play back data (see “Playing Back the Flight Trajectory” on page 2-63). If you cannot view scenes, see “Installing Additional FlightGear Scenery” on page 2-56.

---

**Tip** If FlightGear uses more computer resources than you want, you can change its scheduling priority to a lesser one. For example, see commands like Windows `start` and Linux `nice` or their equivalents.

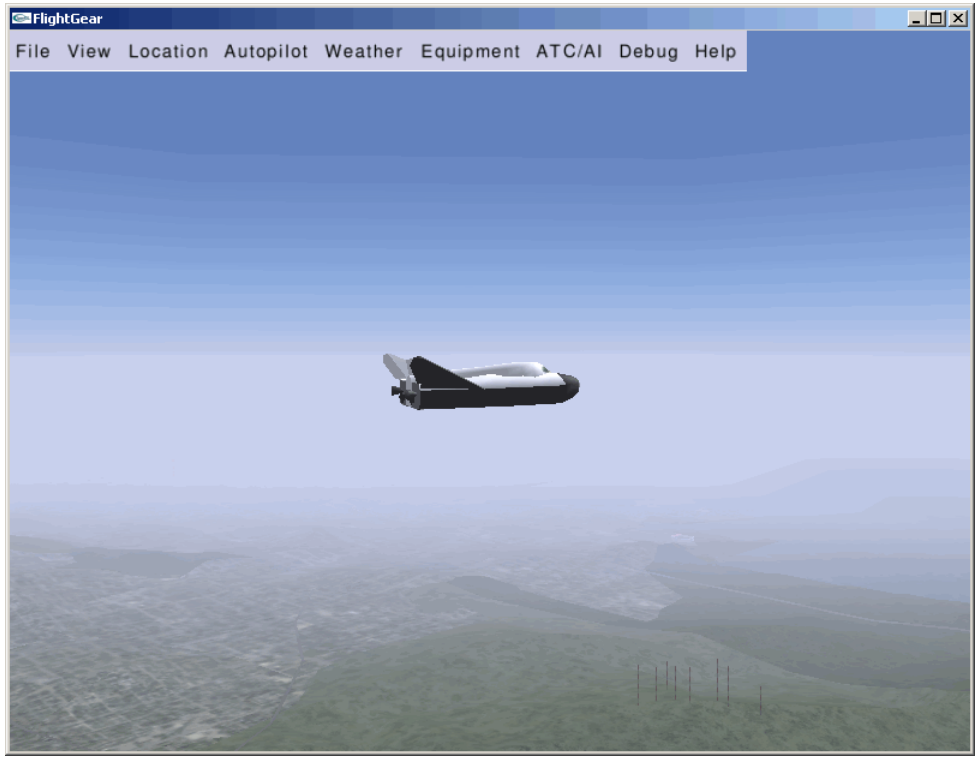
---

## 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.


FlightGear
File View Location Autopilot Weather Equipment ATC/AI Debug Help

# Display Flight Trajectory Data Using Flight Instruments and Flight Animation

This example shows how to visualize flight trajectories in a UI figure window using flight instrument components. In this example, you will create and configure standard flight instruments in conjunction with the Aero.Animation object.

### Load Recorded Data for Flight Trajectories and Instrument Display

Load logged aircraft position, attitude, and time to the workspace.

```
load simdata
```

### Create Animation Interface

To display the flight trajectories stored in the flight trajectory data, create an Aero.Animation object. The aircraft used in this example is the Piper PA24-250 Comanche.

```
h = Aero.Animation;
h.createBody('pa24-250_orange.ac','Ac3d');
h.Bodies{1}.TimeSeriesSource = simdata;
h.Camera.PositionFcn = @staticCameraPosition;
h.Figure.Position(1) = h.Figure.Position(1) + 572/2;
h.show();
```

### Create Flight Instruments

Create a UI figure window to contain the flight instruments.

```
fig = uifigure('Name','Flight Instruments',...
    'Position',[h.Figure.Position(1)-572 h.Figure.Position(2)+h.Figure.Position(4)-502
    'Color',[0.2667 0.2706 0.2784],'Resize','off');
```

Load panel image into an axis:

```
imgPanel = imread('astFlightInstrumentPanel.png');
ax = uiaxes('Parent',fig,'Visible','off','Position',[10 30 530 460],...
    'BackgroundColor',[0.2667 0.2706 0.2784]);
image(ax,imgPanel);
disableDefaultInteractivity(ax);
```

Create standard flight instruments for navigation:

Create altimeter:

```
alt = uiaeroaltimeter('Parent',fig,'Position',[369 299 144 144]);
```

Create heading indicator:

```
head = uiaeroheading('Parent',fig,'Position',[212 104 144 144]);
```

Create airspeed indicator:

```
air = uiaeroairspeed('Parent',fig,'Position',[56 299 144 144]);
```

Change the airspeed indicator limits according to the Piper PA 24-250 Comanche capabilities:

```
air.Limits = [20 200];
air.ScaleColorLimits = [0 50;40 160;160 190;190 200];
```

Create artificial horizon:

```
hor = uiaerohorizon('Parent',fig,'Position',[212 299 144 144]);
```

Create climb rate indicator:

```
climb = uiaeroclimb('Parent',fig,'Position',[369 104 144 144]);
```

Change the climb indicator maximum climb rate according to the aircraft capabilities:

```
climb.MaximumRate = 4000;
```

Create turn coordinator:

```
turn = uiaeroturn('Parent',fig,'Position',[56 104 144 144]);
```

To update the flight instruments and animation figure, assign the `ValueChangingFcn` callback to the `astHelperFlightInstrumentsAnimation` helper function. Then, when a time is selected on the slider, the flight instruments and animation figure will be updated according to the selected time value.

```
sl = uislider('Parent',fig,'Limits',[simdata(1,1) simdata(end,1)],'FontColor','white');
sl.Position = [50 60 450 3];
sl.ValueChangingFcn = @(sl,event) astHelperFlightInstrumentsAnimation(fig,simdata,h,eve
```

To display the time selected in the slider, create a label component.

```
lbl = uilabel('Parent',fig,'Text',['Time: ' num2str(sl.Value,4) ' sec'],'FontColor','wh
lbl.Position = [230 10 90 30];
```

# Create and Configure Flight Instrument Component and an Animation Object

You can display flight data using any of the standard flight instrument components:

- Airspeed indicator
- Altimeter
- Climb indicator
- Exhaust gas temperature (EGT) indicator
- Heading indicator
- Artificial horizon
- Revolutions per minute (RPM) indicator
- Turn coordinator

As a general workflow:

1. Load simulation data.
2. Create an animation object.
3. Create a figure window.
4. Create a flight control panel to contain the flight instrument components.
5. Create the flight instrument components.
6. Trigger a display of the animation in the instrument panel.

**Note** Use Aerospace Toolbox flight instruments only with figures created using the `uifigure` function. Apps created using GUIDE or the `figure` function do not support flight instrument components.

## Load and Visualize Data

To load and visualize data, consider this workflow:

1. Load simulation data. For example, the `simdata` variable contains logged simulated flight trajectory data.

   ```
   load simdata
   ```

2. To visualize animation data, create an animation object. For example:

   a. Create an `Aero.Animation` object.

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

   b. Create a body using the `pa24-250_orange.ac` AC3D file and its associated patches.`pa24-250_orange.ac`

   ```
   h.createBody('pa24-250_orange.ac','Ac3d');
   ```

   c. Set up the bodies of the animation object `h`. Set the `TimeSeriesSource` property to the loaded `simdata`.

   d. Set up the camera and figure positions.

   ```
   h.Camera.PositionFcn = @staticCameraPosition;
   h.Figure.Position(1) = h.Figure.Position(1) + 572/2;
   ```

   e. Create and show the figure graphics object for `h`.

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

To create the flight instrument components, see “Create Flight Instrument Components” on page 2-70

## Create Flight Instrument Components

This workflow assumes that you have loaded data and created an animation object as described in “Load and Visualize Data” on page 2-69.

1. Create a `uifigure` figure window. This example creates `fig`, to contain the flight instrument for `h`.

   ```
   fig = uifigure('Name','Flight Instruments',...
   'Position',[h.Figure.Position(1)-572 h.Figure.Position(2)+h.Figure.Position(4)-502 572 502],...
   'Color',[0.2667 0.2706 0.2784],'Resize','off');
   ```

2. Create a flight instrument panel image for the flight instruments and save it as a graphic file, such as a PNG file.

3. Read the flight instrument panel image into MATLAB and create and load it into UI axes in App Designer using the `uiaxes` function. To display the flight instrument panel image in the current axes, use the `image` function. For example:

   ```
   imgPanel = imread('astFlightInstrumentPanel.png');
   ax = uiaxes('Parent',fig,'Visible','off','Position',[10 30 530 460],...
   'BackgroundColor',[0.2667 0.2706 0.2784]);
   image(ax,imgPanel);
   ```

4. Create a flight instruments component. For example, create an artificial horizon component. Specify the parent object as the `uifigure` and the position and size of the artificial horizon.

   ```
   hor = uiaerohorizon('Parent',fig,'Position',[212 299 144 144]);
   ```

5. To trigger a display of the animation in the instrument panel, you must input a time step. For example, connect a time input device such as a slider or knob that can change the time. As you change the time on the time input device, the flight instrument component updates to show the result. This example uses the `uislider` function to create a slider component.

   ```
   sl = uislider('Parent',fig,'Limits',[simdata(1,1) simdata(end,1)],'FontColor','white');
   sl.Position = [50 60 450 3];
   sl.ValueChangingFcn = @(sl,event) astHelperFlightInstrumentsAnimation(sl,fig,simdata,h);
   ```

6. The slider component has a `ValueChangedFcn` callback, which executes when you move the slider thumb to a different position. To update the flight instruments and animation figure, assign the `ValueChangedFcn` callback to a helper function. This example uses the `astHelperFlightInstrumentsAnimation` helper function.

   ```
   sl = uislider('Parent',fig,'Limits',[simdata(1,1) simdata(end,1)],'FontColor','white');
   sl.Position = [50 60 450 3];
   sl.ValueChangedFcn = @(sl,event) astHelperFlightInstrumentsAnimation(sl,fig,simdata,h);
   ```

7. To display the time selected in the slider, use the `uilabel` function to create a label component. This code creates the label text in white and places the label at position [230 10 90 30].

   ```
   lbl = uilabel('Parent',fig,'Text',['Time: ' num2str(sl.Value,4) ' sec'],'FontColor','white');
   lbl.Position = [230 10 90 30];
   ```

For a complete example, see Display Flight Trajectory Data Using Flight Instruments and Flight Animation.

# See Also

**Functions**

`imread` | `uiaeroairspeed` | `uiaeroaltimeter` | `uiaeroclimb` | `uiaeroegt` | `uiaeroheading` | `uiaerohorizon` | `uiaerorpm` | `uiaeroturn` | `uiaxes` | `uifigure` | `uilabel` | `uislider`

**Properties**

AirspeedIndicator Properties | Altimeter Properties | ArtificialHorizon Properties | ClimbIndicator Properties | EGTIndicator Properties | HeadingIndicator Properties | RPMIndicator Properties | TurnCoordinator Properties

## More About

- “Create and Configure Flight Instrument Component and an Animation Object” on page 2-69
- “Flight Instruments”

3

# Add-On for Ephemeris and Geoid Data Support

# Add Ephemeris and Geoid Data for Aerospace Products

Add ephemeris and/or geoid data to use it with the Aerospace Toolbox functions and Aerospace Blockset blocks. You can add data for these functions and blocks.

| Aerospace Toolbox Functions | Aerospace Blockset Blocks |
|---|---|
| `geoidheight`<br><br>**Note** Only for the EGM2008 Geopotential Model. Aerospace Toolbox provides EGM96 Geopotential Model data. | Geoid Height<br><br>**Note** Only for the EGM2008 Geopotential Model. Aerospace Toolbox provides EGM96 Geopotential Model data. |
| `earthNutation` | Earth Nutation |
| `moonLibration` | Moon Libration |
| `planetEphemeris` | Planetary Ephemeris |

To add ephemeris and geoid data for these functions and blocks.

1. In a MATLAB Command Window, type:

   ```
   aeroDataPackage
   ```

   The Add-On Explorer starts.
2. Select the data you want to add, for example:
   - `Geoid Data for Aerospace Toolbox`
   - `Ephemeris Data for Aerospace Toolbox`
3. On the data page, click the **Install** button.

**Note** You must have write privileges for the folder to which you are adding data.

To check for updates, repeat this process when a new version of MATLAB software is released. You can also check for updates between releases using this process.

# Alphabetical List

# addBody

**Class:** Aero.Animation
**Package:** Aero

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);
```

# addNode (Aero.VirtualRealityAnimation)

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

**Introduced in R2007b**

# addRoute (Aero.VirtualRealityAnimation)

Add VRML ROUTE statement to virtual reality animation

## Syntax

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

## Description

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

**Introduced in R2007b**

# addViewpoint (Aero.VirtualRealityAnimation)

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 character vector or 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 character vector or 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 character vector or 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`

**Introduced in R2007b**

# Aero.Animation class

**Package:** Aero

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 |
| VideoCompression | Video recording compression file type |
| VideoFileName | Video recording file name |
| VideoQuality | Video recording quality |
| VideoRecord | Video recording |
| VideoTFinal | Video recording stop time for scheduled recording |
| VideoTStart | Video recording start time for scheduled recording |

## See Also

`Aero.FlightGearAnimation` | `Aero.VirtualRealityAnimation`

### Topics

“Aero.Animation Objects” on page 2-24

# Aero.Animation

**Class:** Aero.Animation
**Package:** Aero

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

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. | Character vector \| 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 |
| `PatchGenerationFcn` | 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 TimeseriesSourceType Properties. The default value is `'Array6DoF'`. | Character vector \| 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:

**TimeseriesSourceType Properties**

| Property | Description |
|---|---|
| `'Timeseries'` | MATLAB time series data with six values per time:<br>`lat lon alt phi theta psi`<br>The values are resampled. |
| `'StructureWithTime'` | Simulink struct with time (for example, Simulink root outport logging `'Structure with time'`):<br>• `signals(1).values: lat lon alt`<br>• `signals(2).values: phi theta psi`<br>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`

**Introduced in R2007a**

# Aero.Camera

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.

For more information, see:

- “Overlaying Simulated and Actual Flight Data”
- “Camera Graphics Terminology” (MATLAB)
- “Low-Level Camera Properties” (MATLAB)

## 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]` |
| `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`

**Introduced in R2007a**

# aeroDataPackage

Start Add-On Explorer to download, install, or uninstall aerospace-specific data

## Syntax

```
aeroDataPackage
```

## Description

`aeroDataPackage` opens Add-On Explorer. To see a list of available data, run Add-On Explorer and select the data you want.

## Examples

### Start Add-On Explorer

Start Add-On Explorer to add data.

```
aeroDataPackage
```

The Add-On Explorer starts. Follow the instructions to download your data.

## Limitations

The `aeroDataPackage` function is not available for Aerospace Toolbox Online.

## See Also

### Topics

“Add Ephemeris and Geoid Data for Aerospace Products” on page 3-2

**Introduced in R2014a**

# Aero.FlightGearAnimation

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`.

## Limitations

These capabilities are not available for Aerospace Toolbox Online:

- The `Aero.FlightGearAnimation` object
- The related example, “Create a Flight Animation from Trajectory Data”

## Constructor

| Method | Description |
|---|---|
| `fganimation` | Construct FlightGear animation object. |

## Method Summary

| Method | Description |
|---|---|
| `ClearTimer` | Clear and delete timer for animation of FlightGear flight simulator. |
| `delete` | Destroy FlightGear animation object. |

| Method | Description |
|---|---|
| `GenerateRunScript` | Generate run script for FlightGear flight simulator. |
| `initialize` | Set up FlightGear animation object. |
| `play` | Animate FlightGear flight simulator using given position/angle time series. |
| `SetTimer` | Set name of timer for animation of FlightGear flight simulator. |
| `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 TimeseriesSourceType Properties. 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`. |
| `FramesPerSecond` | Specify the number of frames per second used to animate the `'TimeseriesSource'`. The default value is `12` frames per second. |

| Properties | Description |
|---|---|
| `FlightGearVersion` | Select your FlightGear software version: `v2018.1`, `v2017.3`, `v2017.1`, `v2016.3`, `v2016.1`, `v3.4`, `v3.2`, `v3.0`, `v2.12`, `v2.10`, `v2.8`, `v2.6`, `v2.4`, or `'2.0'`. The default version is the latest version.<br><br>**Note** If you are using a FlightGear version older than 2.0, the software returns a warning when you use the `initialize` method. Consider upgrading your FlightGear version. For more information, see “Supported FlightGear Versions” on page 2-53. |
| `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'`.<br><br>**Note** The run script file name must be composed of ASCII characters. |
| `FlightGearBase-Directory` | Specify the name of your FlightGear installation folder. The default value is `'D:\Applications\FlightGear'`.<br><br>**Note** FlightGear must be installed in a folder path name composed of ASCII characters. |
| `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'`. |

| Properties | Description |
|---|---|
| `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. |
| `TStart` | Specify start time as a double. |
| `TFinal` | Specify end time as a double. |
| `Architecture` | Specify the architecture the FlightGear software is running on. `GenerateRunScript` takes this setting into account when generating the bash run script to start FlightGear. The platforms are listed in Architecture Properties. The default value is `'Default'`. |

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

**TimeseriesSourceType Properties**

| Property | Description |
|---|---|
| `'Timeseries'` | MATLAB time series data with six values per time:<br>`lat lon alt phi theta psi`<br>The values are resampled. |
| `'StructureWithTime'` | Simulink struct with time (for example, Simulink root outport logging `'Structure with time'`):<br>• `signals(1).values: lat lon alt`<br>• `signals(2).values: phi theta psi`<br>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'`. |

Specify one of these values for the `Architecture` property:

**Architecture Properties**

| Property | Description |
|---|---|
| `'Default'` | Architecture the MATLAB software is currently running on. If the property has this value, `GenerateRunScript` creates a bash file that can work in the architecture that MATLAB is currently running on. |
| `'Win64'` | Windows (64-bit) architecture. |
| `'Mac'` | Mac OS X (64-bit) architecture. |
| `'Linux'` | Linux (64-bit) architecture. |

`'Default'` Architecture the MATLAB software is currently running on. If the property has this value, `GenerateRunScript` creates a bash file that can work in the architecture that MATLAB is currently running on.

`'Win64'` Windows (64-bit) architecture.

`'Mac'` Mac OS X (64-bit) architecture.

`'Linux'` Linux (64-bit) architecture.

# Examples

Construct a FlightGear animation object, `h`:

```
h = fganimation
```

# See Also

`fganimation` | `generaterunscript` | `play`

**Introduced in R2007a**

# aeroReadIERSData

File containing current International Astronomical Union (IAU) 2000A Earth orientation data

## Syntax

```
file=aeroReadIERSData(foldername)
file=aeroReadIERSData(foldername,'url',urladdress)
```

## Description

`file=aeroReadIERSData(foldername)` creates a MAT-file, `file`, based on IAU 2000A Earth orientation data from the International Earth Rotation and Reference Systems Service (IERS). It saves the file to `foldername`. `file` name has the format `aeroiersdata`*`YYYYMMDD`*`.mat`, where:

- YYYY - Year
- MM - Month
- DD - Day

`file=aeroReadIERSData(foldername,'url',urladdress)` creates the MAT-file based on Earth orientation data from a specific website or data file.

## Examples

### Create File for Current Day

Create the Earth orientation data file for the current day, in the current folder, using data from the default website `http://maia.usno.navy.mil/ser7/finals2000A.data`.

```
aeroReadIERSData(pwd)
```

### Create File from Specified Website

Create the Earth orientation file for the current day, in the current folder, using data from the alternate website `https://datacenter.iers.org/eop/-/somos/5Rgv/latest/10`.

```
aeroReadIERSData(pwd,'url','https://datacenter.iers.org/eop/-/somos/5Rgv/latest/10')
```

### Create File from Specified File

Create the Earth orientation file for the current day, in the current folder, using data from a specified file `file:///C:\Documents\final2000A.data`.

```
aeroReadIERSData(pwd,'url','file:///C:\Documents\finals2000A.data')
```

## Input Arguments

**`foldername` — Folder for IERS data file**
folder name

Folder for IERS data file, specified as a character array or string. Before running this function, create *foldername* with write permission.

Data Types: `char` | `string`

**`'url',urladdress` — Optional website or Earth orientation data file**
http://maia.usno.navy.mil/ser7/finals2000A.data (default) | website address | file name

Optional website or file containing the IAU 2000A Earth orientation data, specified as a website address or file name.

Example: https://datacenter.iers.org/eop/-/somos/5Rgv/latest/10

Data Types: `char` | `string`

## Output Arguments

**`file` — Location of Earth orientation data MAT-file**
character array

Location of Earth orientation data MAT-file, specified as a character array.

# Definitions

## International Astronomical Union (IAU) 2000A Earth Orientation Data Format

The function expects the International Astronomical Union (IAU) 2000A Earth orientation data to use the format referenced here http://maia.usno.navy.mil/ser7/readme.finals2000A:

| Column | Description |
|---|---|
| 1 to 2 | Year (to get true calendar year, add 1900 for MJD<=51543 or add 2000 for MJD>=51544) |
| 3 to 4 | Month number |
| 5 to 6 | Day of month |
| 7 | Blank |
| 8 to 15 | Fractional modified Julian date (MJD UTC) |
| 16 | Blank |
| 17 | IERS (I) or Prediction (P) flag for Bull. A polar motion values* |
| 18 | Blank |
| 19 to 27 | Bull. A PM-x (sec. of arc)* |
| 28-36 | Error in PM-x (sec. of arc)* |
| 37 | Blank |
| 38-46 | Bull. A PM-y (sec. of arc)* |
| 47-55 | Error in PM-y (sec. of arc)* |
| 56-57 | Blank |
| 58 | IERS (I) or Prediction (P) flag for Bulletin A UT1-UTC values* |

| Column | Description |
|---|---|
| 59-68 | Bull. A UT1-UTC (sec. of time)* |
| 69-78 | Error in UT1-UTC (sec. of time)* |
| 79 | Blank |
| 80-86 | Bull. A LOD (msec. of time) -- not always filled* |
| 87-93 | Error in LOD (msec. of time) -- not always filled* |
| 94-95 | Blank |
| 96 | IERS (I) or Prediction (P) flag for Bull. A nutation values* |
| 97 | Blank |
| 98-106 | Bull. A dX wrt IAU2000A nutation (msec. of arc), free core nutation not removed* |
| 107-115 | Error in dX (msec. of arc) |
| 116 | Blank |
| 117-125 | Bull. A dY wrt IAU2000A nutation (msec. of arc), free core nutation not removed* |
| 126-134 | Error in dY (msec. of arc) |
| 135-144 | Bull. B PM-x (sec. of arc)* |
| 145-154 | Bull. B PM-x (sec. of arc)* |
| 155-165 | Bull. B UT1-UTC (sec. of time)* |
| 166-175 | Bull. B dX wrt IAU2000A nutation (msec. of arc)* |
| 176-185 | Bull. B dY wrt IAU2000A nutation (msec. of arc)* |

* Abbreviated terms:

- Bull. — Bulletin
- LOD — Length of day
- wrt — With regard to

- pm — Polar motion

## See Also

`dcmeci2ecef` | `deltaUT1` | `eci2aer` | `eci2lla` | `lla2eci` | `mjuliandate`

## External Websites

http://maia.usno.navy.mil/ser7/finals2000A.data
http://maia.usno.navy.mil/ser7/readme.finals2000A

**Introduced in R2017b**

# Aero.Geometry

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. | Character vector \| string |

| Property | Description | Values | |
|---|---|---|---|
| `Source` | Specify geometry data source. | `{['Auto'], 'Variable', 'MatFile', 'Ac3dFile', 'Custom'}` | |
| `Reader` | Specify geometry reader. | MATLAB array | |
| `FaceVertexColorData` | Specify the color of the geometry face vertex. | MATLAB structure with the following fields | |
| | | `name` | Character vector or string that contains the name of the geometry being loaded. |
| | | `faces` | See Faces. |
| | | `vertices` | See Vertices. |
| | | `cdata` | See CData. |
| | | `alpha` | See FaceVertexAlphaData. |

## See Also

`read`

**Introduced in R2007a**

# Aero.Node

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.

When working with nodes, consider the translation and rotation. Translation is a 1-by-3 matrix in the aerospace body coordinate system defined for the VirtualRealityAnimation object or another coordinate system. In the latter case, you can use the `CoordTransformFcn` function to move it into the defined aerospace body coordinate system. The defined aerospace body coordinate system is defined relative to the screen as *x*-left, *y*-in, *z*-down.

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 defined aerospace body coordinate system. The function then moves the translation and rotation from the defined aerospace body coordinate system to the defined VRML *x*-*y*-*z* coordinates for the VirtualRealityAnimation object. The defined VRML coordinate system is defined relative to the screen as *x*-right, *y*-up, *z*-out.

## 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. | Character vector \| string |
| `VRNode` | Return the handle to the `vrnode` object associated with the node object. | 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 TimeseriesSourceType Properties. The default value is `'Array6DoF'`. | Character vector \| string |

| Property | Description | Values |
| --- | --- | --- |
| `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:

**TimeseriesSourceType Properties**

| Property | Description |
|---|---|
| `'Timeseries'` | MATLAB time series data with six values per time:<br>`lat lon alt phi theta psi`<br>The values are resampled. |
| `'StructureWithTime'` | Simulink struct with time (for example, Simulink root outport logging `'Structure with time'`):<br>• `signals(1).values: lat lon alt`<br>• `signals(2).values: phi theta psi`<br>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'`. |

**Introduced in R2007b**

# Aero.Viewpoint

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. | Character vector \| string |
| `Node` | Specify node object that contains the viewpoint node. | MATLAB array |

**Introduced in R2007b**

# Aero.VirtualRealityAnimation

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.

## Limitations

The `Aero.VirtualRealityAnimation` object is not available for Aerospace Toolbox Online.

## 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. |

| Method | Description |
|---|---|
| `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. |
| `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. | Character vector \| string |
| `VRWorld` | Returns the vrworld object associated with the animation object. | MATLAB array |
| `VRWorldFilename` | Specify the `.wrl` file for the vrworld. | Character vector \| string |
| `VRWorldOldFilename` | Specify the old `.wrl` files for the vrworld. | MATLAB array |
| `VRWorldTempFilename` | Specify the temporary `.wrl` file for the animation object. | Character vector \| 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 recording start time, in seconds. | double |
| `TFinal` | Specify end time, in seconds. | double |
| `TCurrent` | Specify current time, in seconds. | double |
| `FramesPerSecond` | Specify rate, in frames per second. | double |
| `ShowSaveWarning` | Specify save warning display setting. | double<br>• `0` — No warning is displayed.<br>• Non-zero — Warning is displayed. |

| Property | Description | Values |
|---|---|---|
| `VideoFileName` | Specify video recording file name. | Character vector \| string |
| `VideoCompression` | Specify video recording compression file type. For more information on video compression, see `VideoWriter`. | • `'Archival'`<br>Create Motion JPEG 2000 format file with lossless compression.<br>• `'Motion JPEG AVI'`<br>Create compressed AVI format file using Motion JPEG codec.<br>• `'Motion JPEG 2000'`<br>Create compressed Motion JPEG 2000 format file.<br>• `'MPEG-4'`<br>Create compressed MPEG-4 format file with H.264 encoding (Windows 7 systems only).<br>• `'Uncompressed AVI'`<br>Create uncompressed AVI format file with RGB24 video.<br>`Aero.VideoProfileTypeEnum`<br>**Default:** `'Archival'` |
| `VideoQuality` | Specify video recording quality. For more information on video quality, see the `Quality` property of `VideoWriter`. | Value between `0` and `100`.<br>double<br>**Default:** 75 |

| Property | Description | Values |
|---|---|---|
| `VideoRecord` | Enable video recording. | • `'on'`<br>Enable video recording.<br>• `'off'`<br>Disable video recording.<br>• `'scheduled'`<br>Schedule video recording. Use this property with the `VideoTStart` and `VideoTFinal` properties.<br>**Default:** `'off'` |
| `VideoTStart` | Specify video recording start time for scheduled recording. | Value between `TStart` and `TFinal`.<br>double<br>**Default:** `NaN`, which uses the value of `TStart`. |
| `VideoTFinal` | Specify video recording stop time for scheduled recording. | Value between `TStart` and `TFinal`.<br>double<br>**Default:** `NaN`, which uses the value of `TFinal`. |

# Examples

### Record Virtual Reality Animation Object Simulation

This example shows how to record virtual reality animation of an object simulation.

- Record the simulation of a virtual reality animation object
- Simulate and record flight data

- Create an animation object

```
h = Aero.VirtualRealityAnimation;
% Control the frame display rate.

h.FramesPerSecond = 10;

% 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. These settings result in a time step of
% approximately 0.5 s.
% This code sets the .wrl file to use in the virtual reality animation.

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

% Copy the .wrl file to a temporary directory and set the world file name
% to the copied .wrl file.

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

% Load the animation world described in the 'VRWorldFilename' field of the
% animation object.

h.initialize();

% Set simulation timeseries data. takeoffData.mat contains logged simulated
% data. takeoffData is set up as a 'StructureWithTime', which is one of the
% default data formats.

load takeoffData
[~, idxPlane] = find(strcmp('Plane', h.nodeInfo));
h.Nodes{idxPlane}.TimeseriesSource = takeoffData;
h.Nodes{idxPlane}.TimeseriesSourceType = 'StructureWithTime';

% Use the example custom function vranimCustomTransform to correctly line
% up the position and rotation data with the surrounding objects in the
% virtual world. This code sets the coordinate transformation function for
% the virtual reality animation.

h.Nodes{idxPlane}.CoordTransformFcn = @vranimCustomTransform;

% Set up recording properties.

h.VideoRecord = 'on';
h.VideoQuality = 50;
h.VideoCompression = 'Motion JPEG AVI'
h.VideoFilename = 'astMotion_JPEG_VR';

% Play the animation.
```

```
h.play();

% Verify that a file named astMotion_JPEG_VR.avi was created in the current folder.
% Disable recording to preserve the file.

h.VideoRecord = 'off';
```

### Record Virtual Reality Animation for Four Seconds

This example shows how to simulate flight data for four seconds.

```
% Create an animation object.
h = Aero.VirtualRealityAnimation;

% Control the frame display rate.
h.FramesPerSecond = 10;

% 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 properties determines
% the time step of the simulation. These settings result in a time step of
% approximately 0.5 s.
% This code sets the .wrl file to use in the virtual reality animation.
h.VRWorldFilename = [matlabroot,'/toolbox/aero/astdemos/asttkoff.wrl'];

% Copy the .wrl file to a temporary directory and set the world file name
% to the copied .wrl file.
copyfile(h.VRWorldFilename,[tempdir,'asttkoff.wrl'],'f');
h.VRWorldFilename = [tempdir,'asttkoff.wrl'];

% Load the animation world described in the 'VRWorldFilename' field of the
% animation object.
h.initialize();

% Set simulation timeseries data. takeoffData.mat contains logged simulated
% data. takeoffData is set up as a 'StructureWithTime', which is one of the
% default data formats.
load takeoffData
[~, idxPlane] = find(strcmp('Plane', h.nodeInfo));
h.Nodes{idxPlane}.TimeseriesSource = takeoffData;
h.Nodes{idxPlane}.TimeseriesSourceType = 'StructureWithTime';

% Use the example custom function vranimCustomTransform to correctly line
% up the position and rotation data with the surrounding objects in the
% virtual world. This code sets the coordinate transformation function for
% the virtual reality animation.
h.Nodes{idxPlane}.CoordTransformFcn = @vranimCustomTransform;

% Set up recording properties.
h.VideoRecord = 'on';
h.VideoQuality = 50;
h.VideoCompression = 'Motion JPEG AVI'
h.VideoFilename = 'astMotion_JPEG';
```

```
% Play the animation from TFinal to TStart.
h.TSTart = 1;
h.TFinal = 5;
h.play();

% Verify that a file named astMotion_JPEG_VR.avi was created in the
% current folder. When you rerun the recording, notice that the play time
% is faster than when you record for the length of the simulation time.

% Disable recording to preserve the file.
h.VideoRecord = 'off';
```

### Schedule Three Second Recording of Virtual Reality Object Simulation

This example shows how to schedule a three second recording a virtual reality object animation simulation.

```
% Create an animation object.
h = Aero.VirtualRealityAnimation;

% Control the frame display rate.
h.FramesPerSecond = 10;

% 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 properties determines
% the time step of the simulation. These settings result in a time step of
% approximately 0.5 s.
% This code sets the .wrl file to use in the virtual reality animation.
h.VRWorldFilename = [matlabroot,'/toolbox/aero/astdemos/asttkoff.wrl'];

% Copy the .wrl file to a temporary directory and set the world file name
% to the copied .wrl file.
copyfile(h.VRWorldFilename,[tempdir,'asttkoff.wrl'],'f');
h.VRWorldFilename = [tempdir,'asttkoff.wrl'];

% Load the animation world described in the 'VRWorldFilename' field of the
% animation object.
h.initialize();

% Set simulation timeseries data. takeoffData.mat contains logged
% simulated data. takeoffData is set up as a 'StructureWithTime', which is
% one of the default data formats.
load takeoffData
[~, idxPlane] = find(strcmp('Plane', h.nodeInfo));
h.Nodes{idxPlane}.TimeseriesSource = takeoffData;
h.Nodes{idxPlane}.TimeseriesSourceType = 'StructureWithTime';

% Use the example custom function vranimCustomTransform to correctly line
% up the position and rotation data with the surrounding objects in the
% virtual world. This code sets the coordinate transformation function for
```

```
% the virtual reality animation.
h.Nodes{idxPlane}.CoordTransformFcn = @vranimCustomTransform;

% Set up recording properties.
h.VideoQuality = 50;
h.VideoCompression = 'Motion JPEG AVI';
h.VideoFilename = 'astMotion_JPEG';

% Set up simulation time from TFinal to TStart.
h.TSTart = 1;
h.TFinal = 5;

% Set up to record between two and four seconds of the four second
% simulation.
h.VideoRecord='scheduled';
h.VideoTSTart = 2;
h.VideoTFinal = 4;

% Play the animation.
h.play();

% Verify that a file named astMotion_JPEG_VR.avi was created in the
% current folder. When you rerun the recording, notice that the play time
% is faster than when you record for the length of the simulation time.
% Disable recording to preserve the file.
h.VideoRecord = 'off';
```

### Introduced in R2007b

# airspeed

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`

**Introduced in R2006b**

# AirspeedIndicator Properties

Control airspeed indicator appearance and behavior

## Description

Airspeed indicators are components that represent an airspeed indicator. Properties control the appearance and behavior of an airspeed indicator. Use dot notation to refer to a particular object and property:

```
figure = uifigure;
airspeed = uiaeroairspeed(figure);
airspeed.Airspeed = 100;
```

## Properties

**Airspeed Indicator**

### `Airspeed` — Airspeed

`0` (default) | finite, real, and scalar numeric

Airspeed value, specified as a finite, real, and scalar numeric, in knots. The airspeed value determines the airspeed of the aircraft.

- If the value is less than the minimum `Limits` property value, then the needle points to a location immediately before the beginning of the scale.
- If the value is more than the maximum `Limits` property value, then the needle points to a location immediately after the end of the scale.

Example: 100

### `Limits` — Minimum and maximum airspeed indicator scale values

[40 400] (default) | two-element finite and real numeric array

Minimum and maximum gauge scale values, specified as a two-element numeric array. The first value in the array must be less than the second value, in knots.

If you change `Limits` such that the `Value` property is less than the new lower limit, or more than the new upper limit, then the gauge needle points to a location off the scale.

For example, suppose `Limits` is `[0 100]` and the `Value` property is 20. If the `Limits` changes to `[50 100]`, then the needle points to a location off the scale, slightly less than 50.

### `ScaleColors` — Scale colors

[ ] (default) | n-by-3 array of RGB triplets | cell array

Scale colors, specified as one of the following arrays:

- An n-by-3 array of RGB triplets
- A cell array containing RGB triplets, any of the color options listed in the table below, or a combination of both.

An RGB triplet is a three-element row vector whose elements specify the intensities of the red, green, and blue components of the color. The intensities must be in the range `[0,1]`; for example, `[0.4 0.6 0.7]`. Alternatively, you can specify some common colors by name. This table lists the long and short color name options and the equivalent RGB triplet values.

| Option | Description | Equivalent RGB Triplet |
|---|---|---|
| `'red'` or `'r'` | Red | `[1 0 0]` |
| `'green'` or `'g'` | Green | `[0 1 0]` |
| `'blue'` or `'b'` | Blue | `[0 0 1]` |
| `'yellow'` or `'y'` | Yellow | `[1 1 0]` |
| `'magenta'` or `'m'` | Magenta | `[1 0 1]` |
| `'cyan'` or `'c'` | Cyan | `[0 1 1]` |
| `'white'` or `'w'` | White | `[1 1 1]` |
| `'black'` or `'k'` | Black | `[0 0 0]` (not recommended) |

Each color of the `ScaleColors` array corresponds to a colored section of the gauge. Set the `ScaleColorLimits` property to map the colors to specific sections of the gauge.

If you do not set the `ScaleColorLimits` property, MATLAB distributes the colors equally over the range of the gauge.

### `ScaleColorLimits` — Scale color limits

[ ] (default) | n-by-2 array

Scale color limits, specified as an n-by-2 array of numeric values. For every row in the array, the first element must be less than the second element. The first `ScaleColorLimits` value can overlap (see Display Flight Trajectory Data Using Flight Instruments and Flight Animation).

When applying colors to the gauge, MATLAB applies the colors starting with the first color in the `ScaleColors` array. Therefore, if two rows in `ScaleColorLimits` array overlap, then the color applied later takes precedence.

The gauge does not display any portion of the `ScaleColorLimits` that falls outside of the `Limits` property.

If the `ScaleColors` and `ScaleColorLimits` property values are different sizes, then the gauge shows only the colors that have matching limits. For example, if the `ScaleColors` array has three colors, but the `ScaleColorLimits` has only two rows, then the gauge displays the first two color/limit pairs only.

### `Value` — Airspeed

`0` (default) | finite, real, and scalar numeric

Airspeed value, specified as a finite, real, and scalar numeric. The airspeed value determines the airspeed of the aircraft.

- If the value is less than the minimum `Limits` property value, then the needle points to a location immediately before the beginning of the scale.
- If the value is more than the maximum `Limits` property value, then the needle points to a location immediately after the end of the scale.

Example: 100

#### Interactivity

### `Visible` — Visibility of airspeed indicator

`'on'` (default) | `'off'`

Visibility of the airspeed indicator, specified as `'on'` or `'off'`. The `Visible` property determines whether the airspeed indicator is displayed on the screen. If the `Visible` property is set to `'off'`, then the entire airspeed indicator is hidden, but you can still specify and access its properties.

### Enable — Operational state of airspeed indicator

'on' (default) | 'off'

Operational state of airspeed indicator, specified as 'on' or 'off'.

- If you set this property to 'on', then the appearance of the indicator indicates that the indicator is operational.
- If you set this property to 'off', then the appearance of the indicator appears dimmed, indicating that the indicator is not operational.

#### Position

### Position — Location and size of airspeed indicator

[100 100 120 120] (default) | [left bottom width height]

Location and size of the airspeed indicator relative to the parent container, specified as the vector, [left bottom width height]. This table describes each element in the vector.

| Element | Description |
|---|---|
| left | Distance from the inner left edge of the parent container to the outer left edge of an imaginary box surrounding the airspeed indicator |
| bottom | Distance from the inner bottom edge of the parent container to the outer bottom edge of an imaginary box surrounding the airspeed indicator |
| width | Distance between the right and left outer edges of the airspeed indicator |
| height | Distance between the top and bottom outer edges of the airspeed indicator |

All measurements are in pixel units.

The Position values are relative to the drawable area of the parent container. The drawable area is the area inside the borders of the container and does not include the area occupied by decorations such as a menu bar or title.

Example: [200 120 120 120]

### InnerPosition — Inner location and size of airspeed indicator

[100 100 120 120] (default) | [left bottom width height]

Inner location and size of the airspeed indicator, specified as `[left bottom width height]`. Position values are relative to the parent container. All measurements are in pixel units. This property value is identical to the `Position` property.

### `OuterPosition` — Outer location and size of airspeed indicator

`[100 100 120 120]]` (default) | `[left bottom width height]`

This property is read-only.

Outer location and size of the airspeed indicator returned as `[left bottom width height]`. Position values are relative to the parent container. All measurements are in pixel units. This property value is identical to the `Position` property.

### `Layout` — Layout options

empty `LayoutOptions` array (default) | `GridLayoutOptions` object

Layout options, specified as a `GridLayoutOptions` object. This property specifies options for components that are children of grid layout containers. If the component is not a child of a grid layout container (for example, it is a child of a figure or panel), then this property is empty and has no effect. However, if the component is a child of a grid layout container, you can place the component in the desired row and column of the grid by setting the `Row` and `Column` properties on the `GridLayoutOptions` object.

For example, this code places an airspeed indicator in the third row and second column of its parent grid.

```
g = ui([4 3]);
gauge = uiaeroairspeed(g);
gauge.Layout.Row = 3;
gauge.Layout.Column = 2;
```

To make the airspeed indicator span multiple rows or columns, specify the `Row` or `Column` property as a two-element vector. For example, this airspeed indicator spans columns 2 through 3:

```
gauge.Layout.Column = [2 3];
```

#### Callbacks

### `CreateFcn` — Creation function

`''` (default) | function handle | cell array | character vector

Object creation function, specified as one of these values:

- Function handle.
- Cell array in which the first element is a function handle. Subsequent elements in the cell array are the arguments to pass to the callback function.
- Character vector containing a valid MATLAB expression (not recommended). MATLAB evaluates this expression in the base workspace.

For more information about specifying a callback as a function handle, cell array, or character vector, see “Write Callbacks in App Designer” (MATLAB).

This property specifies a callback function to execute when MATLAB creates the object. MATLAB initializes all property values before executing the `CreateFcn` callback. If you do not specify the `CreateFcn` property, then MATLAB executes a default creation function.

Setting the `CreateFcn` property on an existing component has no effect.

If you specify this property as a function handle or cell array, you can access the object that is being created using the first argument of the callback function. Otherwise, use the `gcbo` function to access the object.

**`DeleteFcn` — Deletion function**
`''` (default) | function handle | cell array | character vector

Object deletion function, specified as one of these values:

- Function handle.
- Cell array in which the first element is a function handle. Subsequent elements in the cell array are the arguments to pass to the callback function.
- Character vector containing a valid MATLAB expression (not recommended). MATLAB evaluates this expression in the base workspace.

For more information about specifying a callback as a function handle, cell array, or character vector, see “Write Callbacks in App Designer” (MATLAB).

This property specifies a callback function to execute when MATLAB deletes the object. MATLAB executes the `DeleteFcn` callback before destroying the properties of the object. If you do not specify the `DeleteFcn` property, then MATLAB executes a default deletion function.

If you specify this property as a function handle or cell array, you can access the object that is being deleted using the first argument of the callback function. Otherwise, use the `gcbo` function to access the object.

**Callback Execution Control**

### `Interruptible` — Callback interruption

`'on'` (default) | `'off'`

Callback interruption, specified as `'on'` or `'off'`. The `Interruptible` property determines if a running callback can be interrupted.

There are two callback states to consider:

- The running callback is the currently executing callback.
- The interrupting callback is a callback that tries to interrupt the running callback.

Whenever MATLAB invokes a callback, that callback attempts to interrupt the running callback (if one exists). The `Interruptible` property of the object owning the running callback determines if interruption is allowed. The `Interruptible` property has two possible values:

- `'on'` — Allows other callbacks to interrupt the object's callbacks. The interruption occurs at the next point where MATLAB processes the queue, such as when there is a `drawnow`, `figure`, `uifigure`, `getframe`, `waitfor`, or `pause` command.
  - If the running callback contains one of those commands, then MATLAB stops the execution of the callback at that point and executes the interrupting callback. MATLAB resumes executing the running callback when the interrupting callback completes.
  - If the running callback does not contain one of those commands, then MATLAB finishes executing the callback without interruption.
- `'off'` — Blocks all interruption attempts. The `BusyAction` property of the object owning the interrupting callback determines if the interrupting callback is discarded or put into a queue.

---

**Note** Callback interruption and execution behave differently in these situations:

- If the interrupting callback is a `DeleteFcn`, `CloseRequestFcn` or `SizeChangedFcn` callback, then the interruption occurs regardless of the `Interruptible` property value.

- If the running callback is currently executing the `waitfor` function, then the interruption occurs regardless of the `Interruptible` property value.
- `Timer` objects execute according to schedule regardless of the `Interruptible` property value.

When an interruption occurs, MATLAB does not save the state of properties or the display. For example, the object returned by the `gca` or `gcf` command might change when another callback executes.

### `BusyAction` — Callback queuing

`'queue'` (default) | `'cancel'`

Callback queuing, specified as `'queue'` or `'cancel'`. The `BusyAction` property determines how MATLAB handles the execution of interrupting callbacks. There are two callback states to consider:

- The running callback is the currently executing callback.
- The interrupting callback is a callback that tries to interrupt the running callback.

Whenever MATLAB invokes a callback, that callback attempts to interrupt a running callback. The `Interruptible` property of the object owning the running callback determines if interruption is permitted. If interruption is not permitted, then the `BusyAction` property of the object owning the interrupting callback determines if it is discarded or put in the queue. These are possible values of the `BusyAction` property:

- `'queue'` — Puts the interrupting callback in a queue to be processed after the running callback finishes execution.
- `'cancel'` — Does not execute the interrupting callback.

### `BeingDeleted` — Deletion status

`'off'` | `'on'`

This property is read-only.

Deletion status, returned as `'off'` or `'on'`. MATLAB sets the `BeingDeleted` property to `'on'` when the `DeleteFcn` callback begins execution. The `BeingDeleted` property remains set to `'on'` until the component object no longer exists.

Check the value of the `BeingDeleted` property to verify that the object is not about to be deleted before querying or modifying it.

#### Parent/Child

### `HandleVisibility` — Visibility of object handle

`'on'` (default) | `'callback'` | `'off'`

Visibility of the object handle, specified as `'on'`, `'callback'`, or `'off'`.

This property controls the visibility of the object in its parent's list of children. When an object is not visible in its parent's list of children, it is not returned by functions that obtain objects by searching the object hierarchy or querying properties. These functions include `get`, `findobj`, `clf`, and `close`. Objects are valid even if they are not visible. If you can access an object, you can set and get its properties, and pass it to any function that operates on objects.

| HandleVisibility Value | Description |
|---|---|
| `'on'` | The object is always visible. |
| `'callback'` | The object is visible from within callbacks or functions invoked by callbacks, but not from within functions invoked from the command line. This option blocks access to the object at the command-line, but allows callback functions to access it. |
| `'off'` | The object is invisible at all times. This option is useful for preventing unintended changes to the UI by another function. Set the `HandleVisibility` to `'off'` to temporarily hide the object during the execution of that function. |

### `Parent` — Parent container

`Figure` object (default) | `Panel` object | `Tab` object | `ButtonGroup` object | `GridLayout` object

Parent container, specified as a `Figure` created using the `uifigure` function, or one of its child containers: `Tab`, `Panel`, `ButtonGroup`, or `GridLayout`.

#### Identifiers

### `Tag` — Object identifier

`''` (default) | character vector | string scalar

Object identifier, specified as a character vector or string scalar. You can specify a unique `Tag` value to serve as an identifier for an object. When you need access to the object

elsewhere in your code, you can use the `findobj` function to search for the object based on the `Tag` value.

**Type — Type of graphics object**
`'uiaeroairspeed'`

This property is read-only.

Type of graphics object, returned as `'uiaeroairspeed'`.

**`UserData` — User data**
`[ ]` (default) | array

User data, specified as any MATLAB array. For example, you can specify a scalar, vector, matrix, cell array, character array, table, or structure. Use this property to store arbitrary data on an object.

If you are working in App Designer, create public or private properties in the app to share data instead of using the `UserData` property. For more information, see “Share Data Within App Designer Apps” (MATLAB).

## See Also

`uiaeroairspeed`

### Topics

“Create and Configure Flight Instrument Component and an Animation Object” on page 2-69
“Display Flight Trajectory Data Using Flight Instruments and Flight Animation” on page 2-65

**Introduced in R2018b**

# alphabeta

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`

**Introduced in R2006b**

# Altimeter Properties

Control altimeter appearance and behavior

## Description

Altimeters are components that represent an altimeter. Properties control the appearance and behavior of an altimeter. Use dot notation to refer to a particular object and property:

```
figure = uifigure;
altimeter = uiaeroaltimeter(figure);
altimeter.Altitude = 100;
```

## Properties

#### Altimeter

#### `Altitude` — Altitude of aircraft

`0` (default) | finite, real, and scalar numeric

Altitude of the aircraft, specified as any finite and scalar numeric, in feet.

Example: `60`

#### Dependencies

Specifying this value changes the value of `Value`.

Data Types: `double`

#### `Value` — Location of aircraft heading

`0` (default) | finite, real, and scalar numeric

Location of the aircraft altitude, specified as a finite and scalar numeric, in feet.

- Changing the value changes the direction of the heading in 5-degree increments.

Example: `60`

#### Dependencies

Specifying this value changes the value of the `Altitude` value.

Data Types: `double`

#### Interactivity

### `Visible` — Visibility of altimeter

`'on'` (default) | `'off'`

Visibility of the altimeter, specified as `'on'` or `'off'`. The `Visible` property determines whether the altimeter is displayed on the screen. If the `Visible` property is set to `'off'`, then the entire altimeter is hidden, but you can still specify and access its properties.

### `Enable` — Operational state of altimeter

`'on'` (default) | `'off'`

Operational state of altimeter, specified as `'on'` or `'off'`.

- If you set this property to `'on'`, then the appearance of the altimeter indicates that the altimeter is operational.
- If you set this property to `'off'`, then the appearance of the altimeter appears dimmed, indicating that the altimeter is not operational.

#### Position

### `Position` — Location and size of altimeter

`[100 100 120 120]` (default) | `[left bottom width height]`

Location and size of the altimeter relative to the parent container, specified as the vector, `[left bottom width height]`. This table describes each element in the vector.

| Element | Description |
|---|---|
| `left` | Distance from the inner left edge of the parent container to the outer left edge of an imaginary box surrounding the altimeter |
| `bottom` | Distance from the inner bottom edge of the parent container to the outer bottom edge of an imaginary box surrounding the altimeter |

| Element | Description |
|---|---|
| `width` | Distance between the right and left outer edges of the altimeter |
| `height` | Distance between the top and bottom outer edges of the altimeter |

All measurements are in pixel units.

The `Position` values are relative to the drawable area of the parent container. The drawable area is the area inside the borders of the container and does not include the area occupied by decorations such as a menu bar or title.

Example: `[200 120 120 120]`

### `InnerPosition` — Inner location and size of altimeter

`[100 100 120 120]` (default) | `[left bottom width height]`

Inner location and size of the altimeter, specified as `[left bottom width height]`. Position values are relative to the parent container. All measurements are in pixel units. This property value is identical to the `Position` property.

### `OuterPosition` — Outer location and size of altimeter

`[100 100 120 120]]` (default) | `[left bottom width height]`

This property is read-only.

Outer location and size of the altimeter returned as `[left bottom width height]`. Position values are relative to the parent container. All measurements are in pixel units. This property value is identical to the `Position` property.

### `Layout` — Layout options

empty `LayoutOptions` array (default) | `GridLayoutOptions` object

Layout options, specified as a `GridLayoutOptions` object. This property specifies options for components that are children of grid layout containers. If the component is not a child of a grid layout container (for example, it is a child of a figure or panel), then this property is empty and has no effect. However, if the component is a child of a grid layout container, you can place the component in the desired row and column of the grid by setting the `Row` and `Column` properties on the `GridLayoutOptions` object.

For example, this code places an altimeter in the third row and second column of its parent grid.

```
g = uigridlayout([4 3]);
gauge = uiaeroaltimeter(g);
gauge.Layout.Row = 3;
gauge.Layout.Column = 2;
```

To make the altimeter span multiple rows or columns, specify the `Row` or `Column` property as a two-element vector. For example, this altimeter spans columns `2` through `3`:

```
gauge.Layout.Column = [2 3];
```

**Callbacks**

### `CreateFcn` — Creation function

`''` (default) | function handle | cell array | character vector

Object creation function, specified as one of these values:

- Function handle.
- Cell array in which the first element is a function handle. Subsequent elements in the cell array are the arguments to pass to the callback function.
- Character vector containing a valid MATLAB expression (not recommended). MATLAB evaluates this expression in the base workspace.

For more information about specifying a callback as a function handle, cell array, or character vector, see “Write Callbacks in App Designer” (MATLAB).

This property specifies a callback function to execute when MATLAB creates the object. MATLAB initializes all property values before executing the `CreateFcn` callback. If you do not specify the `CreateFcn` property, then MATLAB executes a default creation function.

Setting the `CreateFcn` property on an existing component has no effect.

If you specify this property as a function handle or cell array, you can access the object that is being created using the first argument of the callback function. Otherwise, use the `gcbo` function to access the object.

### `DeleteFcn` — Deletion function

`''` (default) | function handle | cell array | character vector

Object deletion function, specified as one of these values:

- Function handle.
- Cell array in which the first element is a function handle. Subsequent elements in the cell array are the arguments to pass to the callback function.
- Character vector containing a valid MATLAB expression (not recommended). MATLAB evaluates this expression in the base workspace.

For more information about specifying a callback as a function handle, cell array, or character vector, see “Write Callbacks in App Designer” (MATLAB).

This property specifies a callback function to execute when MATLAB deletes the object. MATLAB executes the `DeleteFcn` callback before destroying the properties of the object. If you do not specify the `DeleteFcn` property, then MATLAB executes a default deletion function.

If you specify this property as a function handle or cell array, you can access the object that is being deleted using the first argument of the callback function. Otherwise, use the `gcbo` function to access the object.

**Callback Execution Control**

### `Interruptible` — Callback interruption

`'on'` (default) | `'off'`

Callback interruption, specified as `'on'` or `'off'`. The `Interruptible` property determines if a running callback can be interrupted.

There are two callback states to consider:

- The running callback is the currently executing callback.
- The interrupting callback is a callback that tries to interrupt the running callback.

Whenever MATLAB invokes a callback, that callback attempts to interrupt the running callback (if one exists). The `Interruptible` property of the object owning the running callback determines if interruption is allowed. The `Interruptible` property has two possible values:

- `'on'` — Allows other callbacks to interrupt the object's callbacks. The interruption occurs at the next point where MATLAB processes the queue, such as when there is a `drawnow`, `figure`, `uifigure`, `getframe`, `waitfor`, or `pause` command.
    - If the running callback contains one of those commands, then MATLAB stops the execution of the callback at that point and executes the interrupting callback.

MATLAB resumes executing the running callback when the interrupting callback completes.

- If the running callback does not contain one of those commands, then MATLAB finishes executing the callback without interruption.

- `'off'` — Blocks all interruption attempts. The `BusyAction` property of the object owning the interrupting callback determines if the interrupting callback is discarded or put into a queue.

---

**Note** Callback interruption and execution behave differently in these situations:

- If the interrupting callback is a `DeleteFcn`, `CloseRequestFcn` or `SizeChangedFcn` callback, then the interruption occurs regardless of the `Interruptible` property value.
- If the running callback is currently executing the `waitfor` function, then the interruption occurs regardless of the `Interruptible` property value.
- `Timer` objects execute according to schedule regardless of the `Interruptible` property value.

When an interruption occurs, MATLAB does not save the state of properties or the display. For example, the object returned by the `gca` or `gcf` command might change when another callback executes.

---

**`BusyAction` — Callback queuing**
`'queue'` (default) | `'cancel'`

Callback queuing, specified as `'queue'` or `'cancel'`. The `BusyAction` property determines how MATLAB handles the execution of interrupting callbacks. There are two callback states to consider:

- The running callback is the currently executing callback.
- The interrupting callback is a callback that tries to interrupt the running callback.

Whenever MATLAB invokes a callback, that callback attempts to interrupt a running callback. The `Interruptible` property of the object owning the running callback determines if interruption is permitted. If interruption is not permitted, then the `BusyAction` property of the object owning the interrupting callback determines if it is discarded or put in the queue. These are possible values of the `BusyAction` property:

- `'queue'` — Puts the interrupting callback in a queue to be processed after the running callback finishes execution.
- `'cancel'` — Does not execute the interrupting callback.

### `BeingDeleted` — Deletion status

`'off'` | `'on'`

This property is read-only.

Deletion status, returned as `'off'` or `'on'`. MATLAB sets the `BeingDeleted` property to `'on'` when the `DeleteFcn` callback begins execution. The `BeingDeleted` property remains set to `'on'` until the component object no longer exists.

Check the value of the `BeingDeleted` property to verify that the object is not about to be deleted before querying or modifying it.

#### Parent/Child

### `HandleVisibility` — Visibility of object handle

`'on'` (default) | `'callback'` | `'off'`

Visibility of the object handle, specified as `'on'`, `'callback'`, or `'off'`.

This property controls the visibility of the object in its parent's list of children. When an object is not visible in its parent's list of children, it is not returned by functions that obtain objects by searching the object hierarchy or querying properties. These functions include `get`, `findobj`, `clf`, and `close`. Objects are valid even if they are not visible. If you can access an object, you can set and get its properties, and pass it to any function that operates on objects.

| HandleVisibility Value | Description |
|---|---|
| `'on'` | The object is always visible. |
| `'callback'` | The object is visible from within callbacks or functions invoked by callbacks, but not from within functions invoked from the command line. This option blocks access to the object at the command-line, but allows callback functions to access it. |

| HandleVisibility Value | Description |
|---|---|
| `'off'` | The object is invisible at all times. This option is useful for preventing unintended changes to the UI by another function. Set the `HandleVisibility` to `'off'` to temporarily hide the object during the execution of that function. |

### `Parent` — Parent container

`Figure` object (default) | `Panel` object | `Tab` object | `ButtonGroup` object | `GridLayout` object

Parent container, specified as a `Figure` created using the `uifigure` function, or one of its child containers: `Tab`, `Panel`, `ButtonGroup`, or `GridLayout`.

#### Identifiers

### Type — Type of graphics object

`'uiaeroaltimeter'`

This property is read-only.

Type of graphics object, returned as `'uiaeroaltimeter'`.

### `Tag` — Object identifier

`''` (default) | character vector | string scalar

Object identifier, specified as a character vector or string scalar. You can specify a unique `Tag` value to serve as an identifier for an object. When you need access to the object elsewhere in your code, you can use the `findobj` function to search for the object based on the `Tag` value.

### `UserData` — User data

`[]` (default) | array

User data, specified as any MATLAB array. For example, you can specify a scalar, vector, matrix, cell array, character array, table, or structure. Use this property to store arbitrary data on an object.

If you are working in App Designer, create public or private properties in the app to share data instead of using the `UserData` property. For more information, see “Share Data Within App Designer Apps” (MATLAB).

## See Also

`uiaeroaltimeter`

## Topics

“Create and Configure Flight Instrument Component and an Animation Object” on page 2-69
“Display Flight Trajectory Data Using Flight Instruments and Flight Animation” on page 2-65

**Introduced in R2018b**

# angle2dcm

Convert rotation angles to direction cosine matrix

## 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`**

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 | quat2angle | quat2dcm

**Introduced in R2006b**

# angle2quat

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`**

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

**Introduced in R2007b**

# angle2rod

Convert rotation angles to Euler-Rodrigues vector

## Syntax

```
rod=angle2rod(R1,R2,R3)
rod=angle2rod(R1,R2,R3,S)
```

## Description

`rod=angle2rod(R1,R2,R3)` function converts the rotation described by the three rotation angles, `R1`, `R2`, and `R3`, into an *M*-by-3 Euler-Rodrigues matrix, `rod`.

`rod=angle2rod(R1,R2,R3,S)` function converts the rotation described by the three rotation angles and a rotation sequence, S, into an *M*-by-3 Euler-Rodrigues array, `rod`, that contains the *M* Rodrigues vector.

## Examples

### Determine the Rodrigues Vector from One Rotation Angle

Determine the Rodrigues vector from rotation angles.

```
yaw = 0.7854;
pitch = 0.1;
roll = 0;
r = angle2rod(yaw,pitch,roll)

r =

   -0.0207    0.0500    0.4142
```

### Determine Rodrigues Vectors from Multiple Rotation Angles

Determine the Rodrigues vectors from multiple rotation angles.

```
yaw = [0.7854 0.5];
pitch = [0.1 0.3];
roll = [0 0.1];
r = angle2rod(pitch,roll,yaw,'YXZ')
```

```
r =

    0.0207    0.0500    0.4142
    0.0885    0.1381    0.2473
```

## Input Arguments

### R1 — First rotation angle

*M*-by-1 array

First rotation angle, in radians, from which to determine Euler-Rodrigues vector. Values must be real.

Data Types: `double` | `single`

### R2 — Second rotation angle

*M*-by-1 array

Second rotation angle, in radians, from which to determine Euler-Rodrigues vector. Values must be real.

Data Types: `double` | `single`

### R3 — Third rotation angle

*M*-by-1 array

Third rotation angle, in radians, from which to determine Euler-Rodrigues vector. Values must be real.

Data Types: `double` | `single`

### S — Rotation sequence

ZYX (default) | ZYZ | ZXY | ZXZ | YXZ | YXY | YZX | YZY | XYZ | XYX | XZY | XZX

Rotation sequence. For the default rotation sequence, ZYX, the rotation angle order is:

- R1 — *z*-axis rotation
- R2 — *y*-axis rotation
- R3 — *x*-axis rotation

Data Types: `char` | `string`

# Output Arguments

**`rod` — Euler-Rodrigues vector**
3-element vector

Euler-Rodrigues vector determined from rotation angles.

# Algorithms

An Euler-Rodrigues vector $\vec{b}$ represents a rotation by integrating a direction cosine of a rotation axis with the tangent of half the rotation angle as follows:

$$\vec{b} = \begin{bmatrix} b_x & b_y & b_z \end{bmatrix}$$

where:

$$b_x = \tan\left(\frac{1}{2}\theta\right)s_x,$$
$$b_y = \tan\left(\frac{1}{2}\theta\right)s_y,$$
$$b_z = \tan\left(\frac{1}{2}\theta\right)s_z$$

are the Rodrigues parameters. Vector $\vec{s}$ represents a unit vector around which the rotation is performed. Due to the tangent, the rotation vector is indeterminate when the rotation angle equals ±pi radians or ±180 deg. Values can be negative or positive.

## References

[1] Dai, J.S. "Euler-Rodrigues formula variations, quaternion conjugation and intrinsic connections." *Mechanism and Machine Theory*, 92, 144-152. Elsevier, 2015.

# See Also

`dcm2rod` | `quat2rod` | `rod2angle` | `rod2dcm` | `rod2quat`

**Introduced in R2017a**

# ArtificialHorizon Properties

Control artificial horizon appearance and behavior

## Description

Artificial horizons are components that represent an artificial horizon. Properties control the appearance and behavior of an artificial horizon. Use dot notation to refer to a particular object and property:

```
figure = uifigure;
artificialhorizon = uiaerohorizon(figure);
artificialhorizon.Value = [100 20];
```

## Properties

**Artificial Horizon**

### `Pitch` — Pitch

`0` (default) | finite, real, and scalar numeric

Pitch value, specified as any finite and scalar numeric. The pitch value determines the movement of the aircraft around the transverse axis, in degrees.

Example: 10

**Dependencies**

Specifying this value changes the second element of the `Value` vector. Conversely, changing the second element of the `Value` vector changes the `Pitch` value.

Data Types: `double`

### `Roll` — Roll

`0` (default) | finite, real, and scalar numeric

Roll value, specified as any finite and scalar numeric. The roll value determines the rotation of the aircraft around the longitudinal axis, in degrees.

Example: 10

**Dependencies**

Specifying this value changes the first element of the `Value` vector. Conversely, changing the first element of the `Value` vector changes the `Roll` value.

Data Types: `double`

### `Value` — Roll and pitch

`[0 0]` (default) | two-element vector of finite, real, and scalar numerics

Roll and pitch values, specified as a vector ([`Roll` `Pitch`]).

- The roll value determines the rotation of the aircraft around the longitudinal axis.
- The pitch value determines the movement of the aircraft around the transverse axis.

Example: [100 -200]

**Dependencies**

- Specifying the `Roll` value changes the first element of the `Value` vector. Conversely, changing the first element of the `Value` vector changes the `Roll` value.
- Specifying the `Pitch` value changes the second element of the `Value` vector. Conversely, changing the second element of the `Value` vector changes the `Pitch` value.

Data Types: `double`

**Interactivity**

### `Visible` — Visibility of artificial horizon

`'on'` (default) | `'off'`

Visibility of the artificial horizon, specified as `'on'` or `'off'`. The `Visible` property determines whether the artificial horizon, is displayed on the screen. If the `Visible` property is set to `'off'`, then the entire artificial horizon is hidden, but you can still specify and access its properties.

### `Enable` — Operational state of artificial horizon

`'on'` (default) | `'off'`

Operational state of artificial horizon, specified as `'on'` or `'off'`.

- If you set this property to `'on'`, then the appearance of the artificial horizon indicates that the artificial horizon is operational.

- If you set this property to `'off'`, then the appearance of the artificial horizon appears dimmed, indicating that the artificial horizon is not operational.

**Position**

### `Position` — Location and size of artificial horizon

`[100 100 120 120]` (default) | `[left bottom width height]`

Location and size of the artificial horizon relative to the parent container, specified as the vector, `[left bottom width height]`. This table describes each element in the vector.

| Element | Description |
|---|---|
| `left` | Distance from the inner left edge of the parent container to the outer left edge of an imaginary box surrounding the artificial horizon |
| `bottom` | Distance from the inner bottom edge of the parent container to the outer bottom edge of an imaginary box surrounding the artificial horizon |
| `width` | Distance between the right and left outer edges of the artificial horizon |
| `height` | Distance between the top and bottom outer edges of the artificial horizon |

All measurements are in pixel units.

The `Position` values are relative to the drawable area of the parent container. The drawable area is the area inside the borders of the container and does not include the area occupied by decorations such as a menu bar or title.

Example: `[200 120 120 120]`

### `InnerPosition` — Inner location and size of artificial horizon

`[100 100 120 120]` (default) | `[left bottom width height]`

Inner location and size of the artificial horizon, specified as `[left bottom width height]`. Position values are relative to the parent container. All measurements are in pixel units. This property value is identical to the `Position` property.

### `OuterPosition` — Outer location and size of artificial horizon

`[100 100 120 120]]` (default) | `[left bottom width height]`

This property is read-only.

Outer location and size of the artificial horizon returned as `[left bottom width height]`. Position values are relative to the parent container. All measurements are in pixel units. This property value is identical to the `Position` property.

### `Layout` — Layout options

empty `LayoutOptions` array (default) | `GridLayoutOptions` object

Layout options, specified as a `GridLayoutOptions` object. This property specifies options for components that are children of grid layout containers. If the component is not a child of a grid layout container (for example, it is a child of a figure or panel), then this property is empty and has no effect. However, if the component is a child of a grid layout container, you can place the component in the desired row and column of the grid by setting the `Row` and `Column` properties on the `GridLayoutOptions` object.

For example, this code places an artificial horizon in the third row and second column of its parent grid.

```
g = ui([4 3]);
gauge = uiaerohorizon(g);
gauge.Layout.Row = 3;
gauge.Layout.Column = 2;
```

To make the artificial horizon span multiple rows or columns, specify the `Row` or `Column` property as a two-element vector. For example, this artificial horizon spans columns `2` through `3`:

```
gauge.Layout.Column = [2 3];
```

#### Callbacks

### `CreateFcn` — Creation function

`''` (default) | function handle | cell array | character vector

Object creation function, specified as one of these values:

- Function handle.
- Cell array in which the first element is a function handle. Subsequent elements in the cell array are the arguments to pass to the callback function.
- Character vector containing a valid MATLAB expression (not recommended). MATLAB evaluates this expression in the base workspace.

For more information about specifying a callback as a function handle, cell array, or character vector, see “Write Callbacks in App Designer” (MATLAB).

This property specifies a callback function to execute when MATLAB creates the object. MATLAB initializes all property values before executing the `CreateFcn` callback. If you do not specify the `CreateFcn` property, then MATLAB executes a default creation function.

Setting the `CreateFcn` property on an existing component has no effect.

If you specify this property as a function handle or cell array, you can access the object that is being created using the first argument of the callback function. Otherwise, use the `gcbo` function to access the object.

### `DeleteFcn` — Deletion function

`''` (default) | function handle | cell array | character vector

Object deletion function, specified as one of these values:

- Function handle.
- Cell array in which the first element is a function handle. Subsequent elements in the cell array are the arguments to pass to the callback function.
- Character vector containing a valid MATLAB expression (not recommended). MATLAB evaluates this expression in the base workspace.

For more information about specifying a callback as a function handle, cell array, or character vector, see “Write Callbacks in App Designer” (MATLAB).

This property specifies a callback function to execute when MATLAB deletes the object. MATLAB executes the `DeleteFcn` callback before destroying the properties of the object. If you do not specify the `DeleteFcn` property, then MATLAB executes a default deletion function.

If you specify this property as a function handle or cell array, you can access the object that is being deleted using the first argument of the callback function. Otherwise, use the `gcbo` function to access the object.

#### Callback Execution Control

### `BusyAction` — Callback queuing

`'queue'` (default) | `'cancel'`

Callback queuing, specified as `'queue'` or `'cancel'`. The `BusyAction` property determines how MATLAB handles the execution of interrupting callbacks. There are two callback states to consider:

- The running callback is the currently executing callback.
- The interrupting callback is a callback that tries to interrupt the running callback.

Whenever MATLAB invokes a callback, that callback attempts to interrupt a running callback. The `Interruptible` property of the object owning the running callback determines if interruption is permitted. If interruption is not permitted, then the `BusyAction` property of the object owning the interrupting callback determines if it is discarded or put in the queue. These are possible values of the `BusyAction` property:

- `'queue'` — Puts the interrupting callback in a queue to be processed after the running callback finishes execution.
- `'cancel'` — Does not execute the interrupting callback.

**`BeingDeleted` — Deletion status**
`'off'` | `'on'`

This property is read-only.

Deletion status, returned as `'off'` or `'on'`. MATLAB sets the `BeingDeleted` property to `'on'` when the `DeleteFcn` callback begins execution. The `BeingDeleted` property remains set to `'on'` until the component object no longer exists.

Check the value of the `BeingDeleted` property to verify that the object is not about to be deleted before querying or modifying it.

**`Interruptible` — Callback interruption**
`'on'` (default) | `'off'`

Callback interruption, specified as `'on'` or `'off'`. The `Interruptible` property determines if a running callback can be interrupted.

There are two callback states to consider:

- The running callback is the currently executing callback.
- The interrupting callback is a callback that tries to interrupt the running callback.

Whenever MATLAB invokes a callback, that callback attempts to interrupt the running callback (if one exists). The `Interruptible` property of the object owning the running

callback determines if interruption is allowed. The `Interruptible` property has two possible values:

- `'on'` — Allows other callbacks to interrupt the object's callbacks. The interruption occurs at the next point where MATLAB processes the queue, such as when there is a `drawnow`, `figure`, `uifigure`, `getframe`, `waitfor`, or `pause` command.
  - If the running callback contains one of those commands, then MATLAB stops the execution of the callback at that point and executes the interrupting callback. MATLAB resumes executing the running callback when the interrupting callback completes.
  - If the running callback does not contain one of those commands, then MATLAB finishes executing the callback without interruption.
- `'off'` — Blocks all interruption attempts. The `BusyAction` property of the object owning the interrupting callback determines if the interrupting callback is discarded or put into a queue.

---

**Note** Callback interruption and execution behave differently in these situations:

- If the interrupting callback is a `DeleteFcn`, `CloseRequestFcn` or `SizeChangedFcn` callback, then the interruption occurs regardless of the `Interruptible` property value.
- If the running callback is currently executing the `waitfor` function, then the interruption occurs regardless of the `Interruptible` property value.
- `Timer` objects execute according to schedule regardless of the `Interruptible` property value.

When an interruption occurs, MATLAB does not save the state of properties or the display. For example, the object returned by the `gca` or `gcf` command might change when another callback executes.

---

#### Parent/Child

### `HandleVisibility` — Visibility of object handle

`'on'` (default) | `'callback'` | `'off'`

Visibility of the object handle, specified as `'on'`, `'callback'`, or `'off'`.

This property controls the visibility of the object in its parent's list of children. When an object is not visible in its parent's list of children, it is not returned by functions that

obtain objects by searching the object hierarchy or querying properties. These functions include `get`, `findobj`, `clf`, and `close`. Objects are valid even if they are not visible. If you can access an object, you can set and get its properties, and pass it to any function that operates on objects.

| HandleVisibility Value | Description |
|---|---|
| `'on'` | The object is always visible. |
| `'callback'` | The object is visible from within callbacks or functions invoked by callbacks, but not from within functions invoked from the command line. This option blocks access to the object at the command-line, but allows callback functions to access it. |
| `'off'` | The object is invisible at all times. This option is useful for preventing unintended changes to the UI by another function. Set the `HandleVisibility` to `'off'` to temporarily hide the object during the execution of that function. |

### `Parent` — Parent container

`Figure` object (default) | `Panel` object | `Tab` object | `ButtonGroup` object | `GridLayout` object

Parent container, specified as a `Figure` created using the `uifigure` function, or one of its child containers: `Tab`, `Panel`, `ButtonGroup`, or `GridLayout`.

#### Identifiers

### Type — Type of graphics object

`'uiaerohorizon'`

This property is read-only.

Type of graphics object, returned as `'uiaerohorizon'`.

### Tag — Object identifier

`''` (default) | character vector | string scalar

Object identifier, specified as a character vector or string scalar. You can specify a unique `Tag` value to serve as an identifier for an object. When you need access to the object elsewhere in your code, you can use the `findobj` function to search for the object based on the `Tag` value.

### `UserData` — User data

[ ] (default) | array

User data, specified as any MATLAB array. For example, you can specify a scalar, vector, matrix, cell array, character array, table, or structure. Use this property to store arbitrary data on an object.

If you are working in App Designer, create public or private properties in the app to share data instead of using the `UserData` property. For more information, see “Share Data Within App Designer Apps” (MATLAB).

## See Also

`uiaerohorizon`

## Topics

“Create and Configure Flight Instrument Component and an Animation Object” on page 2-69
“Display Flight Trajectory Data Using Flight Instruments and Flight Animation” on page 2-65

**Introduced in R2018b**

# atmoscoesa

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`**

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`

**Introduced in R2006b**

# atmoscira

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`

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`

Mean value type:

| | |
|---|---|
| `'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`**

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:<br>• Annual mean temperature in kelvin<br>• Annual temperature cycle amplitude in kelvin<br>• Annual temperature cycle phase in month of maximum<br>• Semiannual temperature cycle amplitude in kelvin<br>• Semiannual temperature cycle phase in month of maximum<br>• Terannual temperature cycle amplitude in kelvin<br>• 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:<br>• Annual mean zonal winds in meters per second<br>• Annual zonal winds cycle amplitude in meters per second<br>• Annual zonal winds cycle phase in month of maximum<br>• Semiannual zonal winds cycle amplitude in meters per second<br>• Semiannual zonal winds cycle phase in month of maximum<br>• Terannual zonal winds cycle amplitude in meters per second<br>• 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

`https://ccmc.gsfc.nasa.gov/modelweb/atmos/cospar1.html`

## See Also

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

**Introduced in R2007b**

# atmoshwm

Implement horizontal wind model

## Syntax

```
wind = atmoshwm(latitude,longitude,altitude)
```

```
wind = atmoshwm(latitude,longitude,altitude,Name,Value)
```

## Description

`wind = atmoshwm(latitude,longitude,altitude)` implements the U.S. Naval Research Laboratory Horizontal Wind Model (HWM™) routine to calculate the meridional and zonal components of the wind for one or more sets of geophysical data: `latitude`, `longitude`, and `altitude`.

`wind = atmoshwm(latitude,longitude,altitude,Name,Value)` uses additional options specified by one or more `Name,Value` pair arguments.

## Examples

### Calculate the Total Horizontal Wind Model

dCalculate the total horizontal wind model for a latitude of 45 degrees south, longitude of 85 degrees west, and altitude of 25,000 m above mean sea level (msl). The date is the 150th day of the year, at 11 am UTC, using an Ap index of 80. The horizontal model version is 14.

```
w = atmoshwm(-45,-85,25000,'day',150,'seconds',39600,'apindex',80,'model','total', 'version', '14')
```

```
w =

     3.2874   25.8735
```

### Calculate the Quiet Horizontal Wind Model

Calculate the quiet horizontal wind model for a latitude of 50 degrees north, two altitudes of 100,000 m and 150,000 m above msl, and a longitude of 20 degrees west. The date is midnight UTC of January 30. The default horizontal model version is 14.

```
w = atmoshwm([50;50],[-20;-20],[100000;150000],'day',[30;30])
```

```
w =

  -42.9350  -40.3693
   29.1106    0.6253
```

### Calculate a Disturbed Horizontal Wind Model

Calculate the disturbed horizontal wind model for an altitude of 150,000 m above msl at latitude 70 degrees north, longitude 65 degrees west. The date is midnight UTC of June 15. The default horizontal model version is 14.

```
dw = atmoshwm(70,-65,150000,'day',166,'model','disturbance')
```

```
dw =
    1.7954   -1.7130
```

## Input Arguments

### `latitude` — Geodetic latitude

scalar | *M*-by-1 array

Geodetic latitudes, in degrees, specified as a scalar or *M*-by-1 array, where *M* is one or more sets of geophysical data.

Example: -45

Data Types: `double`

### `longitude` — Geodetic longitude

scalar | *M*-by-1 array

Geodetic longitudes, in degrees, specified as a scalar or *M*-by-1 array, where *M* is one or more sets of geophysical data.

Example: -85

Data Types: `double`

**`altitude` — Geopotential height**
scalar | *M*-by-1 array

Geopotential heights, in meters, within the range of 0 to 500 km, specified as a scalar or *M*-by-1 array. *M* is one or more sets of geophysical data.

Example: 25000

Data Types: `double`

## Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name,Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside quotes. You can specify several name and value pair arguments in any order as `Name1,Value1,...,NameN,ValueN`.

Example: `'apindex',80,'model','total'` specifies that the total horizontal wind model be calculated for an Ap index of 80.

**`apindex` — Ap index**
*M*-by-1 array of zeroes (default) | scalar | *M*-by-1 array

Ap index for the Universal Coordinated Time (UTC) at which `atmoshwm` evaluates the model, specified as an *M*-by-1 array of zeroes, a scalar, or an *M*-by-1 array. *M* is one or more sets of geophysical data. Select the index from the NOAA National Geophysical Data Center, which contains three-hour interval geomagnetic disturbance index values. If the Ap index value is greater than zero, the model evaluation accounts for magnetic effects.

Specify the Ap index as a value from 0 through 400. Specify an Ap index value for only the disturbance or total wind model type.

Data Types: `double`

**`day` — Day of year**
*M*-by-1 array of ones (default) | scalar | *M*-by-1 array

Day of year in UTC. Specify the day as a value from 1 through 366 (for a leap year), specified as an *M*-by-1 array of zeroes, a scalar, or an *M*-by-1 array. *M* is one or more sets of geophysical data.

Data Types: `double`

### `seconds` — Elapsed seconds

*M*-by-1 array of zeroes (default) | scalar | *M*-by-1 array

Elapsed seconds since midnight for the selected day, in UTC, specified as specified as an *M*-by-1 array of zeroes, a scalar, or an *M*-by-1 array. *M* is one or more sets of geophysical data.

Specify the seconds as a value from 0 through 86,400.

Data Types: `double`

### `model` — Horizontal wind model type

`'quiet'` (default) | `'disturbance'` | `'total'`

Horizontal wind model type for which to calculate the wind components. This setting applies to all the sets of geophysical data in *M*.

- `'quiet'`

  Calculates the horizontal wind model without the magnetic disturbances. Quiet model types do not account for Ap index values. For this model type, do not specify an Ap index value when using this model type.

- `'disturbance'`

  Calculates the effect of only magnetic disturbances in the wind. For this model type, specify Ap index values greater than or equal to zero.

- `'total'`

  Calculates the combined effect of the quiet and magnetic disturbances. for this model type, specify Ap index values greater than or equal to zero.

Data Types: `double`

### `action` — Function behavior

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

Function behavior when inputs are out of range, specified as one of these values. This type applies to all the sets of geophysical data in *M*.

| Value | Description |
|---|---|
| `'None'` | No action. |

| Value | Description |
|---|---|
| `'Warning'` | Warning in the MATLAB Command Window, model simulation continues. |
| `'Error'` | MATLAB returns an exception, model simulation stops. |

Data Types: `double`

**`version` — Horizontal wind model version**
`'14'` (default) | `'07'`

Implements specified horizontal wind model type.

- `'14'`

  Horizontal Wind Model 14.
- `'07'`

  Horizontal Wind Model 07.

Data Types: `double`

# Output Arguments

**`wind` — Meridional and zonal wind components**
*M*-by-2 array

Meridional and zonal wind components of the horizontal wind model, returned as an *M*-by-2 array, in m/s.

# See Also
`atmoscira` | `atmoscoesa` | `atmosnrlmsise00`

## External Websites
NOAA National Geophysical Data Center
An empirical model of the Earth's horizontal wind fields: HWM07
An update to the Horizontal Wind Model (HWM): The quiet time thermosphere

**Introduced in R2016b**

# atmosisa

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 (at 20 km), temperature and pressure values are held constant.

## 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`

**Introduced in R2006b**

# atmoslapse

Use Lapse Rate Atmosphere model

## Syntax

```
[T, a, P, rho] = atmoslapse(height, g, heatRatio,
characteristicGasConstant, lapseRate, heightTroposphere,
heightTropopause, density0, pressure0, temperature0)
[T, a, P, rho] = atmoslapse(height, g, heatRatio,
characteristicGasConstant, lapseRate, heightTroposphere,
heightTropopause, density0, pressure0, temperature0, height0)
```

## 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. The function calculates the density and speed of sound using a perfect gas relationship.

`[T, a, P, rho] = atmoslapse(height, g, heatRatio, characteristicGasConstant, lapseRate, heightTroposphere, heightTropopause, density0, pressure0, temperature0, height0)` indicates that the values for ambient temperature, pressure, density, and speed of sound are for below mean sea level geopotential altitudes.

The function holds temperature and pressure values below the geopotential altitude of `height0` and above the geopotential altitude of the tropopause. The function calculates the density and speed of sound using a perfect gas relationship.

# 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.

**`height0`**

Scalar of minimum sea level altitude, in meters.

## 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`

**Introduced in R2006b**

# atmosnonstd

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`

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`

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**

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**

Action for out-of-range input:
'Error'
'Warning' (default)
'None'

**specification**

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`

**Introduced in R2006b**

# atmosnrlmsise00

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) of the MSIS® class model. 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 character vector or 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**

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/space-weather/solar-data/solar-features/solar-radio/noontime-flux/penticton/`

See the limitations in “Description” on page 4-119 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/space-weather/solar-data/solar-features/solar-radio/noontime-flux/penticton/`

See the limitations in “Description” on page 4-119 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) |
| `Flags(22)` | All lower mesosphere temperature (TN3) variations |
| `Flags(23)` | Turbopause scale height variations |

**`latitude`**

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

**`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 4-119 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 4-119 for more information.

**`otype`**

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 kg/m$^3$
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 =
   1.0e+03 *

    1.0273    0.2212

rho =

   1.0e+24 *
```

```
    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])

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

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

# See Also

atmoscira

### Introduced in R2007b

# atmospalt

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`**

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`

**Introduced in R2006b**

# Body (Aero.Body)

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`

**Introduced in R2007a**

# Camera (Aero.Camera)

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`

**Introduced in R2007a**

# ClearTimer (Aero.FlightGearAnimation)

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`

**Introduced in R2008b**

# ClimbIndicator Properties

Control climb indicator appearance and behavior

## Description

Climb indicators are components that represent a climb indicator. Properties control the appearance and behavior of a climb indicator. Use dot notation to refer to a particular object and property.

```
figure = uifigure;
climbindicator = uiaeroclimb(figure);
climbindicator.ClimbRate = 100;
```

## Properties

**Climb Indicator**

### `ClimbRate` — Climb rate of aircraft

`0` (default) | finite, real, and scalar numeric

Climb rate of the aircraft, specified as a finite, real, and scalar numeric, in ft/min.

Example: `60`

**Dependencies**

Specifying this value changes the value of `Value`.

Data Types: `double`

### `MaximumRate` — Maximum gauge scale values

`0` (default) | finite, real, positive, and scalar numeric

Maximum gauge scale values, specified as a finite, real, positive, and scalar numeric, representing the +/- maximum climb rate, in ft/min.

Example: `100`

Data Types: `double`

### `Value` — Climb rate of aircraft

`0` (default) | finite, real, and scalar numeric

Climb rate of the aircraft, specified as a finite, real, and scalar numeric, in ft/min.

Example: `60`

#### Dependencies

Specifying this value changes the value of `ClimbRate`.

Data Types: `double`

#### Interactivity

### `Visible` — Visibility of climb indicator

`'on'` (default) | `'off'`

Visibility of the climb indicator, specified as `'on'` or `'off'`. The `Visible` property determines whether the climb indicator is displayed on the screen. If the `Visible` property is set to `'off'`, then the entire climb indicator is hidden, but you can still specify and access its properties.

### `Enable` — Operational state of climb indicator

`'on'` (default) | `'off'`

Operational state of climb indicator, specified as `'on'` or `'off'`.

- If you set this property to `'on'`, then the appearance of the climb indicator indicates that the climb indicator is operational.
- If you set this property to `'off'`, then the appearance of the climb indicator appears dimmed, indicating that the climb indicator is not operational.

#### Position

### `Position` — Location and size of climb indicator

`[100 100 120 120]` (default) | `[left bottom width height]`

Location and size of the climb indicator relative to the parent container, specified as the vector, `[left bottom width height]`. This table describes each element in the vector.

| Element | Description |
|---|---|
| `left` | Distance from the inner left edge of the parent container to the outer left edge of an imaginary box surrounding the climb indicator |
| `bottom` | Distance from the inner bottom edge of the parent container to the outer bottom edge of an imaginary box surrounding the climb indicator |
| `width` | Distance between the right and left outer edges of the climb indicator |
| `height` | Distance between the top and bottom outer edges of the climb indicator |

All measurements are in pixel units.

The `Position` values are relative to the drawable area of the parent container. The drawable area is the area inside the borders of the container and does not include the area occupied by decorations such as a menu bar or title.

Example: `[200 120 120 120]`

**`InnerPosition` — Inner location and size of climb indicator**
`[100 100 120 120]` (default) | `[left bottom width height]`

Inner location and size of the climb indicator, specified as `[left bottom width height]`. Position values are relative to the parent container. All measurements are in pixel units. This property value is identical to the `Position` property.

**`OuterPosition` — Outer location and size of climb indicator**
`[100 100 120 120]]` (default) | `[left bottom width height]`

This property is read-only.

Outer location and size of the climb indicator returned as `[left bottom width height]`. Position values are relative to the parent container. All measurements are in pixel units. This property value is identical to the `Position` property.

**`Layout` — Layout options**
empty `LayoutOptions` array (default) | `GridLayoutOptions` object

Layout options, specified as a `GridLayoutOptions` object. This property specifies options for components that are children of grid layout containers. If the component is

not a child of a grid layout container (for example, it is a child of a figure or panel), then this property is empty and has no effect. However, if the component is a child of a grid layout container, you can place the component in the desired row and column of the grid by setting the `Row` and `Column` properties on the `GridLayoutOptions` object.

For example, this code places an climb rate indicator in the third row and second column of its parent grid.

```
g = ui([4 3]);
gauge = uiaeroclimb(g);
gauge.Layout.Row = 3;
gauge.Layout.Column = 2;
```

To make the climb rate indicator span multiple rows or columns, specify the `Row` or `Column` property as a two-element vector. For example, this climb rate indicator spans columns `2` through `3`:

```
gauge.Layout.Column = [2 3];
```

**Callbacks**

### `CreateFcn` — Creation function

`''` (default) | function handle | cell array | character vector

Object creation function, specified as one of these values:

- Function handle.
- Cell array in which the first element is a function handle. Subsequent elements in the cell array are the arguments to pass to the callback function.
- Character vector containing a valid MATLAB expression (not recommended). MATLAB evaluates this expression in the base workspace.

For more information about specifying a callback as a function handle, cell array, or character vector, see “Write Callbacks in App Designer” (MATLAB).

This property specifies a callback function to execute when MATLAB creates the object. MATLAB initializes all property values before executing the `CreateFcn` callback. If you do not specify the `CreateFcn` property, then MATLAB executes a default creation function.

Setting the `CreateFcn` property on an existing component has no effect.

If you specify this property as a function handle or cell array, you can access the object that is being created using the first argument of the callback function. Otherwise, use the `gcbo` function to access the object.

### `DeleteFcn` — Deletion function

`''` (default) | function handle | cell array | character vector

Object deletion function, specified as one of these values:

- Function handle.
- Cell array in which the first element is a function handle. Subsequent elements in the cell array are the arguments to pass to the callback function.
- Character vector containing a valid MATLAB expression (not recommended). MATLAB evaluates this expression in the base workspace.

For more information about specifying a callback as a function handle, cell array, or character vector, see “Write Callbacks in App Designer” (MATLAB).

This property specifies a callback function to execute when MATLAB deletes the object. MATLAB executes the `DeleteFcn` callback before destroying the properties of the object. If you do not specify the `DeleteFcn` property, then MATLAB executes a default deletion function.

If you specify this property as a function handle or cell array, you can access the object that is being deleted using the first argument of the callback function. Otherwise, use the `gcbo` function to access the object.

#### Callback Execution Control

### `Interruptible` — Callback interruption

`'on'` (default) | `'off'`

Callback interruption, specified as `'on'` or `'off'`. The `Interruptible` property determines if a running callback can be interrupted.

There are two callback states to consider:

- The running callback is the currently executing callback.
- The interrupting callback is a callback that tries to interrupt the running callback.

Whenever MATLAB invokes a callback, that callback attempts to interrupt the running callback (if one exists). The `Interruptible` property of the object owning the running

callback determines if interruption is allowed. The `Interruptible` property has two possible values:

- `'on'` — Allows other callbacks to interrupt the object's callbacks. The interruption occurs at the next point where MATLAB processes the queue, such as when there is a `drawnow`, `figure`, `uifigure`, `getframe`, `waitfor`, or `pause` command.
  - If the running callback contains one of those commands, then MATLAB stops the execution of the callback at that point and executes the interrupting callback. MATLAB resumes executing the running callback when the interrupting callback completes.
  - If the running callback does not contain one of those commands, then MATLAB finishes executing the callback without interruption.
- `'off'` — Blocks all interruption attempts. The `BusyAction` property of the object owning the interrupting callback determines if the interrupting callback is discarded or put into a queue.

---

**Note** Callback interruption and execution behave differently in these situations:

- If the interrupting callback is a `DeleteFcn`, `CloseRequestFcn` or `SizeChangedFcn` callback, then the interruption occurs regardless of the `Interruptible` property value.
- If the running callback is currently executing the `waitfor` function, then the interruption occurs regardless of the `Interruptible` property value.
- `Timer` objects execute according to schedule regardless of the `Interruptible` property value.

When an interruption occurs, MATLAB does not save the state of properties or the display. For example, the object returned by the `gca` or `gcf` command might change when another callback executes.

---

### `BusyAction` — Callback queuing

`'queue'` (default) | `'cancel'`

Callback queuing, specified as `'queue'` or `'cancel'`. The `BusyAction` property determines how MATLAB handles the execution of interrupting callbacks. There are two callback states to consider:

- The running callback is the currently executing callback.
- The interrupting callback is a callback that tries to interrupt the running callback.

Whenever MATLAB invokes a callback, that callback attempts to interrupt a running callback. The `Interruptible` property of the object owning the running callback determines if interruption is permitted. If interruption is not permitted, then the `BusyAction` property of the object owning the interrupting callback determines if it is discarded or put in the queue. These are possible values of the `BusyAction` property:

- `'queue'` — Puts the interrupting callback in a queue to be processed after the running callback finishes execution.
- `'cancel'` — Does not execute the interrupting callback.

**`BeingDeleted` — Deletion status**
`'off'` | `'on'`

This property is read-only.

Deletion status, returned as `'off'` or `'on'`. MATLAB sets the `BeingDeleted` property to `'on'` when the `DeleteFcn` callback begins execution. The `BeingDeleted` property remains set to `'on'` until the component object no longer exists.

Check the value of the `BeingDeleted` property to verify that the object is not about to be deleted before querying or modifying it.

**Parent/Child**

**`HandleVisibility` — Visibility of object handle**
`'on'` (default) | `'callback'` | `'off'`

Visibility of the object handle, specified as `'on'`, `'callback'`, or `'off'`.

This property controls the visibility of the object in its parent's list of children. When an object is not visible in its parent's list of children, it is not returned by functions that obtain objects by searching the object hierarchy or querying properties. These functions include `get`, `findobj`, `clf`, and `close`. Objects are valid even if they are not visible. If you can access an object, you can set and get its properties, and pass it to any function that operates on objects.

| HandleVisibility Value | Description |
|---|---|
| `'on'` | The object is always visible. |
| `'callback'` | The object is visible from within callbacks or functions invoked by callbacks, but not from within functions invoked from the command line. This option blocks access to the object at the command-line, but allows callback functions to access it. |
| `'off'` | The object is invisible at all times. This option is useful for preventing unintended changes to the UI by another function. Set the `HandleVisibility` to `'off'` to temporarily hide the object during the execution of that function. |

### `Parent` — Parent container

`Figure` object (default) | `Panel` object | `Tab` object | `ButtonGroup` object | `GridLayout` object

Parent container, specified as a `Figure` created using the `uifigure` function, or one of its child containers: `Tab`, `Panel`, `ButtonGroup`, or `GridLayout`.

#### Identifiers

### Type — Type of graphics object

`'uiaeroclimb'`

This property is read-only.

Type of graphics object, returned as `'uiaerohorizon'`.

### Tag — Object identifier

`''` (default) | character vector | string scalar

Object identifier, specified as a character vector or string scalar. You can specify a unique `Tag` value to serve as an identifier for an object. When you need access to the object elsewhere in your code, you can use the `findobj` function to search for the object based on the `Tag` value.

### `UserData` — User data

`[]` (default) | array

User data, specified as any MATLAB array. For example, you can specify a scalar, vector, matrix, cell array, character array, table, or structure. Use this property to store arbitrary data on an object.

If you are working in App Designer, create public or private properties in the app to share data instead of using the `UserData` property. For more information, see “Share Data Within App Designer Apps” (MATLAB).

## See Also

`uiaeroclimb`

### Topics

“Create and Configure Flight Instrument Component and an Animation Object” on page 2-69
“Display Flight Trajectory Data Using Flight Instruments and Flight Animation” on page 2-65

**Introduced in R2018b**

# convacc

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. Supported units 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. Supported units 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`

**Introduced in R2006b**

# convang

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 character vectors or 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. Supported units are:

| | |
|---|---|
| `'deg'` | Degrees |
| `'rad'` | Radians |
| `'rev'` | Revolutions |

**`outputAngleUnits`**

Specified output angle units. Supported units 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`

**Introduced in R2006b**

# convangacc

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. Supported units 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. Supported units 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`

**Introduced in R2006b**

# convangvel

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. Supported units are:

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

**`outputAngularVelocityUnits`**

Specified output angular velocity units. Supported units 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`

**Introduced in R2006b**

# convdensity

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. Supported units 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. Supported units 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`

**Introduced in R2006b**

# convforce

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. Supported units are:

| | |
|---|---|
| 'lbf' | Pound force |
| 'N' | Newton |

**outputForceUnits**

Specified output force units. Supported units 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`

**Introduced in R2006b**

# convlength

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. Supported units are:

| | |
|---|---|
| `'ft'` | Feet |
| `'m'` | Meters |
| `'km'` | Kilometers |
| `'in'` | Inches |
| `'mi'` | Miles |

| | |
|---|---|
| `'naut mi'` | Nautical miles |

**`outputLengthUnits`**

Specified output length units. Supported units 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`

**Introduced in R2006b**

# convmass

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. Supported units are:

| | |
|---|---|
| `'lbm'` | Pound mass |
| `'kg'` | Kilograms |
| `'slug'` | Slugs |

### outputMassUnits

Specified output mass units. Supported units are:

| | |
|---|---|
| `'lbm'` | Pound mass |
| `'kg'` | Kilograms |
| `'slug'` | 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`

**Introduced in R2006b**

# convpres

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. Supported units are:

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

**outputPressureUnits**

Specified output pressure units. Supported units 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`

**Introduced in R2006b**

# convtemp

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`. For more information on floating point numbers, see “Floating-Point Numbers” (MATLAB).

**`inputTemperatureUnits`**

Specified input temperature units. Supported units are:

| | |
|---|---|
| `'K'` | Kelvin |
| `'F'` | Degrees Fahrenheit |
| `'C'` | Degrees Celsius |
| `'R'` | Degrees Rankine |

**`outputTemperatureUnits`**

Specified output temperature units. Supported units 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`

**Introduced in R2006b**

# convvel

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. Supported units 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. Supported units 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`

**Introduced in R2006b**

# correctairspeed

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

## Syntax

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

## 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.

`outputAirpseed = correctairspeed(inputAirspeed, speedOfSound, pressure0, inputAirspeedType, outputAirspeedType, method)` uses the specified method to compute the conversion factor.

## 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, specified as a string. Supported airspeeds are:

| | |
|---|---|
| `'TAS'` | True airspeed |
| `'CAS'` | Calibrated airspeed |
| `'EAS'` | Equivalent airspeed |

**outputAirspeedType**

Output airspeed, specified as a string. Supported airspeeds are:

| | |
|---|---|
| `'TAS'` | True airspeed |
| `'CAS'` | Calibrated airspeed |
| `'EAS'` | Equivalent airspeed |

**method**

Specify a method, as a string, for computing the conversion factor.

| | |
|---|---|
| `'TableLookup'` | (Default) Generate output airspeed by looking up or estimating table values based on inputs *`inputAirspeed`*, *`speedOfSound`*, and *`pressure0`*.<br><br>The `'TableLookup'` method is not recommended for either of these instances:<br><br>• *`speedOfSound`* less than 200 m/s or greater than 350 m/s.<br>• *`pressure0`* less than 1000 Pa or greater than 106,500 Pa.<br><br>Using the `'TableLookup'` method in these instances causes inaccuracies. |

| | |
|---|---|
| `'Equation'` | Compute output airspeed directly using input values *`inputAirspeed`*, *`speedOfSound`*, and *`pressure0`*.<br><br>Calculations involving supersonic airspeeds (greater than Mach 1) require an iterative computation. If the function does not conclude within 30 iterations, it displays an error message. |

The `correctairspeed` function automatically uses the `'Equation'` method for any of these instances:

- Conversion with *`inputAirspeedType`* set to `'TAS'` and *`outputAirspeedType`* set to `'EAS'`.
- Conversion with *`inputAirspeedType`* set to `'EAS'` and *`outputAirspeedType`* set to `'TAS'`.
- Conversion with *`inputAirspeed`* is greater than five times the speed of sound at sea level (approximately 1700 m/s).

# Output Arguments

**`outputAirpseed`**

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

# Examples

Convert three airspeeds from true airspeed (`'TAS'`) to equivalent airspeed (`'EAS'`) at 1,000 ms using the `'TableLookup'` method:

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

   24.5077
    9.8024
    2.9407
```

Convert airspeeds from calibrated airspeed (`'CAS'`) to equivalent airspeed (`'EAS'`) at 1,000 m and 0 m using the `'Equation'` method:

```
ain = [25.7222; 10.2889; 3.0867];
sos = [336.4; 340.3; 340.3];
```

```
P0 = [ 89874.6; 101325; 101325];
as = correctairspeed(ain,sos,P0,'CAS','EAS','Equation')
as =

   25.7199
   10.2889
    3.0867
```

Convert airspeed from true airspeed (`'TAS'`) to equivalent airspeed (`'EAS'`) at 15,000 meters. Use the `atmoscoesa` function to first calculate the speed of sound (*`sos`*) and static air pressure (*`P0`*):

```
ain = 376.25;
[~, sos, P0, ~] = atmoscoesa(15000);
as = correctairspeed( ain, sos, P0, 'EAS', 'TAS')
as =

  149.6042
```

# Limitations

This function assumes that air flow is compressible dry air with constant specific heat ratio (gamma).

# References

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

*Aeronautical Vestpocket Handbook*, United Technologies Pratt & Whitney, August1986

Gracey, William, *Measurement of Aircraft Speed and Altitude*, NASA Reference Publication 1046, 1980.

# See Also

`airspeed` | `atmoscoesa` | `atmosisa` | `atmoslapse` | `atmosnonstd`

**Introduced in R2006b**

# createBody

**Class:** Aero.Animation
**Package:** Aero

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

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 character vector or string (or a cell array of file names as character vectors or 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 listed in this table:

| `filetype` Value | Output File from DATCOM |
|---|---|
| `6` | (Default) `for006.dat` output by all DATCOM versions |

| filetype Value | Output File from DATCOM |
|---|---|
| 21 | for021.dat output by DATCOM 2007, DATCOM 2008, DATCOM 2011, and DATCOM 2014 |
| 42 | for042.csv output by DATCOM 2008, DATCOM 2011, and DATCOM 2014 |

When filetype is 6, the function reads the for006.dat file output by DATCOM.

**Note** If filetype is 21, the function collates the breakpoints and data from all the cases and appends them as the last entry of aero.

When filetype is 21, the function reads the for021.dat file output by DATCOM 2007.

When file type is 42, the function reads the for042.csv file output by DATCOM 2008, DATCOM 2011, and DATCOM 2014.

Fields for the 1976, 1999, 2007, 2008, 2011, and 2014 versions of the type 6 output files:

- “Fields for 1976 Version (File Type 6)” on page 4-174
- “Fields for 1999 Version (File Type 6)” on page 4-192
- “Fields for 2007, 2008, 2011, and 2014 Versions (File Type 6)” on page 4-196

Fields for 2007, 2008, 2011, and 2014 versions of the type 21 output file:

- “Fields for 2007, 2008, 2011, and 2014 Versions (File Type 21)” on page 4-200

Fields for 2008, 2011, and 2014 versions of the type 42 output file are described in:

- “Fields for 2008, 2011, and 2014 Version (File Type 42)” on page 4-206

## 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` | Character vector 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. | `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. | `[]` |
| `dim` | Character vector denoting the specified system of units for the case. | `'ft'` |
| `deriv` | Character vector denoting the specified angle units for the case. | `'deg'` |

| Field | Description | Default |
|---|---|---|
| `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` |
| `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` |

| Field | Description | Default |
|---|---|---|
| `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` |
| `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. | `[]` |

| Field | Description | Default |
|---|---|---|
| `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. | `[]` |
| `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.<br>`config.downwash = false;`<br>`config.body = false;`<br>`config.wing = false;`<br>`config.htail = false;`<br>`config.vtail = false;`<br>`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` |
| `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 relative to `alpha`. | `alpha`, `mach`, `alt`, `build`, `grndht`, `delta` |
| `cma` | Derivatives of pitching-moment coefficients relative to `alpha`. | `alpha`, `mach`, `alt`, `build`, `grndht`, `delta` |
| `cyb` | Derivatives of side-force coefficients relative to sideslip angle. | `alpha`, `mach`, `alt`, `build`, `grndht`, `delta` |
| `cnb` | Derivatives of yawing-moment coefficients relative to sideslip angle. | `alpha`, `mach`, `alt`, `build`, `grndht`, `delta` |
| `clb` | Derivatives of rolling-moment coefficients relative 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` |

| Field | Matrix of... | Function of... |
|---|---|---|
| `depsdalp` | Downwash angle relative 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` | Lift force 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` |
| `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, 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 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` |
| `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` |
| `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` |

| Field | Matrix of... | Function of... |
|---|---|---|
| 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 character vectors 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) |
| 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 |

| Field | Matrix of... | Stored with Indices of... |
|---|---|---|
| `cmothetaw` | `(cmo/theta)w` | `mach`, `alt` |
| `cmothetah` | `(cmo/theta)h` | `mach`, `alt` |
| `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`) |
| `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`) |

| Field | Matrix of... | Stored with Indices of... |
|---|---|---|
| `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`) |
| `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`) |

| 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` |
| `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` |

| Field | Matrix of... | Stored with Indices of... |
|---|---|---|
| `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` | Character vector 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 1999 version 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. | `[]` |
| `dim` | Character vector denoting the specified system of units for the case. | `'ft'` |
| `deriv` | Character vector 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. | `[]` |

| Field | Description | Default |
|---|---|---|
| `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` |
| `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`<br>`config.fin1.avail = false;`<br>`config.fin1.npanel = [];`<br>`config.fin1.delta = [];`<br>`config.fin2.avail = false;`<br>`config.fin2.npanel = [];`<br>`config.fin2.delta = [];`<br>`config.fin3.avail = false;`<br>`config.fin3.npanel = [];`<br>`config.fin3.delta = [];`<br>`config.fin4.avail = false;`<br>`config.fin4.npanel = [];`<br>`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` |
| `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 relative to `alpha`. | `alpha`, `mach`, `alt`, `build` |
| `cma` | Derivatives of pitching-moment coefficients relative to `alpha`. | `alpha`, `mach`, `alt`, `build` |
| `cyb` | Derivatives of side-force coefficients relative to sideslip angle. | `alpha`, `mach`, `alt`, `build` |
| `cnb` | Derivatives of yawing-moment coefficients relative to sideslip angle. | `alpha`, `mach`, `alt`, `build` |
| `clb` | Derivatives of rolling-moment coefficients relative 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, 2008, 2011, and 2014 Versions (File Type 6)

### Common Fields for the 2007, 2008, 2011, and 2014 Versions (File Type 6)

| Field | Description | Default |
|---|---|---|
| `case` | Character vector 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.<br><br>**Note** This value does not appear correctly for the 2014 version. It always displays 0. | `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 2007 version of DATCOM is `loop`, 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. | `[]` |
| `dim` | Character vector denoting the specified system of units for the case. | `'ft'` |
| `deriv` | Character vector denoting the specified angle units for the case. | `'deg'` |

| Field | Description | Default |
|---|---|---|
| `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` |
| `ngh` | Scalar denoting the number of ground altitudes. | `0` |
| `nolat` | Logical denoting the calculation of the lateral-direction derivatives is inhibited. | `false` |

| Field | Description | Default |
|---|---|---|
| `config` | Structure of logicals and structures detailing the case configuration and fin deflections. | `config.body = false;`<br>`config.fin1.avail = false;`<br>`config.fin1.npanel = [];`<br>`config.fin1.delta = [];`<br>`config.fin2.avail = false;`<br>`config.fin2.npanel = [];`<br>`config.fin2.delta = [];`<br>`config.fin3.avail = false;`<br>`config.fin3.npanel = [];`<br>`config.fin3.delta = [];`<br>`config.fin4.avail = false;`<br>`config.fin4.npanel = [];`<br>`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, 2008, 2011, and 2014 Versions (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 relative to `alpha`. | `alpha`, `mach`, `alt`, `build` |
| `cma` | Derivatives of pitching-moment coefficients relative to `alpha`. | `alpha`, `mach`, `alt`, `build` |
| `cyb` | Derivatives of side-force coefficients relative to sideslip angle. | `alpha`, `mach`, `alt`, `build` |
| `cnb` | Derivatives of yawing-moment coefficients relative to sideslip angle. | `alpha`, `mach`, `alt`, `build` |
| `clb` | Derivatives of rolling-moment coefficients relative 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 2007, 2008, 2011, and 2014 Versions (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, 2008, 2011, and 2014 Versions (File Type 21)

For 2008, 2011, and 2014, the version is 2008. There are no discernible differences in the outputs of these versions.

**Common Fields for the 2007, 2008, 2011, and 2014 Versions (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.<br><br>**Note** This value does not appear correctly for the 2014 version. It always displays 0. | `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, 2008, 2011, and 2014 versions of DATCOM is `loop` 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);`<br>`config.fin2.delta = zeros(1,8);`<br>`config.fin3.delta = zeros(1,8);`<br>`config.fin4.delta = zeros(1,8);` |
| `version` | Version of DATCOM file. | `2007` |

**Static Longitude and Lateral Stability Fields Available for the 2007, 2008, 2011, and 2014 Versions (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, 2008, 2011, and 2014 Versions (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` |

| 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` |
| `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` |

| Field | Matrix of... | Function of... |
|---|---|---|
| `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` |
| `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, 2011, and 2014 Version (File Type 42)

**Fields for the 2008, 2011, and 2014 Version (File Type 42)**

| Field | Description | Default |
|---|---|---|
| `case` | Character vector 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. | `[]` |
| `beta` | Scalar containing sideslip angle.<br><br>**Note** This value does not appear correctly for the 2014 version. It always displays 0. | `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` | Character vector denoting the specified angle units for the case. | `'deg'` |

| Field | Description | Default |
|---|---|---|
| `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` |
| `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;`<br>`config.fin1.avail = false;`<br>`config.fin1.npanel = [];`<br>`config.fin1.delta = [];`<br>`config.fin2.avail = false;`<br>`config.fin2.npanel = [];`<br>`config.fin2.delta = [];`<br>`config.fin3.avail = false;`<br>`config.fin3.npanel = [];`<br>`config.fin3.delta = [];`<br>`config.fin4.avail = false;`<br>`config.fin4.npanel = [];` |
| `version` | Version of DATCOM file. | `2008` |

**Static Longitude and Lateral Stability Fields Available for the 2008, 2011, and 2014 Versions (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` |
| `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 relative to `alpha`. | `alpha`, `mach`, `build` |
| `cma` | Derivatives of pitching-moment coefficients relative to `alpha`. | `alpha`, `mach`, `build` |
| `cyb` | Derivatives of side-force coefficients relative to sideslip angle. | `alpha`, `mach`, `build` |
| `cnb` | Derivatives of yawing-moment coefficients relative to sideslip angle. | `alpha`, `mach`, `build` |
| `clb` | Derivatives of rolling-moment coefficients relative to sideslip angle. | `alpha`, `mach`, `build` |
| `clod` | Ratios of lift coefficient to drag coefficient. | `alpha`, `mach`, `build` |

| Field | Matrix of... | Function of... |
|---|---|---|
| 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, 2011, and 2014 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 |
| 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 )
```

For more information on creating the digital DATCOM structure, see “Importing from USAF Digital DATCOM Files”. This example shows how to bring United States Air Force (USAF) Digital DATCOM files into the MATLAB environment.

## 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] on page 4-210, 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

4. AFRL-RB-WP-TR-2011-3071: *MISSILE DATCOM*, User's Manual – 2011 Revision

5. AFRL-RQ-WP-TR-2014-3999: *MISSILE DATCOM*, Users Manual – 2014 Revision

**Introduced in R2006b**

# dcm2alphabeta

Convert direction cosine matrix to angle of attack and sideslip angle

## Syntax

```
[a b] = dcm2alphabeta(n)
[a b] = dcm2alplhabeta(n,action)
[a b] = dcm2angle(n,action,tolerance)
```

## 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.

`[a b] = dcm2alplhabeta(n,action)` performs `action` if the direction cosine matrix is invalid (not orthogonal).

- Warning — Displays warning and indicates that the direction cosine matrix is .
- Error — Displays error and indicates that the direction cosine matrix is .
- None — Does not display warning or error (default).

`[a b] = dcm2angle(n,action,tolerance)` uses a `tolerance` level to evaluate if the direction cosine matrix, `n`, is valid (orthogonal). `tolerance` is a scalar whose default is `eps(2)` (`4.4409e-16`). The function considers the direction cosine matrix valid if these conditions are true:

- The transpose of the direction cosine matrix times itself equals `1` within the specified tolerance (`transpose(n)*n == 1±tolerance`)
- The determinant of the direction cosine matrix equals `1` within the specified tolerance (`det(n) == 1±tolerance`).

# 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
```

Determine the angle of attack and sideslip angle from multiple direction cosine matrices validated within tolerance:

```
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,'Warning',0.1)

alpha =

    0.4363
    0.1745


beta =

    0.1745
    0.0873
```

## See Also

angle2dcm | dcm2angle | dcmbody2wind

**Introduced in R2006b**

# dcm2angle

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)
[r1 r2 r3] = dcm2angle(n,s,lim,action)
[r1 r2 r3] = dcm2angle(n,s,lim,action,tolerance)
```

## 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. This function applies only to direction cosine matrices that are orthogonal with determinant +1.

`[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 sequences 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` specifies either `'Default'` or `'ZeroR3'`. See “Assumptions and Limitations” on page 4-217 for full definitions of angle constraints.

`[r1 r2 r3] = dcm2angle(n,s,lim,action)` performs `action` if the direction cosine matrix is invalid (not orthogonal).

- Warning — Displays warning and indicates that the direction cosine matrix is invalid.
- Error — Displays error and indicates that the direction cosine matrix is invalid.
- None — Does not display warning or error (default).

`[r1 r2 r3] = dcm2angle(n,s,lim,action,tolerance)` uses a `tolerance` level to evaluate if the direction cosine matrix, `n`, is valid (orthogonal). `tolerance` is a scalar whose default is `eps(2)` (`4.4409e-16`). The function considers the direction cosine matrix valid if these conditions are true:

- The transpose of the direction cosine matrix times itself equals 1 within the specified tolerance `tolerance` (`transpose(n)*n == 1±tolerance`)
- The determinant of the direction cosine matrix equals 1 within the specified tolerance (`det(n) == 1±tolerance`).

# 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
```

Determine the rotation angles from direction matrices validated within tolerance:

```
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','Default','None',0.1)

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 0–180 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 0–180 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` | `quat2angle` | `quat2dcm`

**Introduced in R2006b**

# dcm2latlon

Convert direction cosine matrix to geodetic latitude and longitude

## Syntax

```
[lat lon] = dcm2latlon(n)
[lat lon] = dcm2latlon(n,action)
[lat lon] = dcm2latlon(n,action,tolerance)
```

## 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.

`[lat lon] = dcm2latlon(n,action)` performs `action` if the direction cosine matrix is invalid (not orthogonal).

- Warning — Displays warning and indicates that the direction cosine matrix is invalid.
- Error — Displays error and indicates that the direction cosine matrix is invalid.
- None — Does not display warning or error (default).

`[lat lon] = dcm2latlon(n,action,tolerance)` uses a `tolerance` level to evaluate if the direction cosine matrix, `n`, is valid (orthogonal). `tolerance` is a scalar whose default is `eps(2)` (`4.4409e-16`). The function considers the direction cosine matrix valid if these conditions are true:

- The transpose of the direction cosine matrix times itself equals `1` within the specified tolerance (`transpose(n)*n == 1±tolerance`)
- The determinant of the direction cosine matrix equals `1` within the specified tolerance (`det(n) == 1±tolerance`).

## 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
```

Determine the geodetic latitude and longitude from multiple direction cosine matrices validated within tolerance:

```
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,'Warning',0.1)

lat =
   44.9995
   37.5028
lon =
 -122.0005
  -84.9975
```

## See Also

angle2dcm | dcm2angle | dcmecef2ned

**Introduced in R2006b**

# dcm2quat

Convert direction cosine matrix to quaternion

## Syntax

```
q = dcm2quat(n)
q = dcm2quat(n,action)
q = dcm2quat(n,action,tolerance)
```

## 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.

This function applies only to direction cosine matrices that are orthogonal with determinant +1.

`q = dcm2quat(n,action)` performs `action` if the direction cosine matrix is invalid (not orthogonal).

- Warning — Displays warning and indicates that the direction cosine matrix is invalid.
- Error — Displays error and indicates that the direction cosine matrix is invalid.
- None — Does not display warning or error (default).

`q = dcm2quat(n,action,tolerance)` uses a `tolerance` level to evaluate if the direction cosine matrix, `n`, is valid (orthogonal). `tolerance` is a scalar whose default is `eps(2)` (`4.4409e-16`). The function considers the direction cosine matrix valid if these conditions are true:

- The transpose of the direction cosine matrix times itself equals `1` within the specified tolerance (`transpose(n)*n == 1±tolerance`)

- The determinant of the direction cosine matrix equals 1 within the specified tolerance (`det(n) == 1±tolerance`).

# Examples

Determine the quaternion from direction cosine matrix:

```
dcm = [0 1 0; 1 0 0; 0 0 -1];
q = dcm2quat(dcm)
q =

         0    0.7071    0.7071         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    0.7071    0.7071         0
    0.8224    0.2006    0.5320    0.0223
```

Determine the quaternion from a direction cosine matrix validated within tolerance:

```
dcm = [0 1 0; 1 0 0; 0 0 -1];
q = dcm2quat(dcm,'Warning',0.1)

q =

         0    0.7071    0.7071         0
```

# See Also

`angle2dcm` | `angle2quat` | `dcm2angle` | `quat2angle` | `quat2dcm`

**Introduced in R2006b**

# dcm2rod

Convert direction cosine matrix to Euler-Rodrigues vector

## Syntax

```
R = dcm2rod(dcm)
R = dcm2rod(dcm,action)
R = dcm2rod(dcm,action,tolerance)
```

## Description

`R = dcm2rod(dcm)` function calculates the Euler-Rodrigues vector (`R`) from the direction cosine matrix. This function applies only to direction cosine matrices that are orthogonal with determinant +1.

`R = dcm2rod(dcm,action)` performs `action` if the direction cosine matrix is invalid (not orthogonal).

`R = dcm2rod(dcm,action,tolerance)` uses a `tolerance` level to evaluate if the direction cosine matrix, `n`, is valid (orthogonal).

## Examples

### Determine Rodrigues Vector from Direction Cosine Matrix

Determine the Rodrigues vector from the direction cosine matrix.

```
DCM = [0.433 0.75 0.5;-0.25 -0.433 0.866;0.866 -0.5 0.0];
r = dcm2rod(DCM)
```

```
r =

    1.3660    0.3660    1.0000
```

**Determine Rodrigues Vector from Direction Cosine Matrix Validated within Tolerance:**

Determine the Rodrigues vector from the direction cosine matrix validated within tolerance.

```
DCM = [0.433 0.75 0.5;-0.25 -0.433 0.866;0.866 -0.5 0.0];
r = dcm2rod(DCM,'Warning',0.1)
```

```
r =
    1.3660    0.3660    1.0000
```

# Input Arguments

### `dcm` — Direction cosine matrix

3-by-3-by-*M* matrix

3-by-3-by-*M* containing *M* direction cosine matrices.

Data Types: `double`

### `action` — Function behavior

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

Function behavior when direction cosine matrix is invalid (not orthogonal).

- Warning — Displays warning and indicates that the direction cosine matrix is invalid.
- Error — Displays error and indicates that the direction cosine matrix is invalid.
- None — Does not display warning or error (default).

Data Types: `char` | `string`

### `tolerance` — Tolerance

`eps(2)` (`4.4409e-16`) (default) | scalar

Tolerance of direction cosine matrix validity, specified as a scalar. The function considers the direction cosine matrix valid if these conditions are true:

- The transpose of the direction cosine matrix times itself equals 1 within the specified tolerance (`transpose(n)*n == 1±tolerance`)
- The determinant of the direction cosine matrix equals 1 within the specified tolerance (`det(n) == 1±tolerance`).

Data Types: `double`

# Output Arguments

**R — Rodrigues vector**
*M*-by-3 matrix

*M*-by-3 matrix containing *M* Rodrigues vectors.

Data Types: `double`

# Algorithms

An Euler-Rodrigues vector $\vec{b}$ represents a rotation by integrating a direction cosine of a rotation axis with the tangent of half the rotation angle as follows:

$$\vec{b} = \begin{bmatrix} b_x & b_y & b_z \end{bmatrix}$$

where:

$$b_x = \tan\left(\frac{1}{2}\theta\right)s_x,$$
$$b_y = \tan\left(\frac{1}{2}\theta\right)s_y,$$
$$b_z = \tan\left(\frac{1}{2}\theta\right)s_z$$

are the Rodrigues parameters. Vector $\vec{s}$ represents a unit vector around which the rotation is performed. Due to the tangent, the rotation vector is indeterminate when the rotation angle equals ±pi radians or ±180 deg. Values can be negative or positive.

## References

[1] Dai, J.S. "Euler-Rodrigues formula variations, quaternion conjugation and intrinsic connections." *Mechanism and Machine Theory*, 92, 144-152. Elsevier, 2015.

## See Also

`angle2rod` | `quat2rod` | `rod2angle` | `rod2dcm` | `rod2quat`

**Introduced in R2017a**

# dcmbody2wind

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

**Introduced in R2006b**

# dcmecef2ned

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. Latitude and longitude values can be any value. However, latitude values of +90 and -90 may return unexpected values because of singularity at the poles. `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

**Introduced in R2006b**

# dcmeci2ecef

Convert Earth-centered inertial (ECI) to Earth-centered Earth-fixed (ECEF) coordinates

## Syntax

```
dcm=dcmeci2ecef(reduction,utc)

dcm=dcmeci2ecef(reduction,utc,deltaAT)
dcm=dcmeci2ecef(reduction,utc,deltaAT,deltaUT1)
dcm=dcmeci2ecef(reduction,utc,deltaAT,deltaUT1,polarmotion)
dcm=dcmeci2ecef(reduction,utc,deltaAT,deltaUT1,polarmotion,
Name,Value)
```

## Description

`dcm=dcmeci2ecef(reduction,utc)` calculates the position direction cosine matrix (ECI to ECEF) as a 3-by-3-by-*M* array. The calculation is based on the specified reduction method and Universal Coordinated Time (UTC).

`dcm=dcmeci2ecef(reduction,utc,deltaAT)` uses the difference between International Atomic Time and UTC to calculate the position direction cosine matrix.

`dcm=dcmeci2ecef(reduction,utc,deltaAT,deltaUT1)` uses the difference between UTC and Universal Time (UT1).

`dcm=dcmeci2ecef(reduction,utc,deltaAT,deltaUT1,polarmotion)` uses the polar displacement.

`dcm=dcmeci2ecef(reduction,utc,deltaAT,deltaUT1,polarmotion, Name,Value)` uses additional options specified by one or more Name,Value pair arguments.

## Examples

### Convert using IAU-2000/2006 reduction

Convert Earth-centered inertial (ECI) to Earth-centered Earth-fixed (ECEF) coordinates for January 12, 2000 at 4 hours, 52 minutes, 12.4 seconds and January 12, 2000 at 4 hours, 52 minutes, and 13 seconds. Use the IAU-2000/2006 reduction. Specify only the reduction method and UTC.

```
dcm = dcmeci2ecef('IAU-2000/2006',[2000 1 12 4 52 12.4;2000 1 12 4 52 13])
```

```
dcm(:,:,1) =

   -0.9975   -0.0708   -0.0000
    0.0708   -0.9975   -0.0000
   -0.0000   -0.0000    1.0000

dcm(:,:,2) =

   -0.9975   -0.0709   -0.0000
    0.0709   -0.9975   -0.0000
   -0.0000   -0.0000    1.0000
```

### Convert using IAU-76/FK5 reduction

Convert Earth-centered inertial (ECI) to Earth-centered Earth-fixed (ECEF) coordinates for January 12, 2000 at 4 hours, 52 minutes, 12.4 seconds. Use the IAU-76/FK5 reduction. Specify all arguments, including optional ones such as polar motion.

```
dcm = dcmeci2ecef('IAU-76/FK5',[2000 1 12 4 52 12.4],32,0.234,[-0.0682e-5 ...
0.1616e-5],'dNutation',[-0.2530e-6 -0.0188e-6])
```

```
dcm =

   -0.9975   -0.0708   -0.0000
    0.0708   -0.9975   -0.0000
   -0.0000   -0.0000    1.0000
```

## Input Arguments

### `reduction` — Reduction method

`'IAU-76/FK5'` | `'IAU-2000/2006'`

Reduction method to calculate the direction cosine matrix, specified as one of the following:

- IAU-76/FK5

  Reduce the calculation using the International Astronomical Union (IAU)-76/Fifth Fundamental Catalogue (FK5) (IAU-76/FK5) reference system. Choose this reduction method if the reference coordinate system for the conversion is FK5. You can use the `'dNutation'` Name,Value pair with this reduction.

  **Note** This method uses the IAU 1976 precession model and the IAU 1980 theory of nutation to reduce the calculation. This model and theory are no longer current, but the software provides this reduction method for existing implementations. Because of the polar motion approximation that this reduction method uses, `dcmeci2ecef` calculates the transformation matrix rather than the direction cosine matrix.

- IAU-2000/2006

  Reduce the calculation using the International Astronomical Union (IAU)-2000/2005 reference system. Choose this reduction method if the reference coordinate system for the conversion is IAU-2000. This reduction method uses the P03 precession model to reduce the calculation. You can use the `'dCIP'` Name,Value pair with this reduction.

### `utc` — Universal Coordinated Time

1-by-6 array | *M*-by-6 matrix

Universal Coordinated Time (UTC) in the order year, month, day, hour, minutes, and seconds, for which the function calculates the direction cosine matrix, specified as one of the following.

- For the year value, enter a double value that is a whole number greater than 1, such as `2013`.
- For the month value, enter a double value that is a whole number greater than 0, within the range `1` to `12`.
- For the day value, enter a double value that is a whole number greater than 0, within the range `1` to `31`.
- For the hour value, enter a double value that is a whole number greater than 0, within the range `1` to `24`.
- For the minute and second values, enter a double value that is a whole number greater than 0, within the range `1` to `60`.

Specify these values in one of the following formats:

- 1-by-6 array

  Specify a 1-row-by-6-column array of UTC values to calculate one direction cosine or transformation matrix.

- *M*-by-6 matrix

  Specify an *M*-by-6 array of UTC values, where *M* is the number of direction cosine or transformation matrices to calculate. Each row corresponds to one set of UTC values.

Example: `[2000 1 12 4 52 12.4]`

This is a one row-by-6 column array of UTC values.

Example: `[2000 1 12 4 52 12.4;2010 6 5 7 22 0]`

This is an *M*-by-6 array of UTC values, where *M* is 2.

Data Types: `double`

**`deltaAT` — Difference between International Atomic Time and UTC**
scalar | one-dimensional array

Difference between International Atomic Time (IAT) and UTC, in seconds, for which the function calculates the direction cosine or transformation matrix. By default, the function assumes an *M*-by-1 array of zeroes.

- scalar

  Specify one difference-time value to calculate one direction cosine or transformation matrix.

- one-dimensional array

  Specify a one-dimensional array with *M* elements, where *M* is the number of direction cosine or transformation matrices to calculate. Each row corresponds to one set of UTC values.

Example: `32`

Specify 32 seconds as the difference between IAT and UTC.

Data Types: `double`

**`deltaUT1` — Difference between UTC and Universal Time (UT1)**
scalar | one-dimensional array

Difference between UTC and Universal Time (UT1) in seconds, for which the function calculates the direction cosine or transformation matrix. By default, the function assumes an *M*-by-1 array of zeroes.

- scalar

  Specify one difference-time value to calculate one direction cosine or transformation matrix.
- one-dimensional array

  Specify a one-dimensional array with *M* elements of difference time values, where *M* is the number of direction cosine or transformation matrices to be calculated. Each row corresponds to one set of UTC values.

Example: `0.234`

Specify `0.234` seconds as the difference between UTC and UT1.

Data Types: `double`

**`polarmotion` — Polar displacement**
1-by-2 array | *M*-by-2 array

Polar displacement of the Earth, in radians, from the motion of the Earth crust, along the *x*- and *y*-axes. By default, the function assumes an *M*-by-2 array of zeroes.

- 1-by-2 array

  Specify a 1-by-2 array of the polar displacement values to convert one direction cosine or transformation matrix.
- *M*-by-2 array

  Specify an *M*-by-2 array of polar displacement values, where *M* is the number of direction cosine or transformation matrices to convert. Each row corresponds to one set of UTC values.

Example: `[-0.0682e-5 0.1616e-5]`

Data Types: `double`

## Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name,Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside quotes. You can specify several name and value pair arguments in any order as `Name1,Value1,...,NameN,ValueN`.

Example: `[-0.2530e-6 -0.0188e-6]`

**`dNutation` — Adjustment to longitude (*dDeltaPsi*) and obliquity (*dDeltaEpsilon*)**
*M*-by-2 array

Adjustment to the longitude (*dDeltaPsi*) and obliquity (*dDeltaEpsilon*), in radians, as the comma-separated pair consisting of `dNutation` and an *M*-by-2 array. Use this Name,Value pair with the IAU-76/FK5 reduction. By default, the function assumes an *M*-by-2 array of zeroes.

For historical values, see the International Earth Rotation and Reference Systems Service Web site (`https://www.iers.org`) and navigate to the Earth Orientation Data Data/ Products page.

- *M*-by-2 array

  Specify *M*-by-2 array of adjustment values, where *M* is the number of direction cosine or transformation matrices to be converted. Each row corresponds to one set of longitude and obliquity values.

Data Types: `double`

**`dCIP` — Adjustment to the location of the Celestial Intermediate Pole (CIP)**
*M*-by-2 array

Adjustment to the location of the Celestial Intermediate Pole (CIP), in radians, specified as the comma-separated pair consisting of `dCIP` and an *M*-by-2 array. This location (*dDeltaX*, *dDeltaY*) is along the *x*- and *y*- axes. Use this argument with the IAU-200/2006 reduction. By default, this function assumes an *M*-by-2 array of zeroes.

For historical values, see the International Earth Rotation and Reference Systems Service Web site (`https://www.iers.org`) and navigate to the Earth Orientation Data Data/ Products page.

- *M*-by-2 array

Specify *M*-by-2 array of location adjustment values, where *M* is the number of direction cosine or transformation matrices to be converted. Each row corresponds to one set of *dDeltaX* and *dDeltaY* values.

Example: `[-0.2530e-6 -0.0188e-6]`

Data Types: `double`

## Output Arguments

### `dcm` — Direction cosine or transformation matrix

3-by-3-*M* array

Direction cosine or transformation matrix, returned as a 3-by-3-*M* array.

## See Also

`ecef2lla` | `geoc2geod` | `geod2geoc` | `lla2ecef`

### Topics

https://www.iers.org

**Introduced in R2013b**

# decyear

Decimal year calculator

## 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 character vectors, `s`, to decimal year, `dy`, using format `f`. `s` can be a character array, where each row corresponds to one date, or a one-dimensional cell array of character vectors. `decyear` returns a column vector of `m` decimal years, where `m` is the number of character vectors in `s`.

All of the dates in `s` must have the same format `f`, composed of the same date format symbols as the `datestr` function. `decyear` does not accept formats containing the letter `Q`.

If a format does not contain enough information to compute a date number, then:

- Hours, minutes, and seconds default to 0.
- Days default to 1.

- Months default to January.
- Years default to the current year.

Dates with two-character years are interpreted to be within 100 years of 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. Specify `y`, `mo`, and `d` as one-dimensional arrays of the same length or scalar values.

`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. Specify the six arguments as one-dimensional arrays of the same length or scalar values.

## 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`

**Introduced in R2006b**

# delete

**Class:** Aero.Animation
**Package:** Aero

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)

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 object contains.

## Examples

Delete the FlightGear animation object, `h`.

```
h=Aero.FlightGearAnimation;
h.delete;
```

## See Also

`initialize`

**Introduced in R2007a**

# delete (Aero.VirtualRealityAnimation)

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`

**Introduced in R2007b**

# deltaCIP

Calculate Celestial Intermediate Pole (CIP) location adjustment

## Syntax

```
DCIP=deltaCIP(utc)
[DCIP,DCIPError]=deltaCIP(utc)

DCIP=deltaCIP(utc,Name,Value)
[DCIP,DCIPError]=deltaCIP(UTC,Name,Value)
```

## Description

`DCIP=deltaCIP(utc)` calculates the adjustment to location of the Celestial Intermediate Pole (CIP) for a specific Universal Coordinated Time (UTC), specified as a modified Julian date. By default, this function uses a prepopulated list of IAU 2000A Earth orientation (IERS) data. This list contains measured and calculated (predicted) data supplied by the IERS. The IERS measures and calculates this data for a set of predetermined dates.

`[DCIP,DCIPError]=deltaCIP(utc)` returns the error for the adjustment to location of the CIP.

`DCIP=deltaCIP(utc,Name,Value)` calculates the location of the CIP using additional options specified by one or more `Name,Value` pair arguments.

`[DCIP,DCIPError]=deltaCIP(UTC,Name,Value)` returns the error for the adjustment to location of the CIP.

## Examples

### Calculate CIP Location Adjustment

Calculate the CIP adjustment for December 28, 2015. Use the `mjuliandate` function to calculate the date as a modified Julian date.

```
mjd = mjuliandate(2015,12,28)
dCIP = deltaCIP(mjd)

mjd =
       57384
dCIP =
   1.0e-09 *
   -0.3927    0.0145
```

### Calculate CIP Location Adjustment and Error Using IERS Data

Calculate the CIP adjustment and CIP adjustment error for December 28, 2015 and January 10, 2016 using the `aeroiersdata.mat` file. Use the `mjuliandate` function to calculate the date as a modified Julian date.

```
mjd = mjuliandate([2015 12 28;2016 1 10])
[dCIP,dCIPErr] = deltaCIP(mjd,'Source','aeroiersdata.mat')

mjd =
       57384
       57397
dCIP =

   1.0e-08 *

   -0.0393    0.0015
   -0.0087   -0.1110

dCIPErr =
   1.0e-09 *
    0.5769    0.1842
    0.2376    0.4121
```

## Input Arguments

### `utc` — Principal Universal Time (UT1) for UTC

*M*-by-1 array

Array of UTC dates, specified as an *M*-by-1 array, represented as modified Julian dates. Use the `mjuliandate` function to convert the UTC date to a modified Julian date.

Data Types: `double`

## Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name,Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside quotes. You can specify several name and value pair arguments in any order as `Name1,Value1,...,NameN,ValueN`.

Example: 'Source','aeroiersdata.mat'

### `Source` — Custom list of Earth orientation data

`aeroiersdata.mat` (default) | MAT-file

Custom list of Earth orientation data, specified in a MAT-file.

### `action` — Out-of-range action

Warning (default) | action

Out-of-range action, specified as a string.

Action to take in case of out-of-range or predicted value dates, specified as a string:

- Warning — Displays warning and indicates that the dates were out-of-range or predicted values.
- Error — Displays error and indicates that the dates were out-of-range or predicted values.
- None — Does not display warning or error.

Data Types: `string`

# Output Arguments

### `DCIP` — Adjustment to location of the CIP

*M*-by-2 array

Adjustment (`[dDeltaX,dDeltaY]`) to location of the Celestial Intermediate Pole (CIP), specified as an *M*-by-2 array, in radians.

**`DCIPError` — Error for adjustment to location of the CIP**
*M*-by-2 array

Error for adjustment to location of the CIP, specified as an *M*-by-2 array, in radians.

## See Also

`aeroReadIERSData` | `dcmeci2ecef` | `deltaUT1` | `eci2aer` | `eci2lla` | `lla2eci` | `mjuliandate` | `polarMotion`

## Topics

“Estimate Sun Analemma Using Planetary Ephemerides and ECI to AER Transformation”

**Introduced in R2018b**

# deltaUT1

Calculate difference between Coordinated Universal Time (UTC) and Principal Universal Time (UT1)

## Syntax

```
DUT1=deltaUT1(utc)
[DUT1,DUT1Error]=deltaUT1(utc)

DUT1=deltaUT1(utc,Name,Value)
[DUT1,DUT1Error]=deltaUT1(utc,Name,Value)
```

## Description

`DUT1=deltaUT1(utc)` calculates the difference between Coordinated Universal Time (UTC) and Principal Universal Time (UT1) for UTC, specified as a modified Julian date (MJD). By default, this function uses a prepopulated list of International Astronomical Union (IAU) 2000A Earth orientation (IERS) data. This list contains measured and calculated (predicted) data supplied by the IERS. The IERS measures and calculates this data for a set of predetermined dates. For dates after those listed in the prepopulated list, `deltaUT1` calculates the data by using this equation, limiting the values to +/- .9s:

```
UT1-UTC=0.5309-0.00123(MJD-57808)-(UT2-UT1)
```

`[DUT1,DUT1Error]=deltaUT1(utc)` returns the error for the difference between Coordinated Universal Time (UTC) and Principal Universal Time (UT1) for UTC.

`DUT1=deltaUT1(utc,Name,Value)` calculates the difference between UTC and UT1 using additional options specified by one or more `Name,Value` pair arguments.

`[DUT1,DUT1Error]=deltaUT1(utc,Name,Value)` returns the error for the difference between Coordinated Universal Time (UTC) and Principal Universal Time (UT1) for UTC.

# Examples

### Calculate Difference Value for December 28, 2015

Calculate the difference between UT1 and UTC values for December 28, 2015.

```
mjd = mjuliandate(2015,12,28)
dUT1 = deltaUT1(mjd)
```

```
mjd =
       57384

dUT1 =
    0.0886
```

### Calculate Difference Value for December 28, 2015 and January 10, 2016

Calculate the difference between UT1 and UTC values for December 28, 2015 and January 10, 2016 using the custom file, aeroiersdata20170101.mat.

```
mjd = mjuliandate([2015 12 28;2016 1 10])
dUT1 = deltaUT1(mjd,'Source','aeroiersdata20170101.mat')
```

```
mjd =
       57384
       57397

dUT1 =
    0.0886
    0.0648
```

### Calculate Difference Value and Error Using IERS Data

Calculate the difference between UT1-UTC values for December 28, 2015 and January 10, 2016 using the custom file, `aeroiersdata.mat`.

```
mjd = mjuliandate([2015 12 28;2016 1 10])
[dUT1,dUT1Err] = deltaUT1(mjd,'Source','aeroiersdata.mat')
```

```
mjd =
       57384
       57397


dUT1 =
    0.0886
    0.0648


dUT1Err =
   1.0e-05 *

    0.3900
    0.7300
```

# Input Arguments

### `utc` — Principal Universal Time (UT1) for UTC

*M*-by-1 array

Array of UTC dates, specified as an *M*-by-1 array, represented as modified Julian dates. Use the `mjuliandate` function to convert the UTC date to a modified Julian date.

## Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name,Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside quotes. You can specify several name and value pair arguments in any order as `Name1,Value1,...,NameN,ValueN`.

Example: 'Source','aeroiersdata.mat'

### `Source` — Custom list of Earth orientation data

`aeroiersdata.mat` (default) | MAT-file

Custom list of Earth orientation data, specified in a MAT-file.

### `action` — Out-of-range action

Warning (default) | action

Out-of-range action, specified as a string.

Action to take in case of out-of-range or predicted value dates, specified as a string:

- Warning — Displays warning and indicates that the dates were out-of-range or predicted values.
- Error — Displays error and indicates that the dates were out-of-range or predicted values.
- None — Does not display warning or error.

Data Types: `string`

# Output Arguments

**`DUT1` — Difference between UT1 and UTC**
*M*-by-1 array

Difference between UT1 and UTC, specified as an *M*-by-1 array.

**`DUT1Error` — Error for difference between UT1 and UTC**
*M*-by-1 array

Error for difference between UT1 and UTC (UT1-UTC), according to the International Astronomical Union (IAU) 2000A resolutions, specified as an *M*-by-1 array, in seconds.

# See Also

`aeroReadIERSData` | `dcmeci2ecef` | `eci2aer` | `eci2lla` | `lla2eci` | `mjuliandate`

## Topics

“Estimate Sun Analemma Using Planetary Ephemerides and ECI to AER Transformation”

**Introduced in R2017b**

# dpressure

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`

**Introduced in R2006b**

# earthNutation

Implement Earth nutation

## Syntax

```
angles= earthNutation(ephemerisTime)
angles= earthNutation(ephemerisTime,ephemerisModel)
angles= earthNutation(ephemerisTime,ephemerisModel,action)

[angles,rates] = earthNutation( ___ )
```

## Description

`angles= earthNutation(ephemerisTime)` implements the International Astronomical Union (IAU) 1980 nutation series for ephemerisTime, expressed in Julian days. It returns angles.

The function uses the Chebyshev coefficients that the NASA Jet Propulsion Laboratory provides.

This function requires that you download ephemeris data with the Add-On Explorer. For more information, see `aeroDataPackage`.

`angles= earthNutation(ephemerisTime,ephemerisModel)` uses the `ephemerisModel` coefficients to implement these values.

`angles= earthNutation(ephemerisTime,ephemerisModel,action)` uses `action` to determine error reporting.

`[angles,rates] = earthNutation( ___ )` implements the International Astronomical Union (IAU) 1980 nutation series using any combination of the input arguments in the previous syntaxes. It returns angles and angular rates.

## Examples

### Implement Earth Nutation Angles

Implement Earth nutation angles for December 1, 1990. Because no ephemerides model is specified, the default, DE405, is used. Use the `juliandate` function to specify the Julian date.

```
angles = earthNutation(juliandate(1990,12,1))
```

```
angles =
   1.0e-04 *
    0.6448    0.2083
```

### Implement Earth Nutation Angles and Angular Rates

Implement Earth nutation angles and angular rates for noon on January 1, 2000 using DE421:

```
[angles,rates] = earthNutation([2451544.5 0.5],'421')
```

```
angles =
   1.0e-04 *
   -0.6750   -0.2799

rates =
   1.0e-07 *
    0.3687   -0.9937
```

## Input Arguments

### `ephemerisTime` — Julian date

scalar | 2-element vector | column vector | *M*-by-2 matrix

Julian dates for which the positions are calculated, specified as one of the following:

- Scalar

  Specify one fixed Julian date.
- 2-element vector

  Specify the Julian date in multiple parts. The first element is the Julian date for a specific epoch that is the most recent midnight at or before the interpolation epoch.

The second element is the fractional part of a day elapsed between the first element and epoch. The second element must be positive. The value of the first element plus the second element cannot exceed the maximum Julian date.

- Column vector

  Specify a column vector with *M* elements, where *M* is the number of fixed Julian dates.

- *M*-by-2 matrix

  Specify a matrix, where *M* is the number of Julian dates and the second column contains the elapsed days (Julian epoch date/elapsed day pairs).

Data Types: `double`

**`ephemerisModel` — Ephemerides coefficients**
`'405'` (default) | `'421'` | `'423'` | `'430'`

Ephemerides coefficients, specified as one of these ephemerides defined by the Jet Propulsion Laboratory:

- `'405'`

  Released in 1998. This ephemerides takes into account the Julian date range 2305424.50 (December 9, 1599 ) to 2525008.50 (February 20, 2201).

  This function calculates these ephemerides with respect to the International Celestial Reference Frame version 1.0, adopted in 1998.

- `'421'`

  Released in 2008. This ephemerides takes into account the Julian date range 2414992.5 (December 4, 1899) to 2469808.5 (January 2, 2050).

  This function calculates these ephemerides with respect to the International Celestial Reference Frame version 1.0, adopted in 1998.

- `'423'`

  Released in 2010. This ephemerides takes into account the Julian date range 2378480.5 (December 16, 1799) to 2524624.5 (February 1, 2200).

  This function calculates these ephemerides with respect to the International Celestial Reference Frame version 2.0, adopted in 2010.

- `'430'`

  Released in 2013. This ephemerides takes into account the Julian date range 2287184.5 (December 21, 1549) to 2688976.5 (January 25, 2650).

  This block implements these ephemerides with respect to the International Celestial Reference Frame version 2.0, adopted in 2010.

Data Types: `char`

### `action` — Function behavior

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

Function behavior when inputs are out of range, specified as one of these values:

| Value | Description |
|---|---|
| `'None'` | No action. |
| `'Warning'` | Warning in the MATLAB Command Window, model simulation continues. |
| `'Error'` | MATLAB returns an exception, model simulation stops. |

Data Types: `char`

## Output Arguments

### `angles` — Earth nutation angles

*M*-by-2 vector

Earth nutation angles, returned as an *M*-by-2 vector, where *M* is the number of Julian dates. The 2 vector contains the *d(psi)* and *d(epsilon)* angles, in radians. The input arguments include multiple Julian dates or epochs. The vector has the same number of rows as the `ephemerisTime` input.

### `rates` — Earth nutation angular rates

*M*-by-2 vector

Earth nutation angular rates, returned as an *M*-by-2 vector, where *M* is the number of Julian dates. The 2 vector contains the *d(psi)* and *d(epsilon)* angular rate, in radians/day. The input arguments include multiple Julian dates or epochs. The vector has the same number of rows as the `ephemerisTime` input.

## References

[1] Folkner, W. M., J. G. Williams, D. H. Boggs, “The Planetary and Lunar Ephemeris DE 421,” *JPL Interplanetary Network Progress Report 24-178*, 2009.

[2] Vallado, D. A., *Fundamentals of Astrodynamics and Applications*, McGraw-Hill, New York, 1997.

# See Also

`juliandate` | `moonLibration` | `planetEphemeris`

## External Websites

`https://ssd.jpl.nasa.gov/?planet_eph_export`

**Introduced in R2013a**

# ecef2lla

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`

### Introduced in R2006b

# eci2aer

Convert Earth-centered inertial (ECI) coordinates to azimuth, elevation, slant range (AER) coordinates

## Syntax

```
aer = eci2aer(position,utc,lla0)

aer = eci2aer(position,utc,lla0,reduction)
aer = eci2aer(position,utc,lla0,reduction,deltaAT)
aer = eci2aer(position,utc,lla0,reduction,deltaAT,deltaUT1)
aer = eci2aer(position,utc,lla0,reduction,deltaAT,deltaUT1,
polarmotion)
aer = eci2aer(position,utc,lla0,reduction,deltaAT,deltaUT1,
polarmotion,Name,Value)
```

## Description

`aer = eci2aer(position,utc,lla0)` converts Earth-centered inertial coordinates, specified by position, to azimuth, elevation, and slant range (AER) coordinates, based on the geodetic position (latitude, longitude, and altitude). The conversion is based on the Universal Coordinated Time (UTC) you specify.

- Azimuth (A) — Angle measured clockwise from true north. It ranges from 0 to 360 degrees.
- Elevation (E) — Angle between a plane perpendicular to the ellipsoid and the line that goes from the local reference to the object position. It ranges from –90 to 90 degrees.
- Slant range (R) — Straight line distance between the local reference and the object, meters.

`aer = eci2aer(position,utc,lla0,reduction)` converts Earth-centered inertial coordinates, specified by `position`, to azimuth, elevation, and slant range coordinates. The conversion is based on the specified reduction method and the Universal Coordinated Time you specify.

`aer = eci2aer(position,utc,lla0,reduction,deltaAT)` uses the difference between International Atomic Time and UTC that you specify as `deltaAT` to calculate the AER coordinates.

`aer = eci2aer(position,utc,lla0,reduction,deltaAT,deltaUT1)` uses the difference between UTC and Universal Time (UT1), which you specify as `deltaUT1`, in the calculation.

`aer = eci2aer(position,utc,lla0,reduction,deltaAT,deltaUT1, polarmotion)` uses the polar displacement, `polarmotion`, in the calculation.

`aer = eci2aer(position,utc,lla0,reduction,deltaAT,deltaUT1, polarmotion,Name,Value)` uses additional options specified by one or more Name,Value pair arguments.

# Examples

### Convert Position to AER Coordinates Using UTC

Convert the position to AER coordinates from ECI coordinates 1e08*[-3.8454 -0.5099 -0.3255] meters for the date 1969/7/20 21:17:40 UTC at 28.4 degrees north, 80.5 degrees west and 2.7 meters altitude.

```
aer = eci2aer(1e08*[-3.8454,-0.5099,-0.3255],...
[1969,7,20,21,17,40], [28.4,-80.5,2.7])
```

```
aer =

   1.0e+08 *

    0.0000    0.0000    3.8401
```

### Convert Position to AER Coordinates Using UTC and Reduction Method IAU-76/FK5

Convert the position to AER coordinates from ECI coordinates 1e08*[-3.8454 -0.5099 -0.3255] meters for the date 1969/7/20 21:17:40 UTC at 28.4 degrees north, 80.5 degrees west and 2.7 meters altitude. For an ellipsoid with a flattening of 1/290 and an equatorial

radius of 60000 meters, use the IAU-76/FK5 reduction, polar motion [-0.0682e-5 0.1616e-5] radians, and nutation angles [-0.2530e-6 -0.0188e-6].

```
aer = eci2aer(1e08*[-3.8454,-0.5099,-0.3255],...
[1969,7,20,21,17,40],[28.4,-80.5,2.7],...
'IAU-76/FK5',32,0.234,[-0.0682e-5 0.1616e-5],...
'dNutation',[-0.2530e-6 -0.0188e-6],...
'flattening',1/290,'RE',60000)
```

```
aer =

   1.0e+08 *

    0.0000    0.0000    3.8922
```

# Input Arguments

### `position` — ECI coordinates

*M*-by-3 array

ECI coordinates in meters, specified as an *M*-by-3 array.

### `utc` — Universal Coordinated Time

1-by-6 array of whole numbers | *M*-by-6 matrix of whole numbers

Universal Coordinated Time (UTC), in the order year, month, day, hour, minutes, and seconds, for which the function calculates the conversion, specified as one of the following:

- For the year value, enter a double value that is a whole number greater than 1, such as `2013`.
- For the month value, enter a double value that is a whole number greater than 0, within the range `1` to `12`.
- For the hour value, enter a double value that is a whole number greater than 0, within the range `1` to `24`.
- For the hour value, enter a double value that is a whole number greater than 0, within the range `1` to `60`.
- For the minute and second values, enter a double value that is a whole number greater than 0, within the range `1` to `60`.

Specify these values in one of the following formats:

- 1-by-6 array

  Specify a 1-row-by-6-column array of UTC values.
- *M*-by-6 matrix

  Specify an *M*-by-6 array of UTC values, where *M* is the number of transformation matrices to calculate. Each row corresponds to one set of UTC values.

This example is a one-row-by-6-column array of UTC values.

Example: `[2000 1 12 4 52 12.4]`

This example is an *M*-by-6 array of UTC values, where *M* is 2.

Example: `[2000 1 12 4 52 12.4;2010 6 5 7 22 0]`

Data Types: `double`

**`lla0` — Geodetic coordinates**
*M*-by-3 array

Geodetic coordinates of the local reference (latitude, longitude, and ellipsoidal altitude), in degrees, degrees, and meters. Latitude and longitude values can be any value. However, latitude values of +90 and –90 can return unexpected values because of singularity at the poles.

**`reduction` — Reduction method**
`'IAU-2000/2006'` (default) | `'IAU-76/FK5'`

Reduction method to calculate the coordinate conversion, specified as one of the following:

- `'IAU-76/FK5'`

  Reduce the calculation using the International Astronomical Union (IAU)-76/Fifth Fundamental Catalogue (FK5) (IAU-76/FK5) reference system. Choose this reduction method if the reference coordinate system for the conversion is FK5. You can use the `'dNutation'` Name,Value pair with this reduction.

  **Note** This method uses the IAU 1976 precession model and the IAU 1980 theory of nutation to reduce the calculation. This model and theory are no longer current, but

the software provides this reduction method for existing implementations. Because of the polar motion approximation that this reduction method uses, `eci2aer` performs a coordinate conversion that is not orthogonal due to the polar motion approximation.

- `'IAU-2000/2006'`

  Reduce the calculation using the International Astronomical Union (IAU)-2000/2005 reference system. Choose this reduction method if the reference coordinate system for the conversion is IAU-2000. This reduction method uses the P03 precession model to reduce the calculation. You can use the `'dCIP'` Name,Value pair with this reduction.

**`deltaAT` — Difference between International Atomic Time and UTC**
scalar | one-dimensional array

Difference between International Atomic Time (IAT) and UTC, in seconds, for which the function calculates the direction cosine or transformation matrix. By default, the function assumes an *M*-by-1 array of zeroes.

- scalar

  Specify one difference-time value to calculate one direction cosine or transformation matrix.

- one-dimensional array

  Specify a one-dimensional array with *M* elements, where *M* is the number of direction cosine or transformation matrices to calculate. Each row corresponds to one set of UTC values.

Example: 32

Specify 32 seconds as the difference between IAT and UTC.

Data Types: `double`

**`deltaUT1` — Difference between UTC and Universal Time (UT1)**
scalar | one-dimensional array

Difference between UTC and Universal Time (UT1) in seconds, for which the function calculates the direction cosine or transformation matrix. By default, the function assumes an *M*-by-1 array of zeroes.

- scalar

Specify one difference-time value to calculate one direction cosine or transformation matrix.

- one-dimensional array

  Specify a one-dimensional array with *M* elements of difference time values, where *M* is the number of direction cosine or transformation matrices to be calculated. Each row corresponds to one set of UTC values.

Example: `0.234`

Specify `0.234` seconds as the difference between UTC and UT1.

Data Types: `double`

**`polarmotion` — Polar displacement**
1-by-2 array | *M*-by-2 array

Polar displacement of the Earth, in radians, from the motion of the Earth crust, along the *x*- and *y*-axes. By default, the function assumes an *M*-by-2 array of zeroes.

- 1-by-2 array

  Specify a 1-by-2 array of the polar displacement values to convert one direction cosine or transformation matrix.

- *M*-by-2 array

  Specify an *M*-by-2 array of polar displacement values, where *M* is the number of direction cosine or transformation matrices to convert. Each row corresponds to one set of UTC values.

Example: `[-0.0682e-5 0.1616e-5]`

Data Types: `double`

## Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name,Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside quotes. You can specify several name and value pair arguments in any order as `Name1,Value1,...,NameN,ValueN`.

Example: `'dNutation',[-0.2530e-6 -0.0188e-6]`

**`dNutation` — Adjustment to longitude (*dDeltaPsi*) and obliquity (*dDeltaEpsilon*)**
*M*-by-2 array of zeroes (default) | *M*-by-2 array

Adjustment to the longitude (*dDeltaPsi*) and obliquity (*dDeltaEpsilon*), in radians, specified as the comma-separated pair consisting of `'dNutation'` and an *M*-by-2 array. You can use this Name,Value pair with the IAU-76/FK5 reduction.

For historical values, see the International Earth Rotation and Reference Systems Service website (`https://www.iers.org`) and navigate to the Earth Orientation Data Data/ Products page.

- *M*-by-2 array

  Specify *M*-by-2 array of adjustment values, where *M* is the number of LLA coordinates to be converted. Each row corresponds to one set of longitude and obliquity values.

Data Types: `double`

**`dCIP` — Adjustment to the location of the celestial intermediate pole (CIP)**
*M*-by-2 array of zeroes (default)

Adjustment to the location of the celestial intermediate pole (CIP), in radians, specified as the comma-separated pair consisting of `'dCIP'` and an *M*-by-2 array. This location (*dDeltaX*, *dDeltaY*) is along the *x*- and *y*- axes. You can use this argument with the IAU-200/2006 reduction.

For historical values, see the International Earth Rotation and Reference Systems Service website (`https://www.iers.org`) and navigate to the Earth Orientation Data Data/ Products page.

- *M*-by-2 array

  Specify *M*-by-2 array of location adjustment values, where *M* is the number of LLA coordinates to convert. Each row corresponds to one set of *dDeltaX* and *dDeltaY* values.

Example: `'dCIP',[-0.2530e-6 -0.0188e-6]`

Data Types: `double`

**`flattening` — Custom ellipsoid planet**
1-by-1 array

Custom ellipsoid planet defined by flattening, specified as the comma-separated pair consisting of `'flattening'` and a 1-by-1 array.

Example: `1/290`

Data Types: `double`

### `re` — Custom planet ellipsoid radius

1-by-1 array

Custom planet ellipsoid radius, in meters, specified as the comma-separated pair consisting of `'re'` and a 1-by-1 array.

Example: `60000`

Data Types: `double`

## See Also

`dcmeci2ecef` | `ecef2lla` | `geoc2geod` | `geod2geoc` | `lla2ecef` | `lla2eci`

**Introduced in R2015a**

# eci2lla

Convert Earth-centered inertial (ECI) coordinates to latitude, longitude, altitude (LLA) geodetic coordinates

## Syntax

```
lla = eci2lla(position,utc)

lla = eci2lla(position,utc,reduction)
lla = eci2lla(position,utc,reduction,deltaAT)
lla = eci2lla(position,utc,reduction,deltaAT,deltaUT1)
lla = eci2lla(position,utc,reduction,deltaAT,deltaUT1,polarmotion)
lla = eci2lla(position,utc,reduction,deltaAT,deltaUT1,polarmotion,
Name,Value)
```

## Description

`lla = eci2lla(position,utc)` converts Earth-centered inertial (ECI) coordinates, specified by position, to latitude, longitude, altitude (LLA) geodetic coordinates. The conversion is based on the Universal Coordinated Time (UTC) you specify.

`lla = eci2lla(position,utc,reduction)` converts Earth-centered inertial (ECI) coordinates, specified by `position`, to latitude, longitude, altitude (LLA) geodetic coordinates. The conversion is based on the specified reduction method and the Universal Coordinated Time (UTC) you specify.

`lla = eci2lla(position,utc,reduction,deltaAT)` uses the difference between International Atomic Time and UTC that you specify as `deltaAT` to calculate the ECI coordinates.

`lla = eci2lla(position,utc,reduction,deltaAT,deltaUT1)` uses the difference between UTC and Universal Time (UT1), which you specify as `deltaUT1`, in the calculation.

`lla = eci2lla(position,utc,reduction,deltaAT,deltaUT1,polarmotion)` uses the polar displacement, `polarmotion`, in the calculation.

`lla = eci2lla(position,utc,reduction,deltaAT,deltaUT1,polarmotion, Name,Value)` uses additional options specified by one or more Name,Value pair arguments.

# Examples

### Convert Position to LLA Coordinates Using UTC

Convert the position to LLA coordinates from ECI coordinates [-6.07 -1.28 0.66]*1e6 at 01/17/2010 10:20:36 UTC.

```
lla = eci2lla([-6.07 -1.28 0.66]*1e6,[2010 1 17 10 20 36])
```

```
lla =

   1.0e+05 *

    0.0001   -0.0008   -1.3940
```

### Convert Position to LLA Coordinates Using UTC and Reduction Method IAU-76/FK5

Convert the position to LLA coordinates from ECI coordinates [-1.1 3.2 -4.9]*1e4 at 01/12/2000 4:52:12.4 UTC, with a difference of 32 seconds between TAI and UTC, and 0.234 seconds between UTC and UT1. For an ellipsoid with a flattening of 1/290 and an equatorial radius of 60000 meters, use the IAU-76/FK5 reduction, polar motion [-0.0682e-5 0.1616e-5] radians, and nutation angles [-0.2530e-6 -0.0188e-6].

```
lla = eci2lla([-1.1 3.2 -4.9]*1e4,[2000 1 12 4 52 12.4],...
'IAU-76/FK5',32,0.234,[-0.0682e-5 0.1616e-5],'dNutation'...
,[-0.2530e-6 -0.0188e-6],...
'flattening',1/290,'RE',60000)
```

```
lla =

  -55.5592  -75.0892 -311.3709
```

# Input Arguments

### `position` — ECI coordinates

*M*-by-3 array

ECI coordinates in meters, specified as an *M*-by-3 array.

### `utc` — Universal Coordinated Time

1-by-6 array | *M*-by-6 matrix

Universal Coordinated Time (UTC), in the order year, month, day, hour, minutes, and seconds, for which the function calculates the conversion, specified as one of the following:

- For the year value, enter a double value that is a whole number greater than 1, such as `2013`.
- For the month value, enter a double value that is a whole number greater than 0, within the range `1` to `12`.
- For the hour value, enter a double value that is a whole number greater than 0, within the range `1` to `24`.
- For the hour value, enter a double value that is a whole number greater than 0, within the range `1` to `60`.
- For the minute and second values, enter a double value that is a whole number greater than 0, within the range `1` to `60`.

Specify these values in one of the following formats:

- 1-by-6 array

  Specify a 1-row-by-6-column array of UTC values.
- *M*-by-6 matrix

  Specify an *M*-by-6 array of UTC values, where *M* is the number of transformation matrices to calculate. Each row corresponds to one set of UTC values.

This is a one row-by-6 column array of UTC values.

Example: `[2000 1 12 4 52 12.4]`

This is an *M*-by-6 array of UTC values, where *M* is 2.

Example: `[2000 1 12 4 52 12.4;2010 6 5 7 22 0]`

Data Types: `double`

### `reduction` — Reduction method

`'IAU-2000/2006'` (default) | `'IAU-76/FK5'`

Reduction method to calculate the coordinate conversion, specified as one of the following:

- `'IAU-76/FK5'`

  Reduce the calculation using the International Astronomical Union (IAU)-76/Fifth Fundamental Catalogue (FK5) (IAU-76/FK5) reference system. Choose this reduction method if the reference coordinate system for the conversion is FK5. You can use the `'dNutation'` Name,Value pair with this reduction.

  **Note** This method uses the IAU 1976 precession model and the IAU 1980 theory of nutation to reduce the calculation. This model and theory are no longer current, but the software provides this reduction method for existing implementations. Because of the polar motion approximation that this reduction method uses, `eci2lla` performs a coordinate conversion that is not orthogonal because of the polar motion approximation.

- `'IAU-2000/2006'`

  Reduce the calculation using the International Astronomical Union (IAU)-2000/2005 reference system. Choose this reduction method if the reference coordinate system for the conversion is IAU-2000. This reduction method uses the P03 precession model to reduce the calculation. You can use the `'dCIP'` Name,Value pair with this reduction.

### `deltaAT` — Difference between International Atomic Time and UTC

*M*-by-1 array of zeroes (default) | scalar | one-dimensional array

Difference between International Atomic Time (IAT) and UTC, in seconds, for which the function calculates the coordinate conversion.

- scalar

Specify difference-time value to calculate one direction cosine or transformation matrix.

- one-dimensional array

  Specify a one-dimensional array with *M* elements, where *M* is the number of ECI coordinates. Each row corresponds to one set of ECI coordinates.

Specify `32` seconds as the difference between IAT and UTC.

Example: `32`

Data Types: `double`

### `deltaUT1` — Difference between UTC and Universal Time (UT1)

*M*-by-1 array of zeroes (default) | scalar | one-dimensional array

Difference between UTC and Universal Time (UT1), in seconds, for which the function calculates the coordinate conversion.

- scalar

  Specify difference-time value to calculate ECI coordinates.

- one-dimensional array

  Specify a one-dimensional array with *M* elements of difference time values, where *M* is the number of ECI coordinates. Each row corresponds to one set of ECI coordinates.

Specify `0.234` seconds as the difference between UTC and UT1.

Example: `0.234`

Data Types: `double`

### `polarmotion` — Polar displacement

*M*-by-2 array of zeroes (default) | 1-by-2 array | *M*-by-2 array

Polar displacement of the Earth, in radians, from the motion of the Earth crust, along the *x*- and *y*-axes.

- 1-by-2 array

  Specify a 1-by-2 array of the polar displacement values to convert one ECI coordinate.

- *M*-by-2 array

Specify an *M*-by-2 array of polar displacement values, where *M* is the number of ECI coordinates to convert. Each row corresponds to one set of UTC values.

Example: `[-0.0682e-5 0.1616e-5]`

Data Types: `double`

## Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name,Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside quotes. You can specify several name and value pair arguments in any order as `Name1,Value1,...,NameN,ValueN`.

Example: `'dNutation',[-0.2530e-6 -0.0188e-6]`

**`dNutation` — Adjustment to longitude (*dDeltaPsi*) and obliquity (*dDeltaEpsilon*)**
*M*-by-2 array of zeroes (default) | *M*-by-2 array

Adjustment to the longitude (*dDeltaPsi*) and obliquity (*dDeltaEpsilon*), in radians, specified as the comma-separated pair consisting of `dNutation` and an *M*-by-2 array. You can use this Name,Value pair with the IAU-76/FK5 reduction.

For historical values, see the International Earth Rotation and Reference Systems Service website (`https://www.iers.org`) and navigate to the Earth Orientation Data Data/ Products page.

- *M*-by-2 array

  Specify *M*-by-2 array of adjustment values, where *M* is the number of LLA coordinates to be converted. Each row corresponds to one set of longitude and obliquity values.

Data Types: `double`

**`dCIP` — Adjustment to the location of the celestial intermediate pole (CIP)**
*M*-by-2 array of zeroes (default)

Adjustment to the location of the celestial intermediate pole (CIP), in radians, specified as the comma-separated pair consisting of `dCIP` and an *M*-by-2 array. This location (*dDeltaX*, *dDeltaY*) is along the *x*- and *y*- axes. You can use this argument with the IAU-200/2006 reduction.

For historical values, see the International Earth Rotation and Reference Systems Service website (`https://www.iers.org`) and navigate to the Earth Orientation Data Data/ Products page.

- *M*-by-2 array

  Specify *M*-by-2 array of location adjustment values, where *M* is the number of LLA coordinates to convert. Each row corresponds to one set of *dDeltaX* and *dDeltaY* values.

Example: `'dcip',[-0.2530e-5 -0.0188e-4]`

Data Types: `double`

**`flattening` — Custom ellipsoid planet**
1-by-1 array

Custom ellipsoid planet defined by flattening.

Example: `1/290`

Data Types: `double`

**`re` — Custom planet ellipsoid radius**
1-by-1 array

Custom planet ellipsoid radius, in meters.

Example: `60000`

Data Types: `double`

# See Also

`dcmeci2ecef` | `ecef2lla` | `geoc2geod` | `geod2geoc` | `lla2ecef` | `lla2eci`

**Introduced in R2014a**

# EGTIndicator Properties

Control exhaust gas temperature (EGT) indicator appearance and behavior

## Description

EGT indicators are components that represent an EGT indicator. Properties control the appearance and behavior of an EGT indicator. Use dot notation to refer to a particular object and property:

```
figure = uifigure;
egtindicator = uiaeroegt(figure);
egtindicator.Value = 100;
```

## Properties

**EGT Indicator**

### `Limits` — Minimum and maximum indicator scale values

[0 1000] (default) | two-element finite, real, and scalar numeric vector

Minimum and maximum indicator scale values, specified as a two-element numeric vector. The first value in the vector must be less than the second value, in degrees Celsius.

If you change `Limits` such that the `Value` property is less than the new lower limit, or more than the new upper limit, then the indicator needle points to a location off the scale.

For example, suppose `Limits` is `[0 100]` and the `Value` property is 20. If the `Limits` changes to `[50 100]`, then the needle points to a location off the scale, slightly less than 50.

### `ScaleColors` — Scale colors

[ ] (default) | n-by-3 array of RGB triplets | cell array

Scale colors, specified one of the following ways:

- An n-by-3 array of RGB triplets

- A cell array containing RGB triplets, any of the color options listed in the table below, or a combination of both.

An RGB triplet is a three-element row vector whose elements specify the intensities of the red, green, and blue components of the color. The intensities must be in the range `[0,1]`; for example, `[0.4 0.6 0.7]`. Alternatively, you can specify some common colors by name. This table lists the long and short color name options and the equivalent RGB triplet values.

| Option | Description | Equivalent RGB Triplet |
|---|---|---|
| `'red'` or `'r'` | Red | `[1 0 0]` |
| `'green'` or `'g'` | Green | `[0 1 0]` |
| `'blue'` or `'b'` | Blue | `[0 0 1]` |
| `'yellow'` or `'y'` | Yellow | `[1 1 0]` |
| `'magenta'` or `'m'` | Magenta | `[1 0 1]` |
| `'cyan'` or `'c'` | Cyan | `[0 1 1]` |
| `'white'` or `'w'` | White | `[1 1 1]` |
| `'black'` or `'k'` | Black | `[0 0 0]` |

Each color of the `ScaleColors` array corresponds to a colored section of the indicator. Set the `ScaleColorLimits` property to map the colors to specific sections of the indicator.

If you do not set the `ScaleColorLimits` property, MATLAB distributes the colors equally over the range of the indicator.

Data Types: `double`

**`ScaleColorLimits` — Scale color limits**

[ ] (default) | n-by-2 array

Scale color limits, specified as an n-by-2 array of numeric values. For every row in the array, the first element must be less than the second element.

When applying colors to the indicator, MATLAB applies the colors starting with the first color in the `ScaleColors` array. Therefore, if two rows in `ScaleColorLimits` array overlap, then the color applied later takes precedence.

The indicator does not display any portion of the `ScaleColorLimits` that falls outside of the `Limits` property.

If the `ScaleColors` and `ScaleColorLimits` property values are different sizes, then the indicator shows only the colors that have matching limits. For example, if the `ScaleColors` array has three colors, but the `ScaleColorLimits` has only two rows, then the indicator displays the first two color/limit pairs only.

### `Temperature` — Temperature value

`0` (default) | finite, real, and scalar numeric

Temperature value, specified as any finite and scalar numeric, in degrees Celsius

Example: 10

#### Dependencies

Specifying this value changes the value of `Value`. Conversely, changing `Value` changes the `Temperature` value.

### `Value` — Temperature value

`0` (default) | finite, real, and scalar numeric

Temperature value, specified as any finite and scalar numeric, in degrees Celsius.

Example: 10

#### Dependencies

Specifying this value changes the value of `Temperature`. Conversely, changing `Temperature` changes the `Value` value.

#### Interactivity

### `Visible` — Visibility of EGT indicator

`'on'` (default) | `'off'`

Visibility of the EGT indicator, specified as `'on'` or `'off'`. The `Visible` property determines whether the EGT indicator, is displayed on the screen. If the `Visible` property is set to `'off'`, then the entire EGT indicator is hidden, but you can still specify and access its properties.

### `Enable` — Operational state of EGT indicator

`'on'` (default) | `'off'`

Operational state of EGT indicator, specified as `'on'` or `'off'`.

- If you set this property to `'on'`, then the appearance of the EGT indicator indicates that the EGT indicator is operational.
- If you set this property to `'off'`, then the appearance of the EGT indicator appears dimmed, indicating that the EGT indicator is not operational.

**Position**

### `Position` — Location and size of EGT indicator

`[100 100 120 120]` (default) | `[left bottom width height]`

Location and size of the EGT indicator relative to the parent container, specified as the vector, `[left bottom width height]`. This table describes each element in the vector.

| Element | Description |
|---|---|
| `left` | Distance from the inner left edge of the parent container to the outer left edge of an imaginary box surrounding the EGT indicator |
| `bottom` | Distance from the inner bottom edge of the parent container to the outer bottom edge of an imaginary box surrounding the EGT indicator |
| `width` | Distance between the right and left outer edges of the EGT indicator |
| `height` | Distance between the top and bottom outer edges of the EGT indicator |

All measurements are in pixel units.

The `Position` values are relative to the drawable area of the parent container. The drawable area is the area inside the borders of the container and does not include the area occupied by decorations such as a menu bar or title.

Example: `[200 120 120 120]`

### `InnerPosition` — Inner location and size of EGT indicator

`[100 100 120 120]` (default) | `[left bottom width height]`

Inner location and size of the EGT indicator, specified as `[left bottom width height]`. Position values are relative to the parent container. All measurements are in pixel units. This property value is identical to the `Position` property.

### `OuterPosition` — Outer location and size of EGT indicator

`[100 100 120 120]]` (default) | `[left bottom width height]`

This property is read-only.

Outer location and size of the EGT indicator returned as `[left bottom width height]`. Position values are relative to the parent container. All measurements are in pixel units. This property value is identical to the `Position` property.

### `Layout` — Layout options

empty `LayoutOptions` array (default) | `GridLayoutOptions` object

Layout options, specified as a `GridLayoutOptions` object. This property specifies options for components that are children of grid layout containers. If the component is not a child of a grid layout container (for example, it is a child of a figure or panel), then this property is empty and has no effect. However, if the component is a child of a grid layout container, you can place the component in the desired row and column of the grid by setting the `Row` and `Column` properties on the `GridLayoutOptions` object.

For example, this code places an EGT indicator in the third row and second column of its parent grid.

```
g = ui([4 3]);
gauge = uiaeroegt(g);
gauge.Layout.Row = 3;
gauge.Layout.Column = 2;
```

To make the EGT indicator span multiple rows or columns, specify the `Row` or `Column` property as a two-element vector. For example, this EGT indicator spans columns `2` through `3`:

```
gauge.Layout.Column = [2 3];
```

#### Callbacks

### `CreateFcn` — Creation function

`''` (default) | function handle | cell array | character vector

Object creation function, specified as one of these values:

- Function handle.
- Cell array in which the first element is a function handle. Subsequent elements in the cell array are the arguments to pass to the callback function.

- Character vector containing a valid MATLAB expression (not recommended). MATLAB evaluates this expression in the base workspace.

For more information about specifying a callback as a function handle, cell array, or character vector, see “Write Callbacks in App Designer” (MATLAB).

This property specifies a callback function to execute when MATLAB creates the object. MATLAB initializes all property values before executing the `CreateFcn` callback. If you do not specify the `CreateFcn` property, then MATLAB executes a default creation function.

Setting the `CreateFcn` property on an existing component has no effect.

If you specify this property as a function handle or cell array, you can access the object that is being created using the first argument of the callback function. Otherwise, use the `gcbo` function to access the object.

### `DeleteFcn` — Deletion function

`''` (default) | function handle | cell array | character vector

Object deletion function, specified as one of these values:

- Function handle.
- Cell array in which the first element is a function handle. Subsequent elements in the cell array are the arguments to pass to the callback function.
- Character vector containing a valid MATLAB expression (not recommended). MATLAB evaluates this expression in the base workspace.

For more information about specifying a callback as a function handle, cell array, or character vector, see “Write Callbacks in App Designer” (MATLAB).

This property specifies a callback function to execute when MATLAB deletes the object. MATLAB executes the `DeleteFcn` callback before destroying the properties of the object. If you do not specify the `DeleteFcn` property, then MATLAB executes a default deletion function.

If you specify this property as a function handle or cell array, you can access the object that is being deleted using the first argument of the callback function. Otherwise, use the `gcbo` function to access the object.

#### Callback Execution Control

### `Interruptible` — Callback interruption

`'on'` (default) | `'off'`

Callback interruption, specified as `'on'` or `'off'`. The `Interruptible` property determines if a running callback can be interrupted.

There are two callback states to consider:

- The running callback is the currently executing callback.
- The interrupting callback is a callback that tries to interrupt the running callback.

Whenever MATLAB invokes a callback, that callback attempts to interrupt the running callback (if one exists). The `Interruptible` property of the object owning the running callback determines if interruption is allowed. The `Interruptible` property has two possible values:

- `'on'` — Allows other callbacks to interrupt the object's callbacks. The interruption occurs at the next point where MATLAB processes the queue, such as when there is a `drawnow`, `figure`, `uifigure`, `getframe`, `waitfor`, or `pause` command.
  - If the running callback contains one of those commands, then MATLAB stops the execution of the callback at that point and executes the interrupting callback. MATLAB resumes executing the running callback when the interrupting callback completes.
  - If the running callback does not contain one of those commands, then MATLAB finishes executing the callback without interruption.
- `'off'` — Blocks all interruption attempts. The `BusyAction` property of the object owning the interrupting callback determines if the interrupting callback is discarded or put into a queue.

---

**Note** Callback interruption and execution behave differently in these situations:

- If the interrupting callback is a `DeleteFcn`, `CloseRequestFcn` or `SizeChangedFcn` callback, then the interruption occurs regardless of the `Interruptible` property value.
- If the running callback is currently executing the `waitfor` function, then the interruption occurs regardless of the `Interruptible` property value.

- `Timer` objects execute according to schedule regardless of the `Interruptible` property value.

When an interruption occurs, MATLAB does not save the state of properties or the display. For example, the object returned by the `gca` or `gcf` command might change when another callback executes.

### `BusyAction` — Callback queuing

`'queue'` (default) | `'cancel'`

Callback queuing, specified as `'queue'` or `'cancel'`. The `BusyAction` property determines how MATLAB handles the execution of interrupting callbacks. There are two callback states to consider:

- The running callback is the currently executing callback.
- The interrupting callback is a callback that tries to interrupt the running callback.

Whenever MATLAB invokes a callback, that callback attempts to interrupt a running callback. The `Interruptible` property of the object owning the running callback determines if interruption is permitted. If interruption is not permitted, then the `BusyAction` property of the object owning the interrupting callback determines if it is discarded or put in the queue. These are possible values of the `BusyAction` property:

- `'queue'` — Puts the interrupting callback in a queue to be processed after the running callback finishes execution.
- `'cancel'` — Does not execute the interrupting callback.

### `BeingDeleted` — Deletion status

`'off'` | `'on'`

This property is read-only.

Deletion status, returned as `'off'` or `'on'`. MATLAB sets the `BeingDeleted` property to `'on'` when the `DeleteFcn` callback begins execution. The `BeingDeleted` property remains set to `'on'` until the component object no longer exists.

Check the value of the `BeingDeleted` property to verify that the object is not about to be deleted before querying or modifying it.

#### Parent/Child

### `Parent` — Parent container

`Figure` object (default) | `Panel` object | `Tab` object | `ButtonGroup` object | `GridLayout` object

Parent container, specified as a `Figure` created using the `uifigure` function, or one of its child containers: `Tab`, `Panel`, `ButtonGroup`, or `GridLayout`.

### `HandleVisibility` — Visibility of object handle

`'on'` (default) | `'callback'` | `'off'`

Visibility of the object handle, specified as `'on'`, `'callback'`, or `'off'`.

This property controls the visibility of the object in its parent's list of children. When an object is not visible in its parent's list of children, it is not returned by functions that obtain objects by searching the object hierarchy or querying properties. These functions include `get`, `findobj`, `clf`, and `close`. Objects are valid even if they are not visible. If you can access an object, you can set and get its properties, and pass it to any function that operates on objects.

| HandleVisibility Value | Description |
|---|---|
| `'on'` | The object is always visible. |
| `'callback'` | The object is visible from within callbacks or functions invoked by callbacks, but not from within functions invoked from the command line. This option blocks access to the object at the command-line, but allows callback functions to access it. |
| `'off'` | The object is invisible at all times. This option is useful for preventing unintended changes to the UI by another function. Set the `HandleVisibility` to `'off'` to temporarily hide the object during the execution of that function. |

#### Identifiers

### `Type` — Type of graphics object

`'uiaeroegt'`

This property is read-only.

Type of graphics object, returned as `'uiaeroegt'`.

### `Tag` — Object identifier

`''` (default) | character vector | string scalar

Object identifier, specified as a character vector or string scalar. You can specify a unique `Tag` value to serve as an identifier for an object. When you need access to the object elsewhere in your code, you can use the `findobj` function to search for the object based on the `Tag` value.

### `UserData` — User data

`[]` (default) | array

User data, specified as any MATLAB array. For example, you can specify a scalar, vector, matrix, cell array, character array, table, or structure. Use this property to store arbitrary data on an object.

If you are working in App Designer, create public or private properties in the app to share data instead of using the `UserData` property. For more information, see “Share Data Within App Designer Apps” (MATLAB).

## See Also

`uiaeroegt`

## Topics

“Create and Configure Flight Instrument Component and an Animation Object” on page 2-69
“Display Flight Trajectory Data Using Flight Instruments and Flight Animation” on page 2-65

### Introduced in R2018b

# fganimation (Aero.FlightGearAnimation)

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`

**Introduced in R2007a**

# findstartstoptimes (Aero.Body)

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`

**Introduced in R2007a**

# findstartstoptimes (Aero.Node)

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;
```

**Introduced in R2007b**

# flat2lla

Convert from flat Earth position to array of geodetic latitude, longitude, and altitude coordinates

## 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`**

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].

**Default:**

# 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`

**Introduced in R2011a**

# flowfanno

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`**

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 |

| Type | Description |
|---|---|
| `'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`

**Introduced in R2010a**

# flowisentropic

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`**

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

`flowfanno` | `flownormalshock` | `flowprandtlmeyer` | `flowrayleigh`

**Introduced in R2010a**

# flownormalshock

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`**

Input mode for the normal shock relations in *normal_shock_relations*, specified as a character vector or string.

| Type | Description |
|---|---|
| `'mach'` | Default. Mach number. |
| `'temp'` | Temperature ratio. |
| `'pres'` | Pressure ratio. |
| `'dens'` | Density ratio. |

| Type | Description |
|---|---|
| `'down'` | Downstream Mach number. |
| `'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

`flowfanno` | `flowisentropic` | `flowprandtlmeyer` | `flowrayleigh`

**Introduced in R2010a**

# flowprandtlmeyer

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`**

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

`flowfanno` | `flowisentropic` | `flownormalshock` | `flowrayleigh`

**Introduced in R2010a**

# flowrayleigh

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`**

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. |
| `'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 stagnation temperature over the reference stagnation 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

`flowfanno` | `flowisentropic` | `flownormalshock` | `flowprandtlmeyer`

**Introduced in R2010a**

# generatePatches (Aero.Body)

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`

**Introduced in R2007a**

# GenerateRunScript (Aero.FlightGearAnimation)

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. |
| `InstallScenery` | Direct FlightGear to automatically install required scenery while the simulator is running. This property requires a steady Internet connection. |
| `DisableShaders` | Disable FlightGear shader options. Your computer built-in video card, such as NVIDIA cards, can conflict with FlightGear shaders. Consider using this property if you have this conflict. |
| `FlightGearVersion` | Specify the version of your FlightGear installation. The default is `2018.1`. |
| `Architecture` | Specify the architecture on which the FlightGear software is running. |

## 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`

**Introduced in R2007a**

# geoc2geod

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. Latitude values can be any value. However, values of +90 and -90 may return unexpected values because of singularity at the poles.

**`radii`**

Array of radii from the center of the planet, in meters.

**`model`**

Specific ellipsoid planet. 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.edu/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

`ecef2lla` | `geod2geoc` | `lla2ecef`

**Introduced in R2006b**

# geocradius

Convert from geocentric latitude to radius of ellipsoid planet

## 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

**Introduced in R2006b**

# geod2geoc

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`. `h` is in meters. Latitude values can be any value. However, values of +90 and -90 may return unexpected values because of singularity at the poles.

`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`. Latitude values can be any value. However, values of +90 and -90 may return unexpected values because of singularity at the poles.

`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. Latitude values can be any value. However, values of +90 and -90 may return unexpected values because of singularity at the poles.

## 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

ecef2lla | geoc2geod | lla2ecef

**Introduced in R2006b**

# geoidegm96

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` | 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 `https://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`

**Introduced in R2007b**

# geoidheight

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.

# 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.

**Default:**

### `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.

### `modelname`

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.<br><br>**Note** This function requires that you download EGM2008 Geopotential Model data with the Add-On Explorer. For more information, see `aeroDataPackage`. |

| Geopotential Model | Description |
|---|---|
| `'Custom'` | Custom geopotential model that you define in *`datafile`*. This function calculates geoid heights to an accuracy of 0.01 m for custom models.<br><br>**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:<br><br>`mcc -m mycustomsgeoidheightfunction...`<br>`-a customDataFile`<br><br>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 `modelname` argument.

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`

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')
```

## 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.

# 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

`gravityspherical harmonic` | `gravitywgs84`

## External Websites

National Geospatial-Intelligence Agency Web site: http://earth-info.nga.mil/GandG/publications/vertdatum.html

**Introduced in R2010b**

# Geometry (Aero.Geometry)

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`

**Introduced in R2007a**

# gravitycentrifugal

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`**

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

`gravitysphericalharmonic` | `gravitywgs84` | `gravityzonal`

**Introduced in R2010a**

# gravitysphericalharmonic

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.

`[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.

# 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`

Planetary model. Default is `'EGM2008'`. Specify one:

| Planetary Model | Planet |
|---|---|
| `'EGM2008'` | Earth Gravitational Model 2008. Planet coordinates are ECEF (WGS84). |
| `'EGM96'` | Earth Gravitational Model 1996. Planet coordinates are ECEF (WGS84). |
| `'LP100K'` | 100th degree Moon model. |
| `'LP165P'` | 165th degree Moon model. |
| `'GMM2B'` | Goddard Mars model 2B. |

| Planetary Model | Planet |
|---|---|
| `'Custom'` | Custom planetary model that you define in *`datafile`*.<br><br>**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:<br><br>`mcc -m mycustomsphericalgravityfunction... -a customDataFile -a customReaderFile`<br><br>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 “Resolve “Out of Memory” Errors” (MATLAB).

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 “Performance and Memory” (MATLAB).

**`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.<br><br>Default degree and order are 120. |
| `'EGM96'` | Maximum degree and order is 360.<br><br>Default degree and order are 70. |
| `'LP100K'` | Maximum degree and order is 100.<br><br>Default degree and order are 60. |
| `'LP165P'` | Maximum degree and order is 165.<br><br>Default degree and order are 60. |

| Planetary Model | Degree and Order |
|---|---|
| `'GMM2B'` | Maximum degree and order is 80.<br><br>Default degree and order are 60. |
| `'Custom'` | Maximum degree is default degree and order. |
| `'EIGENGL04C'` | Maximum degree and order is 360.<br><br>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 “Performance and Memory” (MATLAB).

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 “Performance and Memory” (MATLAB).

**`action`**

Action for out-of-range input. Specify one:
`'Error'`
`'Warning'` (default)
`'None'`

**`'Custom'`**

Character vector or 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) |

| Variable | Description |
|---|---|
| *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 = gravityspherical harmonic( [-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] = gravityspherical harmonic( [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] = gravityspherical harmonic( 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] = gravityspherical harmonic( 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] = gravityspherical harmonic( p, 'EIGENGL04C', ...
120, 'Warning' )
```

# 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 “Performance and Memory” (MATLAB).

- 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 “Performance and Memory” (MATLAB).

## References

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Mission and Altimetry/Gravmetry Surface Data - EIGEN-GL04C”, *Geophysical Research Abstracts*, Vol. 8, 03462, 2006.

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## See Also

`geoidegm96` | `gravitycentrifugal` | `gravitywgs84` | `gravityzonal`

**Introduced in R2010a**

# gravitywgs84

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)
gn = gravitywgs84(h, lat, lon, 'Exact', [noatm, nocent, prec, jd],
action)
[gn gt] = 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'`.

`gn = 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.

`[gn gt] = 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, with respect to the WGS84 ellipsoid. |
| `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` | 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` | 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` 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'`. |
| `gn` | 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'`. |

# 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:

```
[gn, gt] = gravitywgs84( 1000, 0, 20, 'Exact')

gn =

    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];
[gn, gt] = gravitywgs84( h, lat, lon, 'Exact', 'None' )

gn =

    9.7772
    9.7594

gt =

   1.0e-04 *

         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:

```
[gn, gt] = gravitywgs84( 1000, 0, 20, 'Exact', ...
               [ false false true 2451545 ], 'Warning')

gn =

    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:

```
gn = gravitywgs84( 15000, 45, 120, 'Exact', ...
        [ true false true 2451545 ], 'Error')

gn =

    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.”

**Introduced in R2006b**

# gravityzonal

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`

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`**

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.

**Default:**

**`gravityYcoord`**

Array of m gravity values in the *y*-axis of the planet-centered planet-fixed coordinates in meters per second squared.

**Default:**

**`gravityZcoord`**

Array of m gravity values in the *z*-axis of the planet-centered planet-fixed coordinates in meters per second squared.

**Default:**

# 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 |

## Alternatives

Zonal Harmonic Gravity Model block

## 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.

## See Also

`geoidegm96` | `gravitywgs84`

**Introduced in R2009b**

# HeadingIndicator Properties

Control heading indicator appearance and behavior

## Description

Heading indicators are components that represent a heading indicator. Properties control the appearance and behavior of a heading indicator. Use dot notation to refer to a particular object and property:

```
figure = uifigure;
heading = uiaeroheading(figure);
heading.Value = 100;
```

## Properties

**Heading Indicator**

### `Heading` — Location of aircraft heading

`0` (default) | finite, real, and scalar numeric

Location of the aircraft heading, specified as any finite and scalar numeric, in degrees.

- Changing the value changes the direction of the heading. It displays the exact value.

Example: `60`

**Dependencies**

Specifying this value changes the value of `Value`.

Data Types: `double`

### `Value` — Location of aircraft heading

`0` (default) | finite, real, and scalar numeric

Location of the aircraft heading, specified as any finite and scalar numeric, in degrees.

- Changing the value changes the direction of the heading.

Example: `60`

**Dependencies**

Specifying this value changes the value of `Heading`.

Data Types: `double`

**Interactivity**

### `Visible` — Visibility of heading indicator

`'on'` (default) | `'off'`

Visibility of the heading indicator, specified as `'on'` or `'off'`. The `Visible` property determines whether the heading indicator, is displayed on the screen. If the `Visible` property is set to `'off'`, then the entire heading indicator is hidden, but you can still specify and access its properties.

### `Enable` — Operational state of header indicator

`'on'` (default) | `'off'`

Operational state of header indicator, specified as `'on'` or `'off'`.

- If you set this property to `'on'`, then the appearance of the header indicator indicates that the header indicator is operational.
- If you set this property to `'off'`, then the appearance of the header indicator appears dimmed, indicating that the header indicator is not operational.

**Position**

### `Position` — Location and size of header indicator

`[100 100 120 120]` (default) | `[left bottom width height]`

Location and size of the header indicator relative to the parent container, specified as the vector, `[left bottom width height]`. This table describes each element in the vector.

| Element | Description |
|---|---|
| `left` | Distance from the inner left edge of the parent container to the outer left edge of an imaginary box surrounding the header indicator |

| Element | Description |
|---|---|
| `bottom` | Distance from the inner bottom edge of the parent container to the outer bottom edge of an imaginary box surrounding the header indicator |
| `width` | Distance between the right and left outer edges of the header indicator |
| `height` | Distance between the top and bottom outer edges of the header indicator |

All measurements are in pixel units.

The `Position` values are relative to the drawable area of the parent container. The drawable area is the area inside the borders of the container and does not include the area occupied by decorations such as a menu bar or title.

Example: `[200 120 120 120]`

**`InnerPosition` — Inner location and size of heading indicator**
`[100 100 120 120]` (default) | `[left bottom width height]`

Inner location and size of the heading indicator, specified as `[left bottom width height]`. Position values are relative to the parent container. All measurements are in pixel units. This property value is identical to the `Position` property.

**`OuterPosition` — Outer location and size of heading indicator**
`[100 100 120 120]]` (default) | `[left bottom width height]`

This property is read-only.

Outer location and size of the heading indicator returned as `[left bottom width height]`. Position values are relative to the parent container. All measurements are in pixel units. This property value is identical to the `Position` property.

**`Layout` — Layout options**
empty `LayoutOptions` array (default) | `GridLayoutOptions` object

Layout options, specified as a `GridLayoutOptions` object. This property specifies options for components that are children of grid layout containers. If the component is not a child of a grid layout container (for example, it is a child of a figure or panel), then this property is empty and has no effect. However, if the component is a child of a grid

layout container, you can place the component in the desired row and column of the grid by setting the `Row` and `Column` properties on the `GridLayoutOptions` object.

For example, this code places an heading indicator in the third row and second column of its parent grid.

```
g = ui([4 3]);
gauge = uiaeroheading(g);
gauge.Layout.Row = 3;
gauge.Layout.Column = 2;
```

To make the heading indicator span multiple rows or columns, specify the `Row` or `Column` property as a two-element vector. For example, this heading indicator spans columns `2` through `3`:

```
gauge.Layout.Column = [2 3];
```

**Callbacks**

### `CreateFcn` — Creation function

`''` (default) | function handle | cell array | character vector

Object creation function, specified as one of these values:

- Function handle.
- Cell array in which the first element is a function handle. Subsequent elements in the cell array are the arguments to pass to the callback function.
- Character vector containing a valid MATLAB expression (not recommended). MATLAB evaluates this expression in the base workspace.

For more information about specifying a callback as a function handle, cell array, or character vector, see “Write Callbacks in App Designer” (MATLAB).

This property specifies a callback function to execute when MATLAB creates the object. MATLAB initializes all property values before executing the `CreateFcn` callback. If you do not specify the `CreateFcn` property, then MATLAB executes a default creation function.

Setting the `CreateFcn` property on an existing component has no effect.

If you specify this property as a function handle or cell array, you can access the object that is being created using the first argument of the callback function. Otherwise, use the `gcbo` function to access the object.

### `DeleteFcn` — Deletion function

`''` (default) | function handle | cell array | character vector

Object deletion function, specified as one of these values:

- Function handle.
- Cell array in which the first element is a function handle. Subsequent elements in the cell array are the arguments to pass to the callback function.
- Character vector containing a valid MATLAB expression (not recommended). MATLAB evaluates this expression in the base workspace.

For more information about specifying a callback as a function handle, cell array, or character vector, see “Write Callbacks in App Designer” (MATLAB).

This property specifies a callback function to execute when MATLAB deletes the object. MATLAB executes the `DeleteFcn` callback before destroying the properties of the object. If you do not specify the `DeleteFcn` property, then MATLAB executes a default deletion function.

If you specify this property as a function handle or cell array, you can access the object that is being deleted using the first argument of the callback function. Otherwise, use the `gcbo` function to access the object.

#### Callback Execution Control

### `Interruptible` — Callback interruption

`'on'` (default) | `'off'`

Callback interruption, specified as `'on'` or `'off'`. The `Interruptible` property determines if a running callback can be interrupted.

There are two callback states to consider:

- The running callback is the currently executing callback.
- The interrupting callback is a callback that tries to interrupt the running callback.

Whenever MATLAB invokes a callback, that callback attempts to interrupt the running callback (if one exists). The `Interruptible` property of the object owning the running callback determines if interruption is allowed. The `Interruptible` property has two possible values:

- `'on'` — Allows other callbacks to interrupt the object's callbacks. The interruption occurs at the next point where MATLAB processes the queue, such as when there is a `drawnow`, `figure`, `uifigure`, `getframe`, `waitfor`, or `pause` command.
  - If the running callback contains one of those commands, then MATLAB stops the execution of the callback at that point and executes the interrupting callback. MATLAB resumes executing the running callback when the interrupting callback completes.
  - If the running callback does not contain one of those commands, then MATLAB finishes executing the callback without interruption.
- `'off'` — Blocks all interruption attempts. The `BusyAction` property of the object owning the interrupting callback determines if the interrupting callback is discarded or put into a queue.

---

**Note** Callback interruption and execution behave differently in these situations:

- If the interrupting callback is a `DeleteFcn`, `CloseRequestFcn` or `SizeChangedFcn` callback, then the interruption occurs regardless of the `Interruptible` property value.
- If the running callback is currently executing the `waitfor` function, then the interruption occurs regardless of the `Interruptible` property value.
- `Timer` objects execute according to schedule regardless of the `Interruptible` property value.

When an interruption occurs, MATLAB does not save the state of properties or the display. For example, the object returned by the `gca` or `gcf` command might change when another callback executes.

---

### `BusyAction` — Callback queuing

`'queue'` (default) | `'cancel'`

Callback queuing, specified as `'queue'` or `'cancel'`. The `BusyAction` property determines how MATLAB handles the execution of interrupting callbacks. There are two callback states to consider:

- The running callback is the currently executing callback.
- The interrupting callback is a callback that tries to interrupt the running callback.

Whenever MATLAB invokes a callback, that callback attempts to interrupt a running callback. The `Interruptible` property of the object owning the running callback determines if interruption is permitted. If interruption is not permitted, then the `BusyAction` property of the object owning the interrupting callback determines if it is discarded or put in the queue. These are possible values of the `BusyAction` property:

- `'queue'` — Puts the interrupting callback in a queue to be processed after the running callback finishes execution.
- `'cancel'` — Does not execute the interrupting callback.

### `BeingDeleted` — Deletion status

`'off'` | `'on'`

This property is read-only.

Deletion status, returned as `'off'` or `'on'`. MATLAB sets the `BeingDeleted` property to `'on'` when the `DeleteFcn` callback begins execution. The `BeingDeleted` property remains set to `'on'` until the component object no longer exists.

Check the value of the `BeingDeleted` property to verify that the object is not about to be deleted before querying or modifying it.

#### Parent/Child

### `Parent` — Parent container

`Figure` object (default) | `Panel` object | `Tab` object | `ButtonGroup` object | `GridLayout` object

Parent container, specified as a `Figure` created using the `uifigure` function, or one of its child containers: `Tab`, `Panel`, `ButtonGroup`, or `GridLayout`.

### `HandleVisibility` — Visibility of object handle

`'on'` (default) | `'callback'` | `'off'`

Visibility of the object handle, specified as `'on'`, `'callback'`, or `'off'`.

This property controls the visibility of the object in its parent's list of children. When an object is not visible in its parent's list of children, it is not returned by functions that obtain objects by searching the object hierarchy or querying properties. These functions include `get`, `findobj`, `clf`, and `close`. Objects are valid even if they are not visible. If you can access an object, you can set and get its properties, and pass it to any function that operates on objects.

| HandleVisibility Value | Description |
|---|---|
| `'on'` | The object is always visible. |
| `'callback'` | The object is visible from within callbacks or functions invoked by callbacks, but not from within functions invoked from the command line. This option blocks access to the object at the command-line, but allows callback functions to access it. |
| `'off'` | The object is invisible at all times. This option is useful for preventing unintended changes to the UI by another function. Set the `HandleVisibility` to `'off'` to temporarily hide the object during the execution of that function. |

**Identifiers**

### Type — Type of graphics object

`'uiaeroheading'`

This property is read-only.

Type of graphics object, returned as `'uiaeroheading'`.

### Tag — Object identifier

`''` (default) | character vector | string scalar

Object identifier, specified as a character vector or string scalar. You can specify a unique `Tag` value to serve as an identifier for an object. When you need access to the object elsewhere in your code, you can use the `findobj` function to search for the object based on the `Tag` value.

### UserData — User data

`[]` (default) | array

User data, specified as any MATLAB array. For example, you can specify a scalar, vector, matrix, cell array, character array, table, or structure. Use this property to store arbitrary data on an object.

If you are working in App Designer, create public or private properties in the app to share data instead of using the `UserData` property. For more information, see “Share Data Within App Designer Apps” (MATLAB).

## See Also

`uiaeroheading`

## Topics

“Create and Configure Flight Instrument Component and an Animation Object” on page 2-69
“Display Flight Trajectory Data Using Flight Instruments and Flight Animation” on page 2-65

**Introduced in R2018b**

# hide

**Class:** Aero.Animation
**Package:** Aero

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;
```

# igrfmagm

Calculate Earth magnetic field and secular variation using International Geomagnetic Reference Field

## Syntax

```
[magFieldVector,horIntensity,declination,inclination,totalIntensity,
magFieldSecVariation,secVariationHorizontal,secVariationDeclination,
secVariationInclination,secVariationTotal] = igrfmagm(height,
latitude,longitude,decimalYear,generation)
```

## Description

`[magFieldVector,horIntensity,declination,inclination,totalIntensity, magFieldSecVariation,secVariationHorizontal,secVariationDeclination, secVariationInclination,secVariationTotal] = igrfmagm(height, latitude,longitude,decimalYear,generation)` calculates the Earth magnetic field and the secular variation at a specific location and time using different generations of the International Geomagnetic Reference Field.

## Examples

### Calculate the Magnetic Model

Calculate the magnetic model 1000 meters over Natick, Massachusetts on July 4, 2015 using IGRF-12.

```
[mag_field_vector,hor_intensity,declinatioon,inclination,total_intensity] ...
= igrfmagm(1000,42.283,-71.35,decyear(2015,7,4),12)
```

```
mag_field_vector =

   1.0e+04 *
```

```
    1.9460   -0.5091    4.8179

hor_intensity =

   2.0115e+04

declinatioon =

  -14.6612

inclination =

   67.3387

total_intensity =

   5.2209e+04
```

# Input Arguments

### `height` — Distance

scalar

Distance, in meters, from the surface of the Earth, specified as a scalar.

### `latitude` — Geodetic latitude

scalar

Geodetic latitude, in degrees, specified as a scalar. North latitude is positive, and south latitude is negative.

### `longitude` — Geodetic longitude

scalar

Geodetic longitude, in degrees, specified as a scalar. East longitude is positive, and west longitude is negative.

### `decimalYear` — Year

scalar

Year, in decimal format, specified as a decimal. This value is the desired year, including any fraction of the year that has already passed.

**`generation` — Generation version of International Geomagnetic Reference Field**
12 (default) | 11

Generation version of the International Geomagnetic Reference Field, specified as `11` or `12`.

## Output Arguments

**`magFieldVector` — Magnetic field vector**
vector

Magnetic field vector, in nanotesla (nT), returned as a vector. *Z* is the vertical component (+ve down).

**`horIntensity` — Horizontal intensity**
scalar

Horizontal intensity, in nanotesla (nT), returned as a scalar.

**`declination` — Declination**
scalar

Declination, in degrees (+ve east), returned as a scalar.

**`inclination` — Inclination**
scalar

Inclination, in degrees (+ve down), returned as a scalar.

**`totalIntensity` — Total intensity**
scalar

Total intensity, in nanotesla (nT), returned as a scalar.

**`magFieldSecVariation` — Secular variation in magnetic field vector**
vector

Secular variation in magnetic field vector, in nT/year, returned as a vector. *Z* is the vertical component (+ve down).

**`secVariationHorizontal` — Secular variation in horizontal intensity**
scalar

Secular variation in horizontal intensity, in nT/year, returned as a scalar.

**`secVariationDeclination` — Secular variation in declination**
scalar

Secular variation in declination, in minutes/year (+ve east), returned as a scalar.

**`secVariationInclination` — Secular variation in inclination**
scalar

Secular variation in inclination, in minutes/year (+ve down), returned as a scalar.

**`secVariationTotal` — Secular variation in total intensity**
scalar

Secular variation in total intensity, in nT/year, returned as a scalar.

# Limitation

This function is valid between the heights of –1000 meters to 600,000 meters.

The 11th generation is valid between the years of 1900 and 2015, and 12th generation is valid between the years of 1900 and 2020.

This function has the limitations of the International Geomagnetic Reference Field (IGRF). For more information, see the IGRF website, `https://www.ngdc.noaa.gov/IAGA/vmod/igrfhw.html`.

## References

[1] Blakely, R. J. *Potential Theory in Gravity & Magnetic Applications*. Cambridge, UK: Cambridge University Press, 1996.

[2] Lowes, F. J. “The International Geomagnetic Reference Field: A 'Health' Warning.” January, 2010. https://www.ngdc.noaa.gov/IAGA/vmod/igrfhw.html.

# See Also

`decyear` | `wrldmagm`

## External Websites

https://www.ngdc.noaa.gov/IAGA/vmod/igrfhw.html

**Introduced in R2015b**

# initialize

**Class:** Aero.Animation
**Package:** Aero

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)

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

`GenerateRunScript` | `delete` | `play` | `update`

**Introduced in R2007a**

# initialize (Aero.VirtualRealityAnimation)

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 exists, 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`

**Introduced in R2007b**

# initIfNeeded

**Class:** Aero.Animation
**Package:** Aero

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;
```

# juliandate

Julian date calculator

## 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 dates, `s`, into Julian date, `jd`, using format `f`. `s` can be a character array, where each row corresponds to one date character vector, or a one-dimensional cell array of character vectors. `juliandate` returns a column vector of `m` Julian dates, where `m` is the number of character vectors in `s`.

All of the dates in `s` must have the same format `f`, composed of the same date format symbols as `datestr`. `juliandate` does not accept formats containing the letter `Q`.

If the format does not contain enough information to compute a date number, then:

- Hours, minutes, and seconds default to 0.
- Days default to 1.

- Months default to January.
- Years default to the current year.

Dates with two-character years are interpreted to be within 100 years of 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. Specify `y`, `mo`, and `d` as one-dimensional arrays of the same length or scalar values.

`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. Specify the six input arguments as either one-dimensional arrays of the same length or scalar values.

## 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`

**Introduced in R2006b**

# leapyear

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`

**Introduced in R2006b**

# lla2ecef

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. Latitude and longitude values can be any value. However, latitude values of +90 and -90 may return unexpected values because of singularity at the poles.

`p = lla2ecef(lla, model)` is an alternate method for converting the coordinates for a specific ellipsoid planet. Currently only `'WGS84'` is supported for `model`. Latitude and longitude values can be any value. However, latitude values of +90 and -90 may return unexpected values because of singularity at the poles.

`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. Latitude and longitude values can be any value. However, latitude values of +90 and -90 may return unexpected values because of singularity at the poles.

## 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`

**Introduced in R2006b**

# lla2eci

Convert geodetic latitude, longitude, altitude (LLA) coordinates to Earth-centered inertial (ECI) coordinates

## Syntax

```
position = lla2eci(lla,utc)

position = lla2eci(lla,utc,reduction)
position = lla2eci(lla,utc,reduction,deltaAT)
position = lla2eci(lla,utc,reduction,deltaAT,deltaUT1)
position = lla2eci(lla,utc,reduction,deltaAT,deltaUT1,polarmotion)
position = lla2eci(lla,utc,reduction,deltaAT,deltaUT1,polarmotion,
Name,Value)
```

## Description

`position = lla2eci(lla,utc)` converts geodetic latitude, longitude, altitude (LLA) coordinates to Earth-centered inertial (ECI) position coordinates as an *M*-by-3 array. The conversion is based on the Universal Coordinated Time (UTC) you specify.

`position = lla2eci(lla,utc,reduction)` converts geodetic latitude, longitude, altitude (LLA) coordinates to Earth-centered inertial (ECI) position coordinates as an *M*-by-3 array. The conversion is based on the specified reduction method and the Universal Coordinated Time (UTC) you specify.

`position = lla2eci(lla,utc,reduction,deltaAT)` uses the difference between International Atomic Time and UTC that you specify as `deltaAT` to calculate the ECI coordinates.

`position = lla2eci(lla,utc,reduction,deltaAT,deltaUT1)` uses the difference between UTC and Universal Time (UT1), which you specify as `deltaUT1`, in the calculation.

`position = lla2eci(lla,utc,reduction,deltaAT,deltaUT1,polarmotion)` uses the polar displacement, `polarmotion`, in the calculation.

`position = lla2eci(lla,utc,reduction,deltaAT,deltaUT1,polarmotion, Name,Value)` uses additional options specified by one or more Name,Value pair arguments.

# Examples

### Convert Position to ECI Coordinates Using UTC

Convert the position to ECI coordinates from LLA coordinates 6 degrees north, 75 degrees west, and 1000 meters altitude at 01/17/2010 10:20:36 UTC.

```
position = lla2eci([6 -75 1000],[2010 1 17 10 20 36])
```

```
position=

   1.0e+06 *

   -6.0744   -1.8289    0.6685
```

### Convert Position to ECI coordinates Using UTC and Reduction Method IAU-76/FK5

Convert the position to ECI coordinates from LLA coordinates 55 deg south, 75 deg west, and 500 meters altitude at 01/12/2000 4:52:12.4 UTC. Specify all arguments, including optional ones such as polar motion.

```
position = lla2eci([-55 -75 500],[2000 1 12 4 52 12.4],...
'IAU-76/FK5',32,0.234,[-0.0682e-5 0.1616e-5],...
'dNutation',[-0.2530e-6 -0.0188e-6],...
'flattening',1/290,'RE',60000)
```

```
position=

   1.0e+04 *
```

```
   -1.1358    3.2875   -4.9333
```

# Input Arguments

### `lla` — Latitude, longitude, altitude (LLA) coordinates

*M*-by-3 array

Latitude, longitude, altitude (LLA) coordinates as *M*-by-3 array of geodetic coordinates, in degrees, degrees, and meters, respectively. Latitude and longitude values can be any value. However, latitude values of +90 and -90 may return unexpected values because of singularity at the poles.

### `utc` — Universal Coordinated Time

1-by-6 array | *M*-by-6 matrix

Universal Coordinated Time (UTC), in the order year, month, day, hour, minutes, and seconds, for which the function calculates the conversion, specified as one of the following.

- For the year value, enter a double value that is a whole number greater than 1, such as `2013`.
- For the month value, enter a double value that is a whole number greater than 0, within the range `1` to `12`.
- For the hour value, enter a double value that is a whole number greater than 0, within the range `1` to `24`.
- For the hour value, enter a double value that is a whole number greater than 0, within the range `1` to `60`.
- For the minute and second values, enter a double value that is a whole number greater than 0, within the range `1` to `60`.

Specify these values in one of the following formats:

- 1-by-6 array

  Specify a 1-row-by-6-column array of UTC values.
- *M*-by-6 matrix

Specify an *M*-by-6 array of UTC values, where *M* is the number of transformation matrices to calculate. Each row corresponds to one set of UTC values.

This is a one row-by-6 column array of UTC values.

Example: `[2000 1 12 4 52 12.4]`

This is an *M*-by-6 array of UTC values, where *M* is 2.

Example: `[2000 1 12 4 52 12.4;2010 6 5 7 22 0]`

Data Types: `double`

### `reduction` — Reduction method

`'IAU-2000/2006'` (default) | `'IAU-76/FK5'`

Reduction method to calculate the coordinate conversion, specified as one of the following:

- `'IAU-76/FK5'`

  Reduce the calculation using the International Astronomical Union (IAU)-76/Fifth Fundamental Catalogue (FK5) (IAU-76/FK5) reference system. Choose this reduction method if the reference coordinate system for the conversion is FK5. You can use the `'dNutation'` Name,Value pair with this reduction.

  **Note** This method uses the IAU 1976 precession model and the IAU 1980 theory of nutation to reduce the calculation. This model and theory are no longer current, but the software provides this reduction method for existing implementations. Because of the polar motion approximation that this reduction method uses, `lla2eci` performs a coordinate conversion that is not orthogonal because of the polar motion approximation.

- `'IAU-2000/2006'`

  Reduce the calculation using the International Astronomical Union (IAU)-2000/2005 reference system. Choose this reduction method if the reference coordinate system for the conversion is IAU-2000. This reduction method uses the P03 precession model to reduce the calculation. You can use the `'dCIP'` Name,Value pair with this reduction.

### `deltaAT` — Difference between International Atomic Time and UTC

*M*-by-1 array of zeroes (default) | scalar | one-dimensional array

Difference between International Atomic Time (IAT) and UTC, in seconds, for which the function calculates the coordinate conversion.

- scalar

  Specify one difference-time value to calculate one direction cosine or transformation matrix.

- one-dimensional array

  Specify a one-dimensional array with *M* elements, where *M* is the number of ECI coordinates. Each row corresponds to one set of ECI coordinates.

Specify `32` seconds as the difference between IAT and UTC.

Example: `32`

Data Types: `double`

### `deltaUT1` — Difference between UTC and Universal Time (UT1)

*M*-by-1 array of zeroes (default) | scalar | one-dimensional array

Difference between UTC and Universal Time (UT1), in seconds, for which the function calculates the coordinate conversion.

- scalar

  Specify one difference-time value to calculate ECI coordinates.

- one-dimensional array

  Specify a one-dimensional array with *M* elements of difference time values, where *M* is the number of ECI coordinates. Each row corresponds to one set of ECI coordinates.

Specify `0.234` seconds as the difference between UTC and UT1.

Example: `0.234`

Data Types: `double`

### `polarmotion` — Polar displacement

*M*-by-2 array of zeroes (default) | 1-by-2 array | *M*-by-2 array

Polar displacement of the Earth, in radians, from the motion of the Earth crust, along the *x*- and *y*-axes.

- 1-by-2 array

  Specify a 1-by-2 array of the polar displacement values to convert one ECI coordinate.

- *M*-by-2 array

  Specify an *M*-by-2 array of polar displacement values, where *M* is the number of ECI coordinates to convert. Each row corresponds to one set of UTC values.

Example: `[-0.0682e-5 0.1616e-5]`

Data Types: `double`

## Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name,Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside quotes. You can specify several name and value pair arguments in any order as `Name1,Value1,...,NameN,ValueN`.

Example: `'dNutation',[-0.2530e-6 -0.0188e-6]`

**`dNutation` — Adjustment to longitude (*dDeltaPsi*) and obliquity (*dDeltaEpsilon*)**
*M*-by-2 array of zeroes (default) | *M*-by-2 array

Adjustment to the longitude (*dDeltaPsi*) and obliquity (*dDeltaEpsilon*), specified in radians, as the comma-separated pair consisting of `dNutation` and an *M*-by-2 array. You can use this Name,Value pair with the IAU-76/FK5 reduction.

For historical values, see the International Earth Rotation and Reference Systems Service website (`https://www.iers.org`) and navigate to the Earth Orientation Data Data/Products page.

- *M*-by-2 array

  Specify *M*-by-2 array of adjustment values, where *M* is the number of LLA coordinates to be converted. Each row corresponds to one set of longitude and obliquity values.

Data Types: `double`

**`dCIP` — Adjustment to the location of the celestial intermediate pole (CIP)**
*M*-by-2 array of zeroes (default) | *M*-by-2 array

Adjustment to the location of the Celestial Intermediate Pole (CIP), in radians, specified as the comma-separated pair consisting of `dCIP` and an *M*-by-2 array. This location (*dDeltaX*, *dDeltaY*) is along the *x*- and *y*- axes. You can use this argument with the IAU-200/2006 reduction. By default, this function assumes an *M*-by-2 array of zeroes.

For historical values, see the International Earth Rotation and Reference Systems Service website (`https://www.iers.org`) and navigate to the Earth Orientation Data Data/Products page.

- *M*-by-2 array

  Specify *M*-by-2 array of location adjustment values, where *M* is the number of LLA coordinates to be converted. Each row corresponds to one set of *dDeltaX* and *dDeltaY* values.

Example: `'dcip',[-0.2530e-6 -0.0188e-6]`

Data Types: `double`

**`flattening` — Custom ellipsoid planet**
1-by-1 array

Custom ellipsoid planet defined by flattening.

Example: `1/290`

Data Types: `double`

**`re` — Custom planet ellipsoid radius**
1-by-1 array

Custom planet ellipsoid radius, in meters.

Example: `60000`

Data Types: `double`

## See Also

`dcmeci2ecef` | `ecef2lla` | `eci2lla` | `geoc2geod` | `geod2geoc` | `lla2ecef`

**Introduced in R2014a**

# lla2flat

Convert from geodetic latitude, longitude, and altitude to flat Earth position

## 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`.

## Input Arguments

### `lla`

*`m`*-by-3 array of geodetic coordinates (latitude, longitude, and altitude), in [degrees, degrees, meters]. Latitude and longitude values can be any value. However, latitude values of +90 and -90 may return unexpected values because of singularity at the poles.

**Default:**

**`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`**

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
```

# 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.

## 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`

**Introduced in R2011a**

# load (Aero.Body)

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`

**Introduced in R2007a**

# machnumber

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`

**Introduced in R2006b**

# mjuliandate

Modified Julian date calculator

## 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 the first two digits of its corresponding Julian date are 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 dates, `s`, into modified Julian date, `mjd`, using format `f`. `s` can be a character array, where each row corresponds to one date character vector, or a one-dimensional cell array of character vectors. `mjuliandate` returns a column vector of `m` modified Julian dates, where `m` is the number of character vectors in `s`.

All of the dates in `s` must have the same format `f`, composed of the same date format symbols as the `datestr` function. `mjuliandate` does not accept formats containing the letter *`Q`*.

If a format does not contain enough information to compute a date number, then:

- Hours, minutes, and seconds default to 0.
- Days default to 1.
- Months default to January.
- Years default to the current year.

Dates with two-character years are interpreted to be within 100 years of 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. Specify `y`, `mo`, and `d` as one-dimensional arrays of the same length or scalar values.

`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. Specify the six arguments as one-dimensional arrays of the same length or scalar values.

# 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`

**Introduced in R2006b**

# moonLibration

Moon librations

## Syntax

```
angles= moonLibration(ephemerisTime)
angles= moonLibration(ephemerisTime,ephemerisModel)
angles= moonLibration(ephemerisTime,ephemerisModel,action)

[angles,rates] = moonLibration( ___ )
```

## Description

`angles= moonLibration(ephemerisTime)` implements the Moon libration angles for `ephemerisTime`, expressed in Julian days.

The function uses the Chebyshev coefficients that the NASA Jet Propulsion Laboratory provides.

This function requires that you download ephemeris data with the Add-On Explorer. For more information, see `aeroDataPackage`.

`angles= moonLibration(ephemerisTime,ephemerisModel)` uses the `ephemerisModel` coefficients to implement these values.

`angles= moonLibration(ephemerisTime,ephemerisModel,action)` uses `action` to determine error reporting.

`[angles,rates] = moonLibration( ___ )` implements the Moon libration angles and rates using any combination of the input arguments in the previous syntaxes.

## Examples

### Implement Libration Angles of Moon

Implement libration angles of the Moon for December 1, 1990 with DE405. Use the juliandate function to calculate the input Julian date value.

```
angles = moonLibration(juliandate(1990,12,1))
```

```
angles =
   1.0e+03 *
    0.0001    0.0004    1.8010
```

### Implement Libration Angles and Rates for Moon

Specify the ephemerides (DE421) and use the juliandate function for the date (January 1, 2000) to calculate both the Moon libration angles and rates.

```
[angles,rates] = moonLibration([2451544.5 0.5],'421')
```

```
angles =
   1.0e+03 *
   -0.0001    0.0004    2.5643

rates =
   -0.0001    0.0000    0.2301
```

## Input Arguments

### `ephemerisTime` — Julian dates

scalar | 2-element vector | column vector | *M*-by-2 matrix

Julian dates for which the positions are calculated, specified as one of the following:

- Scalar

  Specify one fixed Julian date.
- 2-element vector

  Specify the Julian date in multiple parts. The first element is the Julian date for a specific epoch that is the most recent midnight at or before the interpolation epoch. The second element is the fractional part of a day elapsed between the first element

and epoch. The second element must be positive. The value of the first element plus the second element cannot exceed the maximum Julian date.

- Column vector

  Specify a column vector with *M* elements, where *M* is the number of Julian dates.

- *M*-by-2 matrix

  Specify a matrix, where *M* is the number of Julian dates and the second column contains the elapsed days (Julian epoch date/elapsed day pairs).

Data Types: `double`

**`ephemerisModel` — Ephemerides coefficients**
`'405'` (default) | `'421'` | `'423'` | `'430'` | `'432t'`

Ephemerides coefficients, specified as one of these ephemerides defined by the Jet Propulsion Laboratory:

- `'405'`

  Released in 1998. This ephemerides takes into account the Julian date range 2305424.50 (December 9, 1599 ) to 2525008.50 (February 20, 2201).

  This function calculates these ephemerides with respect to the International Celestial Reference Frame version 1.0, adopted in 1998.

- `'421'`

  Released in 2008. This ephemerides takes into account the Julian date range 2414992.5 (December 4, 1899) to 2469808.5 (January 2, 2050).

  This function calculates these ephemerides with respect to the International Celestial Reference Frame version 1.0, adopted in 1998.

- `'423'`

  Released in 2010. This ephemerides takes into account the Julian date range 2378480.5 (December 16, 1799) to 2524624.5 (February 1, 2200).

  This function calculates these ephemerides with respect to the International Celestial Reference Frame version 2.0, adopted in 2010.

- `'430'`

Released in 2013. This ephemerides takes into account the Julian date range 2287184.5 (December 21, 1549) to 2688976.5 (January 25, 2650).

This block implements these ephemerides with respect to the International Celestial Reference Frame version 2.0, adopted in 2010.

- `'432t'`

  Released in April 2014. This ephemerides takes into account the Julian date range 2287184.5, (December 21, 1549 ) to 2688976.5, (January 25, 2650).

  This block implements these ephemerides with respect to the International Celestial Reference Frame version 2.0, adopted in 2010.

Data Types: `char`

### `action` — Function behavior

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

Function behavior when inputs are out of range, specified as one of these values:

| Value | Description |
|---|---|
| `'None'` | No action. |
| `'Warning'` | Warning in the MATLAB Command Window, model simulation continues. |
| `'Error'` | MATLAB returns an exception, model simulation stops. |

Data Types: `char`

## Output Arguments

### `angles` — Moon libration angles

*M*-by-3 numeric array

Moon libration angles, specified as an *M*-by-3 numeric array. *M* is the number of Julian dates, in rows. The columns contain the Euler angles (φ θ ψ) for Moon attitude, in radians.

If the input arguments include multiple Julian dates or epochs, this array has the same number of rows as the `ephemerisTime` input.

**`rates` — Moon libration angular rates**
*M*-by-3 numeric array

Moon libration angular rates, specified as an *M*-by-3 numeric array. *M* is the number of Julian dates, in rows. The columns contain the Moon libration Euler angular rates (ω), in radians/day.

If the input arguments include multiple Julian dates or epochs, this array has the same number of rows as the `ephemerisTime` input.

## References

[1] Folkner, W. M., J. G. Williams, D. H. Boggs, "The Planetary and Lunar Ephemeris DE 421," *JPL Interplanetary Network Progress Report 24-178*, 2009.

[2] Vallado, D. A., *Fundamentals of Astrodynamics and Applications*, McGraw-Hill, New York, 1997.

# See Also

`earthNutation` | `juliandate` | `planetEphemeris`

## External Websites

`https://ssd.jpl.nasa.gov/?planet_eph_export`
`https://syrte.obspm.fr/jsr/journees2010/powerpoint/folkner.pdf`

**Introduced in R2013a**

# move (Aero.Body)

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`

**Introduced in R2007a**

# move (Aero.Node)

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. The defined aerospace body coordinate system is defined relative to the screen as *x*-left, *y*-in, *z*-down.

`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. The defined VRML coordinate system is defined relative to the screen as *x*-right, *y*-up, *z*-out.

## 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`

**Introduced in R2007b**

# moveBody

**Class:** Aero.Animation
**Package:** Aero

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)

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`

**Introduced in R2007b**

# nodeInfo (Aero.VirtualRealityAnimation)

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

**Introduced in R2007b**

# planetEphemeris

Position and velocity of astronomical objects

## Syntax

```
position= planetEphemeris(ephemerisTime,center,target)
position = planetEphemeris(ephemerisTime,center,target,
ephemerisModel)
position = planetEphemeris(ephemerisTime,center,target,
ephemerisModel,units)
position= planetEphemeris(ephemerisTime,center,target,
ephemerisModel,units,action)

[position,velocity] = planetEphemeris( ___ )
```

## Description

`position= planetEphemeris(ephemerisTime,center,target)` implements the position of the target object relative to the specified center object for a given Julian date `ephemerisTime`. By default, the function implements the position based on the DE405 ephemerides in units of km.

The function uses the Chebyshev coefficients that the NASA Jet Propulsion Laboratory provides.

This function requires that you download ephemeris data with the Add-On Explorer. For more information, see `aeroDataPackage`.

`position = planetEphemeris(ephemerisTime,center,target, ephemerisModel)` uses the `ephemerisModel` coefficients to implement these values.

`position = planetEphemeris(ephemerisTime,center,target, ephemerisModel,units)` specifies the units for these values.

`position= planetEphemeris(ephemerisTime,center,target, ephemerisModel,units,action)` uses `action` to determine error reporting.

`[position,velocity] = planetEphemeris( ___ )` implements the position and velocity of a the target object relative to the specified center for a given Julian date `ephemerisTime` using any of the input arguments in the previous syntaxes.

# Examples

### Implement Position of Moon

Implement the position of the Moon with respect to the Earth for December 1, 1990 with DE405:

```
position = planetEphemeris(juliandate(1990,12,1),'Earth','Moon')
```

```
position =
   1.0e+05 *
    2.3112    2.3817    1.3595
```

### Implement Position and Velocity for Saturn

Implement the position and velocity for Saturn with respect to the Solar System barycenter for noon on January 1, 2000 using DE421 and AU units:

```
[position,velocity] = planetEphemeris([2451544.5 0.5],...
'SolarSystem','Saturn','421','AU')
```

```
position =
    6.3993    6.1720    2.2738
velocity =
   -0.0043    0.0035    0.0016
```

# Input Arguments

### `ephemerisTime` — Julian date

scalar | 2-element vector | column vector | *M*-by-2 matrix

Julian date for which the positions are calculated, specified as one of the following:

- Scalar

  Specify one fixed Julian date.
- 2-element vector

  Specify the Julian date in multiple parts. The first element is the Julian date for a specific epoch that is the most recent midnight at or before the interpolation epoch. The second element is the fractional part of a day elapsed between the first element and epoch. The second element must be positive. The value of the first element plus the second element cannot exceed the maximum Julian date.
- Column vector

  Specify a column vector with *M* elements, where *M* is the number of fixed Julian dates.
- *M*-by-2 matrix

  Specify a matrix, where *M* is the number of Julian dates and the second column contains the elapsed days (Julian epoch date/elapsed day pairs).

Data Types: `double`

**`center` — Reference body (astronomical object) or point of reference**
`'Sun'` | `'Mercury'` | `'Venus'` | `'Earth'` | `'Moon'` | `'Mars'` | `'Jupiter'` | `'Saturn'` | `'Uranus'` | `'Neptune'` | `'Pluto'` | `'SolarSystem'` | `'EarthMoon'`

Reference body (astronomical object) or point of reference from which to measure the target barycenter position and velocity.

Data Types: `char`

**`target` — Target body (astronomical object) or point of reference**
`'Sun'` | `'Mercury'` | `'Venus'` | `'Earth'` | `'Moon'` | `'Mars'` | `'Jupiter'` | `'Saturn'` | `'Uranus'` | `'Neptune'` | `'Pluto'` | `'SolarSystem'` | `'EarthMoon'`

Target body (astronomical object) or point of reference of the barycenter position and velocity measurement.

Data Types: `char`

**`ephemerisModel` — Ephemerides coefficients**
`'405'` (default) | `'421'` | `'423'` | `'430'` | `'432t'`

Ephemerides coefficients, specified as one of these ephemerides defined by the Jet Propulsion Laboratory:

- `'405'`

  Released in 1998. This ephemerides takes into account the Julian date range 2305424.50 (December 9, 1599 ) to 2525008.50 (February 20, 2201).

  This function calculates these ephemerides with respect to the International Celestial Reference Frame version 1.0, adopted in 1998.

- `'421'`

  Released in 2008. This ephemerides takes into account the Julian date range 2414992.5 (December 4, 1899) to 2469808.5 (January 2, 2050).

  This function calculates these ephemerides with respect to the International Celestial Reference Frame version 1.0, adopted in 1998.

- `'423'`

  Released in 2010. This ephemerides takes into account the Julian date range 2378480.5 (December 16, 1799) to 2524624.5 (February 1, 2200).

  This function calculates these ephemerides with respect to the International Celestial Reference Frame version 2.0, adopted in 2010.

- `'430'`

  Released in 2013. This ephemerides takes into account the Julian date range 2287184.5 (December 21, 1549) to 2688976.5 (January 25, 2650).

  This block implements these ephemerides with respect to the International Celestial Reference Frame version 2.0, adopted in 2010.

- `'432t'`

  Released in April 2014. This ephemerides takes into account the Julian date range 2287184.5, (December 21, 1549 ) to 2688976.5, (January 25, 2650).

  This block implements these ephemerides with respect to the International Celestial Reference Frame version 2.0, adopted in 2010.

Data Types: `char`

### `units` — Output units

`'km'` (default) | `'AU'`

Output units for position and velocity, specified as `'km'` for km and km/s or `'AU'` for astronomical units or AU/day.

Data Types: `char`

### `action` — Function behavior

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

Function behavior when inputs are out of range.

| Value | Description |
|---|---|
| `'None'` | No action. |
| `'Warning'` | Warning in the MATLAB Command Window, model simulation continues. |
| `'Error'` | MATLAB returns an exception, model simulation stops. |

Data Types: `char`

## Output Arguments

### `position` — Barycenter position

*M*-by-3 vector

Barycenter position of the `target` object relative to the barycenter of the `center` object, returned as an *M*-by-3 vector, where *M* is the number of Julian dates. The 3 vector contains the *x*, *y*, and *z* of the position along the International Celestial Reference Frame (ICRF). Units are km or astronomical units (AU). If input arguments include multiple Julian dates or epochs, this vector has the same number of rows as the `ephemerisTime` input.

### `velocity` — Barycenter velocity

*M*-by-3 vector

Barycenter velocity of the `target` object relative to the barycenter of the `center` object, returned as an *M*-by-3 vector, where *M* is the number of Julian dates. The 3 vector contains the velocity in the *x*, *y*, and *z* directions along the ICRF. Velocity of the Units are km or astronomical units (AU). If the input includes multiple Julian dates or epochs, this vector has the same number of rows as the `ephemerisTime` input.

## References

[1] Folkner, W. M., J. G. Williams, D. H. Boggs, “The Planetary and Lunar Ephemeris DE 421,” *JPL Interplanetary Network Progress Report 24-178*, 2009.

[2] Ma, C. et al., “The International Celestial Reference Frame as Realized by Very Long Baseline Interferometry,” *Astronomical Journal*, Vol. 116, 516–546, 1998.

[3] Vallado, D. A., *Fundamentals of Astrodynamics and Applications*, McGraw-Hill, New York, 1997.

# See Also

`earthNutation` | `juliandate` | `moonLibration`

## Topics

“Estimate Sun Analemma Using Planetary Ephemerides and ECI to AER Transformation”
“Marine Navigation Using Planetary Ephemerides”

## External Websites

`https://ssd.jpl.nasa.gov/?planet_eph_export`

**Introduced in R2013a**

# play

**Class:** Aero.Animation
**Package:** Aero

Animate `Aero.Animation` object given position/angle time series

## Syntax

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

## Description

`play(h)` and `h.play` 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:<br>`x y z phi theta psi`<br>The values are resampled. |
| `'Simulink.Timeseries'` | Simulink.Timeseries (Simulink signal logging):<br>• First data item<br>`x y z`<br>• Second data item<br>`phi theta psi` |

| | |
|---|---|
| `'StructureWithTime'` | Simulink struct with time (for example, Simulink root outport logging `'Structure with time'`):<br>• `signals(1).values: x y z`<br>• `signals(2).values: phi theta psi`<br>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)

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:<br>`latitude longitude altitude phi theta psi`<br>The values are resampled. |
| `'StructureWithTime'` | Simulink struct with time (for example, Simulink root outport logging `'Structure with time'`):<br>• `signals(1).values: latitude longitude altitude`<br>• `signals(2).values: phi theta psi`<br>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`

**Introduced in R2007a**

# play (Aero.VirtualRealityAnimation)

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:<br>`x y z phi theta psi`<br>The values are resampled. |
| `'Simulink.Timeseries'` | Simulink.Timeseries (Simulink signal logging):<br>• First data item<br>`x y z`<br>• Second data item<br>`phi theta psi` |

| | |
|---|---|
| `'StructureWithTime'` | Simulink struct with time (for example, Simulink root outport logging `'Structure with time'`):<br>• `signals(1).values: x y z`<br>• `signals(2).values: phi theta psi`<br>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'];
copyfile(h.VRWorldFilename,[tempdir,'asttkoff.wrl'],'f');
h.VRWorldFilename = [tempdir,'asttkoff.wrl'];
h.initialize();
load takeoffData
[~, idxPlane] = find(strcmp('Plane', h.nodeInfo));
h.Nodes{idxPlane}.TimeseriesSource = takeoffData;
h.Nodes{idxPlane}.TimeseriesSourceType = 'StructureWithTime';
h.Nodes{idxPlane}.CoordTransformFcn = @vranimCustomTransform;
h.play();
```

# See Also

`initialize`

**Introduced in R2007b**

# polarMotion

Calculate Earth polar motion

## Syntax

```
polarmotion=polarMotion(utc)
[polarmotion,polarmotionError]=polarMotion(utc)

polarmotion=polarMotion(utc,Name,Value)
[polarmotion,polarmotionError]=polarMotion(utc,Name,Value)
```

## Description

`polarmotion=polarMotion(utc)` calculates the movement of the rotation axis with respect to the crust of the Earth for a specific Universal Coordinated Time (UTC), specified as a modified Julian date. By default, this function uses a prepopulated list of IAU 2000A Earth orientation (IERS) data. This list contains measured and calculated (predicted) data supplied by the IERS. The IERS measures and calculates this data for a set of predetermined dates.

`[polarmotion,polarmotionError]=polarMotion(utc)` calculates the error for the movement of the rotation axis with respect to the crust of the Earth.

`polarmotion=polarMotion(utc,Name,Value)` calculates the movement of the rotation axis with respect to the crust of the Earth using additional options specified by one or more `Name,Value` pair arguments.

`[polarmotion,polarmotionError]=polarMotion(utc,Name,Value)` calculates the error for the movement of the rotation axis with respect to the crust of the Earth.

## Examples

### Calculate Polar Motion

Calculate the polar motion for December 28, 2015.

```
mjd = mjuliandate(2015,12,28)
polarmotion = polarMotion(mjd)
```

```
mjd =
       57384

polarmotion =
   1.0e-05 *
    0.0289    0.1233
```

### Calculate Polar Motion and Error Using IERS Data

Calculate the polar motion and polar motion error for December 28, 2015 and January 10, 2016 using the `aeroiersdata.mat` file. Use the `mjuliandate` function to calculate the date as a modified Julian date.

```
mjd = mjuliandate([2015 12 28;2016 1 10])
[polarmotion,polarmotionErr] = polarMotion(mjd,'Source','aeroiersdata.mat')
```

```
mjd =
       57384
       57397

polarmotion =
   1.0e-05 *
    0.0289    0.1233
    0.0174    0.1304
```

# Input Arguments

### `utc` — Principal Universal Time (UT1) for UTC

*M*-by-1 array

Array of UTC dates, specified as an *M*-by-1 array, represented as modified Julian dates. Use the `mjuliandate` function to convert the UTC date to a modified Julian date.

Data Types: `double`

## Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name,Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside quotes. You can specify several name and value pair arguments in any order as `Name1,Value1,...,NameN,ValueN`.

Example: 'Source','aeroiersdata.mat'

**`Source` — Custom list of Earth orientation data**
`aeroiersdata.mat` (default) | MAT-file

Custom list of Earth orientation data, specified in a MAT-file.

**`action` — Out-of-range action**
Warning (default) | action

Out-of-range action, specified as a string.

Action to take in case of out-of-range or predicted value dates, specified as a string:

- Warning — Displays warning and indicates that the dates were out-of-range or predicted values.
- Error — Displays error and indicates that the dates were out-of-range or predicted values.
- None — Does not display warning or error.

Data Types: `string`

# Output Arguments

**`polarmotion` — Movement of the rotation axis with respect to the crust of the Earth**
*M*-by-2 array

Movement of the rotation axis with respect to the crust of the Earth, *M*-by-2 array, in radians.

**`polarmotionError` — Error for movement of the rotation axis with respect to the crust of the Earth**
*M*-by-2 array

Error for movement of the rotation axis with respect to the crust of the Earth, specified as an *M*-by-2 array, in radians.

## See Also

`aeroReadIERSData` | `dcmeci2ecef` | `deltaCIP` | `deltaUT1` | `eci2aer` | `eci2lla` | `lla2eci` | `mjuliandate`

## Topics

“Estimate Sun Analemma Using Planetary Ephemerides and ECI to AER Transformation”

**Introduced in R2018b**

# quat2angle

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 sequences 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`

**Introduced in R2007b**

# quat2dcm

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 | angle2quat | dcm2angle | dcm2quat | quat2angle | quatrotate

**Introduced in R2006b**

# quat2rod

Convert quaternion to Euler-Rodrigues vector

## Syntax

```
rod=quat2rod(quat)
```

## Description

`rod=quat2rod(quat)` function calculates the Euler-Rodrigues vector, `rod`, for a given quaternion `quat`.

## Examples

### Determine Euler-Rodrigues Vector from Quaternion

Determine the Euler-Rodrigues vector from the quaternion.

```
q = [-0.7071 0 0.7071 0]
r = quat2rod( q )
```

```
q =

   -0.7071         0    0.7071         0
r =

         0   -1.0000         0
```

## Input Arguments

### quat — Quaternion

*M*-by-4 array

*M*-by-4 array of quaternions. `quat` has its scalar number as the first column.

Data Types: `double`

# Output Arguments

**`rod` — Euler-Rodrigues vector**
*M*-by-3 matrix

*M*-by-3 matrix containing *M* Euler-Rodrigues vectors.

# Algorithms

An Euler-Rodrigues vector $\vec{b}$ represents a rotation by integrating a direction cosine of a rotation axis with the tangent of half the rotation angle as follows:

$$\vec{b} = \begin{bmatrix} b_x & b_y & b_z \end{bmatrix}$$

where:

$$b_x = \tan\left(\frac{1}{2}\theta\right)s_x,$$
$$b_y = \tan\left(\frac{1}{2}\theta\right)s_y,$$
$$b_z = \tan\left(\frac{1}{2}\theta\right)s_z$$

are the Rodrigues parameters. Vector $\vec{s}$ represents a unit vector around which the rotation is performed. Due to the tangent, the rotation vector is indeterminate when the rotation angle equals ±pi radians or ±180 deg. Values can be negative or positive.

## References

[1] Dai, J.S. "Euler-Rodrigues formula variations, quaternion conjugation and intrinsic connections." *Mechanism and Machine Theory*, 92, 144-152. Elsevier, 2015.

## See Also

angle2rod | dcm2rod | rod2angle | rod2dcm | rod2quat

**Introduced in R2017a**

# quatconj

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.

The quaternion has the form of

$$q = q_0 + \mathbf{i}q_1 + \mathbf{j}q_2 + \mathbf{k}q_3$$

The quaternion conjugate has the form of

$$q' = q_0 - \mathbf{i}q_1 - \mathbf{j}q_2 - \mathbf{k}q_3$$

## Examples

Determine the conjugate of `q = [1 0 1 0]`:

```
conj = quatconj([1 0 1 0])


conj =

     1     0    -1     0
```

### References

[1] Stevens, Brian L., Frank L. Lewis, *Aircraft Control and Simulation*, Wiley–Interscience, 2nd Edition.

# Extended Capabilities

## C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

Code generation for this function requires the Aerospace Blockset software.

## See Also

`quatdivide` | `quatinv` | `quatmod` | `quatmultiply` | `quatnorm` | `quatnormalize` | `quatrotate`

**Introduced in R2006b**

# quatdivide

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.

The quaternions have the form of

$$q = q_0 + \mathbf{i}q_1 + \mathbf{j}q_2 + \mathbf{k}q_3$$

and

$$r = r_0 + \mathbf{i}r_1 + \mathbf{j}r_2 + \mathbf{k}r_3$$

The resulting quaternion from the division has the form of

$$t = \frac{q}{r} = t_0 + \mathbf{i}t_1 + \mathbf{j}t_2 + \mathbf{k}t_3$$

where

$$t_0 = \frac{(r_0 q_0 + r_1 q_1 + r_2 q_2 + r_3 q_3)}{r_0^2 + r_1^2 + r_2^2 + r_3^2}$$
$$t_1 = \frac{(r_0 q_1 - r_1 q_0 - r_2 q_3 + r_3 q_2)}{r_0^2 + r_1^2 + r_2^2 + r_3^2}$$
$$t_2 = \frac{(r_0 q_2 + r_1 q_3 - r_2 q_0 - r_3 q_1)}{r_0^2 + r_1^2 + r_2^2 + r_3^2}$$
$$t_3 = \frac{(r_0 q_3 - r_1 q_2 + r_2 q_1 - r_3 q_0)}{r_0^2 + r_1^2 + r_2^2 + r_3^2}$$

# 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
```

## References

[1] Stevens, Brian L., Frank L. Lewis, *Aircraft Control and Simulation*, Wiley–Interscience, 2nd Edition.

# Extended Capabilities

## C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

Code generation for this function requires the Aerospace Blockset software.

## See Also

`quatconj` | `quatinv` | `quatmod` | `quatmultiply` | `quatnorm` | `quatnormalize` | `quatrotate`

**Introduced in R2006b**

# quatexp

Exponential of quaternion

## Syntax

```
qe=quatexp(q)
```

## Description

`qe=quatexp(q)` calculates the exponential, `qe`, for the specified quaternion, `q`.

## Examples

### Calculate the Exponential of Quaternion

Calculate the exponentials of quaternion matrix `[0 0 0.7854 0]`.

```
qe = quatexp([0 0 0.7854 0])
```

```
qe =
    0.7071         0    0.7071         0
```

## Input Arguments

### q — Quaternions

*M*-by-4 matrix

Quaternions for which to calculate exponentials, specified as an *M*-by-4 matrix containing *M* quaternions.

Data Types: `double`

## Output Arguments

**qe — Exponential of quaternion**
*M*-by-4 matrix

Exponential of quaternion.

## See Also

`quatconj` | `quatdivide` | `quatinterp` | `quatinv` | `quatlog` | `quatmod` | `quatmultiply` | `quatnormalize` | `quatpower` | `quatrotate`

### External Websites

`http://web.mit.edu/2.998/www/QuaternionReport1.pdf`

**Introduced in R2016a**

# quatinterp

Quaternion interpolation between two quaternions

## Syntax

```
qi=quatinterp(p,q,f,method)
```

## Description

`qi=quatinterp(p,q,f,method)` calculates the quaternion interpolation between two normalized quaternions `p` and `q` by interval fraction `f`.

`p` and `q` are the two extremes between which the function calculates the quaternion.

## Examples

### Quaternion Interpolation Between Two Quaternions

Use interpolation to calculate quaternion between two quaternions `p=[1.0 0 1.0 0]` and `q=[-1.0 0 1.0 0]` using the SLERP method. This example uses the `quatnormalize` function to first-normalize the two quaternions to `pn` and `qn`.

```
pn = quatnormalize([1.0 0 1.0 0])
qn = quatnormalize([-1.0 0 1.0 0])
qi = quatinterp(pn,qn,0.5,'slerp')
```

```
pn =

    0.7071         0    0.7071         0

qn =

   -0.7071         0    0.7071         0

qi =
```

```
     0     0     1     0
```

# Input Arguments

### p — First-normalized quaternion

*M*-by-4 matrix

First normalized quaternion for which to calculate the interpolation, specified as an *M*-by-4 matrix containing *M* quaternions. This quaternion must be a normalized quaternion.

Data Types: `double`

### q — Quaternions

*M*-by-4 matrix

Second normalized quaternion for which to calculate the interpolation, specified as an *M*-by-4 matrix containing *M* quaternions. This quaternion must be a normalized quaternion.

Data Types: `double`

### f — Interval fraction

*M*-by-1 matrix

Interval fraction by which to calculate the quaternion interpolation, specified as an *M*-by-1 matrix containing *M* fractions (scalar). `f` varies between 0 and 1. It represents the intermediate rotation of the quaternion to be calculated.

$q_i$=($q_p$,$q_n$,$q_f$), where:

- If $f$ equals `0`, $q_i$ equals $q_p$.
- If $f$ is between `0` and `1`, $q_i$ equals `method`.
- If $f$ equals `1`, $q_i$ equals $q_n$.

Data Types: `double`

### method — Quaternion interpolation method

`'slerp'` (default) | `'lerp'` | `'nlerp'`

Quaternion interpolation method to calculate the quaternion interpolation. These methods have different rotational velocities, depending on the interval fraction. For more

information on interval fractions, see `http://web.mit.edu/2.998/www/QuaternionReport1.pdf`.

- `slerp`

  Quaternion slerp. Spherical linear quaternion interpolation method. This method is most accurate, but also most computation intense.

  $$Slerp(p,q,h) = p(p^{*}q)^{h} \text{ with } h \in [0,1].$$

- `lerp`

  Quaternion lerp. Linear quaternion interpolation method. This method is the quickest, but is also least accurate. The method does not always generate normalized output.

  $$LERP(p,q,h) = p(1-h) + qh \text{ with } h \in [0,1].$$

- `nlerp`

  Normalized quaternion linear interpolation method.

  With $r = LERP(p,q,h)$, $NLERP(p,q,h) = \frac{r}{|r|}$.

Data Types: `char`

# Output Arguments

**`qi` — Interpolation of quaternion**
*M*-by-4 matrix

Interpolation of quaternion.

# See Also

`quatconj` | `quatdivide` | `quatexp` | `quatinv` | `quatlog` | `quatmod` | `quatmultiply` | `quatnormalize` | `quatpower` | `quatrotate`

## External Websites

http://web.mit.edu/2.998/www/QuaternionReport1.pdf

**Introduced in R2016a**

# quatinv

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.

The quaternion has the form of

$$q = q_0 + \mathbf{i}q_1 + \mathbf{j}q_2 + \mathbf{k}q_3$$

The quaternion inverse has the form of

$$q^{-1} = \frac{q_0 - \mathbf{i}q_1 - \mathbf{j}q_2 - \mathbf{k}q_3}{q_0^2 + q_1^2 + q_2^2 + q_3^2}$$

## Examples

Determine the inverse of `q = [1 0 1 0]`:

```
qinv = quatinv([1 0 1 0])


qinv =

    0.5000         0   -0.5000         0
```

### References

[1] Stevens, Brian L., Frank L. Lewis, *Aircraft Control and Simulation*, Wiley–Interscience, 2nd Edition.

# Extended Capabilities

## C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

Code generation for this function requires the Aerospace Blockset software.

## See Also

`quatconj` | `quatdivide` | `quatmod` | `quatmultiply` | `quatnorm` | `quatnormalize` | `quatrotate`

**Introduced in R2006b**

# quatnorm

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.

The quaternion has the form of

The quaternion norm has the form of

$$norm(q) = q_0^2 + q_1^2 + q_2^2 + q_3^2$$

## Examples

Determine the norm of `q = [1 0 0 0]`:

```
norm=quatnorm([.5 -.5 .5 0])

norm =

    0.7500
```

### References

[1] Stevens, Brian L., Frank L. Lewis, *Aircraft Control and Simulation*, Wiley–Interscience, 2nd Edition.

# Extended Capabilities

## C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

Code generation for this function requires the Aerospace Blockset software.

## See Also

`quatconj` | `quatdivide` | `quatinv` | `quatmod` | `quatmultiply` | `quatnormalize` | `quatrotate`

**Introduced in R2006b**

# quatnormalize

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.

The quaternion has the form of

$$q = q_0 + \mathbf{i}q_1 + \mathbf{j}q_2 + \mathbf{k}q_3$$

The normalized quaternion has the form of

$$normal(q) = \frac{q_0 + \mathbf{i}q_1 + \mathbf{j}q_2 + \mathbf{k}q_3}{\sqrt{q_0^2 + q_1^2 + q_2^2 + q_3^2}}$$

## Examples

Normalize `q = [1 0 1 0]`:

```
normal = quatnormalize([1 0 1 0])


normal =

    0.7071         0    0.7071         0
```

### References

[1] Stevens, Brian L., Frank L. Lewis, *Aircraft Control and Simulation*, Wiley–Interscience, 2nd Edition.

# Extended Capabilities

## C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

Code generation for this function requires the Aerospace Blockset software.

## See Also

`quatconj` | `quatdivide` | `quatinv` | `quatmod` | `quatmultiply` | `quatnorm` | `quatrotate`

**Introduced in R2006b**

# quatpower

Power of quaternion

## Syntax

```
qp=quatpower(q,pow)
```

## Description

`qp=quatpower(q,pow)` calculates `q` to the power of `pow` for a normalized quaternion, `q`.

$q^t = \exp(t \cdot \log(q)),\ \text{with}\ t \in R.$

## Examples

### Calculate the Power of Quaternion

Calculate the power of 2 of quaternion `q = [1.0 0 1.0 0]`.

```
qp = quatpower(quatnormalize([1.0 0 1.0 0]),2)
```

```
qp =

   -0.0000         0    1.0000         0
```

## Input Arguments

### q — Quaternions

*M*-by-4 matrix

Quaternions for which to calculate exponentials, specified as an *M*-by-4 matrix containing *M* quaternions.

Data Types: `double`

**`pow` — Power**
*M*-by-1 vector

Power to which to calculate quaternion power, specified as an *M*-by-1 vector containing *M* power scalars.

Data Types: `double`

# Output Arguments

**`qp` — Power of quaternion**
*M*-by-4 matrix

Power of quaternion.

# See Also

`quatconj` | `quatdivide` | `quatexp` | `quatinterp` | `quatinv` | `quatlog` | `quatmod` | `quatmultiply` | `quatnormalize` | `quatrotate`

## External Websites

`http://web.mit.edu/2.998/www/QuaternionReport1.pdf`

**Introduced in R2016a**

# quatrotate

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. The function normalizes the quaternions if they are not yet normalized. `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.

The quaternion has the form of

$$q = q_0 + \mathbf{i}q_1 + \mathbf{j}q_2 + \mathbf{k}q_3$$

The vector has the form of

$$v = \mathbf{i}v_1 + \mathbf{j}v_2 + \mathbf{k}v_3$$

The rotated vector has the form of

$$v' = \begin{bmatrix} v_1' \\ v_2' \\ v_3' \end{bmatrix} = \begin{bmatrix} (1-2q_2^2-2q_3^2) & 2(q_1q_2+q_0q_3) & 2(q_1q_3-q_0q_2) \\ 2(q_1q_2-q_0q_3) & (1-2q_1^2-2q_3^2) & 2(q_2q_3+q_0q_1) \\ 2(q_1q_3+q_0q_2) & 2(q_2q_3-q_0q_1) & (1-2q_1^2-2q_2^2) \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \\ v_3 \end{bmatrix}$$

The direction cosine matrix for this equation expects a normalized quaternion.

For more information, see Representing Attitude: Euler Angles, Unit Quaternions, and Rotation Vectors.

## 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
```

## References

[1] Stevens, Brian L., Frank L. Lewis, *Aircraft Control and Simulation*, Wiley–Interscience, 2nd Edition.

[2] Representing Attitude: Euler Angles, Unit Quaternions, and Rotation Vectors

# See Also

`quatconj` | `quatinv` | `quatmod` | `quatmultiply` | `quatnorm` | `quatnormalize`

**Introduced in R2006b**

# read (Aero.Geometry)

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');
```

**Introduced in R2007a**

# removeBody

**Class:** Aero.Animation
**Package:** Aero

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)
```

# removeNode (Aero.VirtualRealityAnimation)

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`

**Introduced in R2007b**

# removeViewpoint (Aero.VirtualRealityAnimation)

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`

**Introduced in R2007b**

# rod2angle

Convert Euler-Rodrigues vector to rotation angles

## Syntax

```
[R1 R2 R3]=rod2angle(rod)
[R1 R2 R3]=rod2angle(rod,S)
```

## Description

`[R1 R2 R3]=rod2angle(rod)` function calculates the set of rotation angles, `R1`, `R2`, and `R3`, for a given Euler-Rodrigues (also known as Rodrigues) vector, `rod`.

`[R1 R2 R3]=rod2angle(rod,S)` function calculates the set of rotation angles for a given Rodrigues vector and a specified rotation sequence, `S`.

## Examples

### Determine Rotation Angles from One Vector

Determine rotation angles from vector, `[.1 .2 -.1]`.

```
r = [.1 .2 -.1];
[yaw, pitch, roll] = rod2angle(r)
```

```
yaw =

   -0.1651

pitch =

    0.4074

roll =
```

```
    0.1651
```

# Input Arguments

**rod — Rodrigues vector**
*M*-by-3 matrix

*M*-by-3 matrix containing *M* Rodrigues vector.

Data Types: `double`

**S — Rotation sequence**
ZYX (default) | ZYZ | ZXY | ZXZ | YXZ | YXY | YZX | YZY | XYZ | XYX | XZY | XZX

Rotation angles, in radians, from which to determine Rodrigues vector. For the default rotation sequence, ZYX, the rotation angle order is:

- R1 — *z*-axis rotation
- R2 — *y*-axis rotation
- R3 — *x*-axis rotation

Data Types: `char` | `string`

# Output Arguments

**R1 — First rotation angles**
*M*-by-1 array

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

**R2 — Second rotation angles**
*M*-by-1 array

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

**R3 — Third rotation angles**
*M*-by-1 array

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

# Algorithms

An Euler-Rodrigues vector $\vec{b}$ represents a rotation by integrating a direction cosine of a rotation axis with the tangent of half the rotation angle as follows:

$$\vec{b} = \begin{bmatrix} b_x & b_y & b_z \end{bmatrix}$$

where:

$$b_x = \tan\left(\frac{1}{2}\theta\right)s_x,$$
$$b_y = \tan\left(\frac{1}{2}\theta\right)s_y,$$
$$b_z = \tan\left(\frac{1}{2}\theta\right)s_z$$

are the Rodrigues parameters. Vector $\vec{s}$ represents a unit vector around which the rotation is performed. Due to the tangent, the rotation vector is indeterminate when the rotation angle equals ±pi radians or ±180 deg. Values can be negative or positive.

## References

[1] Dai, J.S. "Euler-Rodrigues formula variations, quaternion conjugation and intrinsic connections." *Mechanism and Machine Theory*, 92, 144-152. Elsevier, 2015.

# See Also

`angle2rod` | `dcm2rod` | `quat2rod` | `rod2dcm` | `rod2quat`

**Introduced in R2017a**

# rod2dcm

Convert Euler-Rodrigues vector to direction cosine matrix

## Syntax

```
dcm=rod2dcm(R)
```

## Description

`dcm=rod2dcm(R)` function calculates the direction cosine matrix, for a given Euler-Rodrigues (also known as Rodrigues) vector, `R`.

## Examples

### Determine Direction Cosine Matrix from Euler-Rodrigues Vector

Determine the direction cosine matrix from the Euler-Rodrigues vector.

```
r = [.1 .2 -.1];
DCM = rod2dcm(r)
```

```
DCM =

    0.9057   -0.1509   -0.3962
    0.2264    0.9623    0.1509
    0.3585   -0.2264    0.9057
```

## Input Arguments

### R — Rodrigues vector

*M*-by-3 matrix

*M*-by-3 matrix containing *M* Rodrigues vectors.

Data Types: `double`

# Output Arguments

**`dcm` — Direction cosine matrix**
3-by-3-by-*M* matrix

3-by-3-by-*M* containing *M* direction cosine matrices.

# Algorithms

An Euler-Rodrigues vector $\vec{b}$ represents a rotation by integrating a direction cosine of a rotation axis with the tangent of half the rotation angle as follows:

$$\vec{b} = \begin{bmatrix} b_x & b_y & b_z \end{bmatrix}$$

where:

$$b_x = \tan\left(\frac{1}{2}\theta\right)s_x,$$
$$b_y = \tan\left(\frac{1}{2}\theta\right)s_y,$$
$$b_z = \tan\left(\frac{1}{2}\theta\right)s_z$$

are the Rodrigues parameters. Vector $\vec{s}$ represents a unit vector around which the rotation is performed. Due to the tangent, the rotation vector is indeterminate when the rotation angle equals ±pi radians or ±180 deg. Values can be negative or positive.

## References

[1] Dai, J.S. "Euler-Rodrigues formula variations, quaternion conjugation and intrinsic connections." *Mechanism and Machine Theory*, 92, 144-152. Elsevier, 2015.

## See Also

angle2rod | dcm2rod | quat2rod | rod2angle | rod2quat

**Introduced in R2017a**

# rod2quat

Convert Euler-Rodrigues vector to quaternion

## Syntax

```
quat=rod2quat(R)
```

## Description

`quat=rod2quat(R)` function calculates the quaternion, `quat`, for a given Euler-Rodrigues (also known as Rodrigues) vector, `R`.

## Examples

### Determine Quaternion from Rodrigues Vector

Determine the quaternion from Rodrigues vector.

```
r = [.1 .2 -.1];
q = rod2quat(r)
```

```
q =

    0.9713    0.0971    0.1943   -0.0971
```

## Input Arguments

### R — Rodrigues vector

*M*-by-1 matrix

*M*-by-1 array of Rodrigues vectors.

Data Types: `double`

# Output Arguments

**quat — Rodrigues vector**
*M*-by-4 matrix

*M*-by-4 matrix of *M* quaternions. `quat` has its scalar number as the first column.

# Algorithms

An Euler-Rodrigues vector $\vec{b}$ represents a rotation by integrating a direction cosine of a rotation axis with the tangent of half the rotation angle as follows:

$$\vec{b} = \begin{bmatrix} b_x & b_y & b_z \end{bmatrix}$$

where:

$$b_x = \tan\left(\frac{1}{2}\theta\right)s_x,$$
$$b_y = \tan\left(\frac{1}{2}\theta\right)s_y,$$
$$b_z = \tan\left(\frac{1}{2}\theta\right)s_z$$

are the Rodrigues parameters. Vector $\vec{s}$ represents a unit vector around which the rotation is performed. Due to the tangent, the rotation vector is indeterminate when the rotation angle equals ±pi radians or ±180 deg. Values can be negative or positive.

## References

[1] Dai, J.S. "Euler-Rodrigues formula variations, quaternion conjugation and intrinsic connections." *Mechanism and Machine Theory*, 92, 144-152. Elsevier, 2015.

# See Also

`angle2rod` | `dcm2rod` | `quat2rod` | `rod2angle` | `rod2dcm`

**Introduced in R2017a**

# RPMIndicator Properties

Control revolutions per minute (RPM) indicator appearance and behavior

## Description

RPM indicators are components that represent an RPM indicator. Properties control the appearance and behavior of an RMP indicator. Use dot notation to refer to a particular object and property:

```
figure = uifigure;
rpm = uiaerorpm(figure);
rpm.Value = 100;
```

## Properties

**RMP Indicator**

### `Limits` — Minimum and maximum indicator scale values

`[0 110]` (default) | two-element finite, real, and scalar numeric array

Minimum and maximum indicator scale values, specified as a two-element numeric array. The first value in the array must be less than the second value. This value is read-only.

If you change `Limits` such that the `Value` property is less than the new lower limit, or more than the new upper limit, then the indicator needle points to a location off the scale.

For example, suppose `Limits` is `[0 100]` and the `Value` property is 20. If the `Limits` changes to `[50 100]`, then the needle points to a location off the scale, slightly less than 50.

### `RPM` — Location of RPM indicator needle

`0` (default) | finite, real, and scalar numeric

Location of the RPM indicator needle, specified a finite and scalar numeric rev/min.

- Changing the value changes the location of the to align with the corresponding value on the indicator.

Example: `60`

**Dependencies**

Specifying this value changes the value of `Value`.

Data Types: `double`

### `ScaleColors` — Scale colors

[ ] (default) | n-by-3 array of RGB triplets | cell array

Scale colors, specified one of the following arrays:

- An n-by-3 array of RGB triplets
- A cell array containing RGB triplets, any of the color options listed in the table below, or a combination of both.

An RGB triplet is a three-element row vector whose elements specify the intensities of the red, green, and blue components of the color. The intensities must be in the range `[0,1]`; for example, `[0.4 0.6 0.7]`. Alternatively, you can specify some common colors by name. This table lists the long and short color name options and the equivalent RGB triplet values.

| Option | Description | Equivalent RGB Triplet |
|---|---|---|
| `'red'` or `'r'` | Red | `[1 0 0]` |
| `'green'` or `'g'` | Green | `[0 1 0]` |
| `'blue'` or `'b'` | Blue | `[0 0 1]` |
| `'yellow'` or `'y'` | Yellow | `[1 1 0]` |
| `'magenta'` or `'m'` | Magenta | `[1 0 1]` |
| `'cyan'` or `'c'` | Cyan | `[0 1 1]` |
| `'white'` or `'w'` | White | `[1 1 1]` |
| `'black'` or `'k'` | Black | `[0 0 0]` |

Each color of the `ScaleColors` array corresponds to a colored section of the gauge. Set the `ScaleColorLimits` property to map the colors to specific sections of the gauge.

If you do not set the `ScaleColorLimits` property, MATLAB distributes the colors equally over the range of the gauge.

### `ScaleColorLimits` — Scale color limits

[ ] (default) | n-by-2 array

Scale color limits, specified as an n-by-2 array of numeric values. For every row in the array, the first element must be less than the second element.

When applying colors to the gauge, MATLAB applies the colors starting with the first color in the `ScaleColors` array. Therefore, if two rows in `ScaleColorLimits` array overlap, then the color applied later takes precedence.

The gauge does not display any portion of the `ScaleColorLimits` that falls outside of the `Limits` property.

If the `ScaleColors` and `ScaleColorLimits` property values are different sizes, then the gauge shows only the colors that have matching limits. For example, if the `ScaleColors` array has three colors, but the `ScaleColorLimits` has only two rows, then the gauge displays the first two color/limit pairs only.

### `Value` — Location of RPM indicator needle

`0` (default) | finite, real, and scalar numeric

Location of the RPM indicator needle, specified a finite and scalar numeric rev/min.

- Changing the value changes the location of the to align with the corresponding value on the indicator.

Example: `60`

#### Dependencies

Specifying this value changes the value of RPM.

Data Types: `double`

#### Interactivity

### `Visible` — Visibility of RPM indicator

`'on'` (default) | `'off'`

Visibility of the RPM indicator, specified as `'on'` or `'off'`. The `Visible` property determines whether the RPM indicator is displayed on the screen. If the `Visible` property is set to `'off'`, then the entire RPM indicator is hidden, but you can still specify and access its properties.

### `Enable` — Operational state of RPM indicator

`'on'` (default) | `'off'`

Operational state of RPM indicator, specified as `'on'` or `'off'`.

- If you set this property to `'on'`, then the appearance of the RPM indicator indicates that the RPM indicator is operational.
- If you set this property to `'off'`, then the appearance of the RPM indicator appears dimmed, indicating that the RPM indicator is not operational.

#### Position

### `Position` — Location and size of RPM indicator

`[100 100 120 120]` (default) | `[left bottom width height]`

Location and size of the RPM indicator relative to the parent container, specified as the vector, `[left bottom width height]`. This table describes each element in the vector.

| Element | Description |
|---|---|
| `left` | Distance from the inner left edge of the parent container to the outer left edge of an imaginary box surrounding the RPM indicator |
| `bottom` | Distance from the inner bottom edge of the parent container to the outer bottom edge of an imaginary box surrounding the RPM indicator |
| `width` | Distance between the right and left outer edges of the RPM indicator |
| `height` | Distance between the top and bottom outer edges of the RPM indicator |

All measurements are in pixel units.

The `Position` values are relative to the drawable area of the parent container. The drawable area is the area inside the borders of the container and does not include the area occupied by decorations such as a menu bar or title.

Example: `[200 120 120 120]`

### `InnerPosition` — Inner location and size of RPM indicator

`[100 100 120 120]` (default) | `[left bottom width height]`

Inner location and size of the RPM indicator, specified as `[left bottom width height]`. Position values are relative to the parent container. All measurements are in pixel units. This property value is identical to the `Position` property.

### `OuterPosition` — Outer location and size of RPM indicator

`[100 100 120 120]]` (default) | `[left bottom width height]`

This property is read-only.

Outer location and size of the RPM indicator returned as `[left bottom width height]`. Position values are relative to the parent container. All measurements are in pixel units. This property value is identical to the `Position` property.

### `Layout` — Layout options

empty `LayoutOptions` array (default) | `GridLayoutOptions` object

Layout options, specified as a `GridLayoutOptions` object. This property specifies options for components that are children of grid layout containers. If the component is not a child of a grid layout container (for example, it is a child of a figure or panel), then this property is empty and has no effect. However, if the component is a child of a grid layout container, you can place the component in the desired row and column of the grid by setting the `Row` and `Column` properties on the `GridLayoutOptions` object.

For example, this code places an RPM indicator in the third row and second column of its parent grid.

```
g = uigridlayout([4 3]);
gauge = uiaerorpm(g);
gauge.Layout.Row = 3;
gauge.Layout.Column = 2;
```

To make the RPM indicator span multiple rows or columns, specify the `Row` or `Column` property as a two-element vector. For example, this RPM indicator spans columns 2 through 3:

```
gauge.Layout.Column = [2 3];
```

#### Callbacks

### `CreateFcn` — Creation function

`''` (default) | function handle | cell array | character vector

Object creation function, specified as one of these values:

- Function handle.
- Cell array in which the first element is a function handle. Subsequent elements in the cell array are the arguments to pass to the callback function.
- Character vector containing a valid MATLAB expression (not recommended). MATLAB evaluates this expression in the base workspace.

For more information about specifying a callback as a function handle, cell array, or character vector, see “Write Callbacks in App Designer” (MATLAB).

This property specifies a callback function to execute when MATLAB creates the object. MATLAB initializes all property values before executing the `CreateFcn` callback. If you do not specify the `CreateFcn` property, then MATLAB executes a default creation function.

Setting the `CreateFcn` property on an existing component has no effect.

If you specify this property as a function handle or cell array, you can access the object that is being created using the first argument of the callback function. Otherwise, use the `gcbo` function to access the object.

### `DeleteFcn` — Deletion function

`''` (default) | function handle | cell array | character vector

Object deletion function, specified as one of these values:

- Function handle.
- Cell array in which the first element is a function handle. Subsequent elements in the cell array are the arguments to pass to the callback function.
- Character vector containing a valid MATLAB expression (not recommended). MATLAB evaluates this expression in the base workspace.

For more information about specifying a callback as a function handle, cell array, or character vector, see “Write Callbacks in App Designer” (MATLAB).

This property specifies a callback function to execute when MATLAB deletes the object. MATLAB executes the `DeleteFcn` callback before destroying the properties of the object. If you do not specify the `DeleteFcn` property, then MATLAB executes a default deletion function.

If you specify this property as a function handle or cell array, you can access the object that is being deleted using the first argument of the callback function. Otherwise, use the `gcbo` function to access the object.

**Callback Execution Control**

### `Interruptible` — Callback interruption

`'on'` (default) | `'off'`

Callback interruption, specified as `'on'` or `'off'`. The `Interruptible` property determines if a running callback can be interrupted.

There are two callback states to consider:

- The running callback is the currently executing callback.
- The interrupting callback is a callback that tries to interrupt the running callback.

Whenever MATLAB invokes a callback, that callback attempts to interrupt the running callback (if one exists). The `Interruptible` property of the object owning the running callback determines if interruption is allowed. The `Interruptible` property has two possible values:

- `'on'` — Allows other callbacks to interrupt the object's callbacks. The interruption occurs at the next point where MATLAB processes the queue, such as when there is a `drawnow`, `figure`, `uifigure`, `getframe`, `waitfor`, or `pause` command.
  - If the running callback contains one of those commands, then MATLAB stops the execution of the callback at that point and executes the interrupting callback. MATLAB resumes executing the running callback when the interrupting callback completes.
  - If the running callback does not contain one of those commands, then MATLAB finishes executing the callback without interruption.
- `'off'` — Blocks all interruption attempts. The `BusyAction` property of the object owning the interrupting callback determines if the interrupting callback is discarded or put into a queue.

---

**Note** Callback interruption and execution behave differently in these situations:

- If the interrupting callback is a `DeleteFcn`, `CloseRequestFcn` or `SizeChangedFcn` callback, then the interruption occurs regardless of the `Interruptible` property value.

- If the running callback is currently executing the `waitfor` function, then the interruption occurs regardless of the `Interruptible` property value.
- `Timer` objects execute according to schedule regardless of the `Interruptible` property value.

When an interruption occurs, MATLAB does not save the state of properties or the display. For example, the object returned by the `gca` or `gcf` command might change when another callback executes.

### `BusyAction` — Callback queuing

`'queue'` (default) | `'cancel'`

Callback queuing, specified as `'queue'` or `'cancel'`. The `BusyAction` property determines how MATLAB handles the execution of interrupting callbacks. There are two callback states to consider:

- The running callback is the currently executing callback.
- The interrupting callback is a callback that tries to interrupt the running callback.

Whenever MATLAB invokes a callback, that callback attempts to interrupt a running callback. The `Interruptible` property of the object owning the running callback determines if interruption is permitted. If interruption is not permitted, then the `BusyAction` property of the object owning the interrupting callback determines if it is discarded or put in the queue. These are possible values of the `BusyAction` property:

- `'queue'` — Puts the interrupting callback in a queue to be processed after the running callback finishes execution.
- `'cancel'` — Does not execute the interrupting callback.

### `BeingDeleted` — Deletion status

`'off'` | `'on'`

This property is read-only.

Deletion status, returned as `'off'` or `'on'`. MATLAB sets the `BeingDeleted` property to `'on'` when the `DeleteFcn` callback begins execution. The `BeingDeleted` property remains set to `'on'` until the component object no longer exists.

Check the value of the `BeingDeleted` property to verify that the object is not about to be deleted before querying or modifying it.

#### Parent/Child

### HandleVisibility — Visibility of object handle

`'on'` (default) | `'callback'` | `'off'`

Visibility of the object handle, specified as `'on'`, `'callback'`, or `'off'`.

This property controls the visibility of the object in its parent's list of children. When an object is not visible in its parent's list of children, it is not returned by functions that obtain objects by searching the object hierarchy or querying properties. These functions include `get`, `findobj`, `clf`, and `close`. Objects are valid even if they are not visible. If you can access an object, you can set and get its properties, and pass it to any function that operates on objects.

| HandleVisibility Value | Description |
|---|---|
| `'on'` | The object is always visible. |
| `'callback'` | The object is visible from within callbacks or functions invoked by callbacks, but not from within functions invoked from the command line. This option blocks access to the object at the command-line, but allows callback functions to access it. |
| `'off'` | The object is invisible at all times. This option is useful for preventing unintended changes to the UI by another function. Set the `HandleVisibility` to `'off'` to temporarily hide the object during the execution of that function. |

### Parent — Parent container

`Figure` object (default) | `Panel` object | `Tab` object | `ButtonGroup` object | `GridLayout` object

Parent container, specified as a `Figure` created using the `uifigure` function, or one of its child containers: `Tab`, `Panel`, `ButtonGroup`, or `GridLayout`.

#### Identifiers

### Type — Type of graphics object

`'uiaerorpm'`

This property is read-only.

Type of graphics object, returned as `'uiaerorpm'`.

### `Tag` — Object identifier

`''` (default) | character vector | string scalar

Object identifier, specified as a character vector or string scalar. You can specify a unique `Tag` value to serve as an identifier for an object. When you need access to the object elsewhere in your code, you can use the `findobj` function to search for the object based on the `Tag` value.

### `UserData` — User data

`[]` (default) | array

User data, specified as any MATLAB array. For example, you can specify a scalar, vector, matrix, cell array, character array, table, or structure. Use this property to store arbitrary data on an object.

If you are working in App Designer, create public or private properties in the app to share data instead of using the `UserData` property. For more information, see “Share Data Within App Designer Apps” (MATLAB).

## See Also

`uiaerorpm`

## Topics

“Display Flight Trajectory Data Using Flight Instruments and Flight Animation” on page 2-65

**Introduced in R2018b**

# rrdelta

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`

**Introduced in R2006b**

# rrsigma

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`

**Introduced in R2006b**

# rrtheta

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`

**Introduced in R2006b**

# saveas (Aero.VirtualRealityAnimation)

Save virtual reality world associated with virtual reality animation object

## Syntax

```
saveas(h, filename)
h.saveas(filename)
saveas(h, filename, '-nothumbnail')
h.saveas(filename, '-nothumbnail')
```

## 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.

`saveas(h, filename, '-nothumbnail')` and `h.saveas(filename, '-nothumbnail')` suppress creating a thumbnail image used for virtual world preview.

## 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']);
```

**Introduced in R2007b**

# SetTimer (Aero.FlightGearAnimation)

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

**Introduced in R2008b**

# show

**Class:** Aero.Animation
**Package:** Aero

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;
```

# tdbjuliandate

terrConvert from Barycentric Dynamical Time Estimate to Julian date

## Syntax

```
jdtdb = tdbjuliandate(terrestrial_time)
[jdtdb,tttdb] = tdbjuliandate(terrestrial_time)
```

## Description

`jdtdb = tdbjuliandate(terrestrial_time)` returns an estimate of the Julian date for Barycentric Dynamical Time (TDB). These estimations are valid for the years 1980 to 2050.

`[jdtdb,tttdb] = tdbjuliandate(terrestrial_time)` additionally returns an array of Julian dates for the Barycentric Dynamical Time (TDB) based on the Terrestrial Time (TT).

## Examples

### Estimate Julian Date for Barycentric Dynamical Time

Estimate the Julian date for the Barycentric Dynamical Time for the Terrestrial Time 2014/10/15 16:22:31.

```
jdtdb = tdbjuliandate([2014,10,15,16,22,31])
```

```
jdtdb =

   2.4569e+06
```

### Estimate Julian Dates for the Barycentric Dynamical Time and TT-TDB

Estimate the Julian dates for the Barycentric Dynamical Time and TT-TDB in seconds for the terrestrial time 2014/10/15 16:22:31 and 2010/7/22 1:57:17.

```
[jdtdb,tttdb] = tdbjuliandate([2014,10,15,16,22,31;2010,7,22,1,57,17])
```

```
JDTDB =

   1.0e+06 *

    2.4569
    2.4554


TTTDB =

    0.0016
    0.0005
```

## Input Arguments

### `terrestrial_time` — Terrestrial Time

1-by-6 array | *M*-by-6 array

Terrestrial Time (TT) in year, month, day, hour, minutes, and seconds for which the function calculates the Julian date for Barycentric Dynamical Time. *M* is the number of Julian dates, one for each TT date. Specify values for year, month, day, hour, and minutes as whole numbers.

## Output Arguments

### `jdtdb` — Julian date

*M*-by-1 array

Julian date for the Barycentric Dynamical Time, returned as an *M*-by-1 array. *M* is the number of rows, one for each Terrestrial Time input.

### `tttdb` — Difference in seconds

*M*-by-1 array

Difference in seconds between Terrestrial Time and Barycentric Dynamical Time (TT-TDB), returned as an *M*-by-1 array. *M* is the number of rows, one for each Terrestrial Time input.

# Limitations

*Fundamentals of Astrodynamics and Applications*[1] indicates an accuracy of 50 microseconds, which this function cannot achieve due to numerical issues with the values involved.

## References

[1] Vallado, D. A., *Fundamentals of Astrodynamics and Applications*, New York: McGraw-Hill, 1997.

# See Also

`dcmeci2ecef` | `ecef2lla` | `geoc2geod` | `geod2geoc` | `lla2ecef` | `lla2eci`

**Introduced in R2015a**

# TurnCoordinator Properties

Control turn coordinator appearance and behavior

## Description

Turn coordinators are components that represent a turn coordinator. Properties control the appearance and behavior of a turn coordinator. Use dot notation to refer to a particular object and property:

```
figure = uifigure;
turn = uiaeroturn(figure);
turn.Turn = 100;
```

## Properties

**Turn Coordinator**

### `Slip` — Slip

`0` (default) | finite, real, and scalar numeric

Slip value, specified as any finite and scalar numeric. The slip value controls the direction of the inclinometer ball. A negative value moves the ball to the right, a positive value moves the ball to the left, in degrees. This value cannot exceed +/–15 degrees. If it exceed 15 degrees, the gauge stays fixed at the minimum or maximum value.

Example: 10

**Dependencies**

Specifying this value changes the second element of the `Value` vector. Conversely, changing the second element of the `Value` vector changes the `Slip` value.

Data Types: `double`

### `Turn` — Turn

`0` (default) | finite, real, and scalar numeric

Turn value, specified as any finite and scalar numeric. The turn value determines the aircraft heading rate of change. This value cannot exceed +/–15 degrees. If it exceed 15 degrees, the gauge stays fixed at the minimum or maximum value.

Example: 10

**Dependencies**

Specifying this value changes the first element of the `Value` vector. Conversely, changing the first element of the `Value` vector changes the `Turn` value.

Data Types: `double`

### `Value` — Turn and slip

`[0 0]` (default) | two-element vector of finite, real, and scalar numerics

Turn and slip values, specified as a vector ([`Turn` `Slip`]).

- The turn value determines the aircraft heading rate of change.
- The slip value controls the direction of the inclinometer ball. A negative value moves the ball to the right, a positive value moves the ball to the left.

Example: [100 -200]

**Dependencies**

- Specifying the `Turn` value changes the first element of the `Value` vector. Conversely, changing the first element of the `Value` vector changes the `Turn` value.
- Specifying the `Slip` value changes the second element of the `Value` vector. Conversely, changing the second element of the `Value` vector changes the `Slip` value.

Data Types: `double`

**Interactivity**

### `Visible` — Visibility of turn coordinator

`'on'` (default) | `'off'`

Visibility of the turn coordinator, specified as `'on'` or `'off'`. The `Visible` property determines whether the turn coordinator, is displayed on the screen. If the `Visible` property is set to `'off'`, then the entire turn coordinator is hidden, but you can still specify and access its properties.

### `Enable` — Operational state of turn coordinator

`'on'` (default) | `'off'`

Operational state of turn coordinator, specified as `'on'` or `'off'`.

- If you set this property to `'on'`, then the appearance of the turn coordinator indicates that the turn coordinator is operational.
- If you set this property to `'off'`, then the appearance of the turn coordinator appears dimmed, indicating that the turn coordinator is not operational.

#### Position

### `Position` — Location and size of turn coordinator

`[100 100 120 120]` (default) | `[left bottom width height]`

Location and size of the turn coordinator relative to the parent container, specified as the vector `[left bottom width height]`. This table describes each element in the vector.

| Element | Description |
|---|---|
| `left` | Distance from the inner left edge of the parent container to the outer left edge of an imaginary box surrounding the turn coordinator |
| `bottom` | Distance from the inner bottom edge of the parent container to the outer bottom edge of an imaginary box surrounding the turn coordinator |
| `width` | Distance between the right and left outer edges of the turn coordinator |
| `height` | Distance between the top and bottom outer edges of the turn coordinator |

All measurements are in pixel units.

The `Position` values are relative to the drawable area of the parent container. The drawable area is the area inside the borders of the container and does not include the area occupied by decorations such as a menu bar or title.

Example: `[200 120 120 120]`

### `InnerPosition` — Inner location and size of turn coordinator

`[100 100 120 120]` (default) | `[left bottom width height]`

Inner location and size of the turn coordinator, specified as `[left bottom width height]`. Position values are relative to the parent container. All measurements are in pixel units. This property value is identical to the `Position` property.

### `OuterPosition` — Outer location and size of turn coordinator

`[100 100 120 120]]` (default) | `[left bottom width height]`

This property is read-only.

Outer location and size of the turn coordinator returned as `[left bottom width height]`. Position values are relative to the parent container. All measurements are in pixel units. This property value is identical to the `Position` property.

### `Layout` — Layout options

empty `LayoutOptions` array (default) | `GridLayoutOptions` object

Layout options, specified as a `GridLayoutOptions` object. This property specifies options for components that are children of grid layout containers. If the component is not a child of a grid layout container (for example, it is a child of a figure or panel), then this property is empty and has no effect. However, if the component is a child of a grid layout container, you can place the component in the desired row and column of the grid by setting the `Row` and `Column` properties on the `GridLayoutOptions` object.

For example, this code places an turn coordinator in the third row and second column of its parent grid.

```
g = uigridlayout([4 3]);
gauge = uiaeroturn(g);
gauge.Layout.Row = 3;
gauge.Layout.Column = 2;
```

To make the turn coordinator span multiple rows or columns, specify the `Row` or `Column` property as a two-element vector. For example, this turn coordinator spans columns 2 through 3:

```
gauge.Layout.Column = [2 3];
```

#### Callbacks

### `CreateFcn` — Creation function

`''` (default) | function handle | cell array | character vector

Object creation function, specified as one of these values:

- Function handle.
- Cell array in which the first element is a function handle. Subsequent elements in the cell array are the arguments to pass to the callback function.
- Character vector containing a valid MATLAB expression (not recommended). MATLAB evaluates this expression in the base workspace.

For more information about specifying a callback as a function handle, cell array, or character vector, see “Write Callbacks in App Designer” (MATLAB).

This property specifies a callback function to execute when MATLAB creates the object. MATLAB initializes all property values before executing the `CreateFcn` callback. If you do not specify the `CreateFcn` property, then MATLAB executes a default creation function.

Setting the `CreateFcn` property on an existing component has no effect.

If you specify this property as a function handle or cell array, you can access the object that is being created using the first argument of the callback function. Otherwise, use the `gcbo` function to access the object.

**`DeleteFcn` — Deletion function**

`''` (default) | function handle | cell array | character vector

Object deletion function, specified as one of these values:

- Function handle.
- Cell array in which the first element is a function handle. Subsequent elements in the cell array are the arguments to pass to the callback function.
- Character vector containing a valid MATLAB expression (not recommended). MATLAB evaluates this expression in the base workspace.

For more information about specifying a callback as a function handle, cell array, or character vector, see “Write Callbacks in App Designer” (MATLAB).

This property specifies a callback function to execute when MATLAB deletes the object. MATLAB executes the `DeleteFcn` callback before destroying the properties of the object. If you do not specify the `DeleteFcn` property, then MATLAB executes a default deletion function.

If you specify this property as a function handle or cell array, you can access the object that is being deleted using the first argument of the callback function. Otherwise, use the `gcbo` function to access the object.

**Callback Execution Control**

### `Interruptible` — Callback interruption

`'on'` (default) | `'off'`

Callback interruption, specified as `'on'` or `'off'`. The `Interruptible` property determines if a running callback can be interrupted.

There are two callback states to consider:

- The running callback is the currently executing callback.
- The interrupting callback is a callback that tries to interrupt the running callback.

Whenever MATLAB invokes a callback, that callback attempts to interrupt the running callback (if one exists). The `Interruptible` property of the object owning the running callback determines if interruption is allowed. The `Interruptible` property has two possible values:

- `'on'` — Allows other callbacks to interrupt the object's callbacks. The interruption occurs at the next point where MATLAB processes the queue, such as when there is a `drawnow`, `figure`, `uifigure`, `getframe`, `waitfor`, or `pause` command.
  - If the running callback contains one of those commands, then MATLAB stops the execution of the callback at that point and executes the interrupting callback. MATLAB resumes executing the running callback when the interrupting callback completes.
  - If the running callback does not contain one of those commands, then MATLAB finishes executing the callback without interruption.
- `'off'` — Blocks all interruption attempts. The `BusyAction` property of the object owning the interrupting callback determines if the interrupting callback is discarded or put into a queue.

---

**Note** Callback interruption and execution behave differently in these situations:

- If the interrupting callback is a `DeleteFcn`, `CloseRequestFcn` or `SizeChangedFcn` callback, then the interruption occurs regardless of the `Interruptible` property value.

- If the running callback is currently executing the `waitfor` function, then the interruption occurs regardless of the `Interruptible` property value.
- `Timer` objects execute according to schedule regardless of the `Interruptible` property value.

When an interruption occurs, MATLAB does not save the state of properties or the display. For example, the object returned by the `gca` or `gcf` command might change when another callback executes.

### `BusyAction` — Callback queuing

`'queue'` (default) | `'cancel'`

Callback queuing, specified as `'queue'` or `'cancel'`. The `BusyAction` property determines how MATLAB handles the execution of interrupting callbacks. There are two callback states to consider:

- The running callback is the currently executing callback.
- The interrupting callback is a callback that tries to interrupt the running callback.

Whenever MATLAB invokes a callback, that callback attempts to interrupt a running callback. The `Interruptible` property of the object owning the running callback determines if interruption is permitted. If interruption is not permitted, then the `BusyAction` property of the object owning the interrupting callback determines if it is discarded or put in the queue. These are possible values of the `BusyAction` property:

- `'queue'` — Puts the interrupting callback in a queue to be processed after the running callback finishes execution.
- `'cancel'` — Does not execute the interrupting callback.

### `BeingDeleted` — Deletion status

`'off'` | `'on'`

This property is read-only.

Deletion status, returned as `'off'` or `'on'`. MATLAB sets the `BeingDeleted` property to `'on'` when the `DeleteFcn` callback begins execution. The `BeingDeleted` property remains set to `'on'` until the component object no longer exists.

Check the value of the `BeingDeleted` property to verify that the object is not about to be deleted before querying or modifying it.

#### Parent/Child

### Parent — Parent container

`Figure` object (default) | `Panel` object | `Tab` object | `ButtonGroup` object | `GridLayout` object

Parent container, specified as a `Figure` created using the `uifigure` function, or one of its child containers: `Tab`, `Panel`, `ButtonGroup`, or `GridLayout`.

### HandleVisibility — Visibility of object handle

`'on'` (default) | `'callback'` | `'off'`

Visibility of the object handle, specified as `'on'`, `'callback'`, or `'off'`.

This property controls the visibility of the object in its parent's list of children. When an object is not visible in its parent's list of children, it is not returned by functions that obtain objects by searching the object hierarchy or querying properties. These functions include `get`, `findobj`, `clf`, and `close`. Objects are valid even if they are not visible. If you can access an object, you can set and get its properties, and pass it to any function that operates on objects.

| HandleVisibility Value | Description |
|---|---|
| `'on'` | The object is always visible. |
| `'callback'` | The object is visible from within callbacks or functions invoked by callbacks, but not from within functions invoked from the command line. This option blocks access to the object at the command-line, but allows callback functions to access it. |
| `'off'` | The object is invisible at all times. This option is useful for preventing unintended changes to the UI by another function. Set the `HandleVisibility` to `'off'` to temporarily hide the object during the execution of that function. |

#### Identifiers

### Type — Type of graphics object

`'uiaeroturn'`

This property is read-only.

Type of graphics object, returned as `'uiaeroturn'`.

### `Tag` — Object identifier

`''` (default) | character vector | string scalar

Object identifier, specified as a character vector or string scalar. You can specify a unique `Tag` value to serve as an identifier for an object. When you need access to the object elsewhere in your code, you can use the `findobj` function to search for the object based on the `Tag` value.

### `UserData` — User data

`[]` (default) | array

User data, specified as any MATLAB array. For example, you can specify a scalar, vector, matrix, cell array, character array, table, or structure. Use this property to store arbitrary data on an object.

If you are working in App Designer, create public or private properties in the app to share data instead of using the `UserData` property. For more information, see “Share Data Within App Designer Apps” (MATLAB).

## See Also

`uiaeroturn`

## Topics

“Create and Configure Flight Instrument Component and an Animation Object” on page 2-69
“Display Flight Trajectory Data Using Flight Instruments and Flight Animation” on page 2-65

### Introduced in R2018b

# uiaeroairspeed

**Package:** Aero.ui.control

Create airspeed indicator component

## Syntax

```
airspeed = uiaeroairspeed
egt = uiaeroairspeed(parent)
egt = uiaeroairspeed( ___ ,Name,Value)
```

## Description

`airspeed = uiaeroairspeed` creates an airspeed indicator in a new figure. MATLAB calls the `uifigure` function to create the figure.

---

**Note** Use this function only with figures created using the `uifigure` function. Apps created using GUIDE or the `figure` function do not support flight instrument components.

---

`egt = uiaeroairspeed(parent)` specifies the object in which to create the airspeed indicator.

`egt = uiaeroairspeed( ___ ,Name,Value)` specifies airspeed indicator properties using one or more `Name,Value` pair arguments. Use this option with any of the input argument combinations in the previous syntaxes.

## Examples

### Create Airspeed Indicator Component

Create an airspeed indicator component named `airspeed`. By default, the function creates a `uifigure` object for the indicator object.

```
airspeed = uiaeroairspeed
```

```
airspeed =

  AirspeedIndicator (0) with properties:

           Airspeed: 0
        ScaleColors: [4×3 double]
    ScaleColorLimits: [4×2 double]
             Limits: [40 400]
           Position: [100 100 120 120]

  Show all properties
```

### Create Figure Window and Airspeed Indicator Component

Create a figure window to contain the airspeed indicator component, then create an airspeed indicator component named `airspeed`.

```
figure = uifigure;
airspeed = uiaeroairspeed(figure)
```

```
airspeed =

  AirspeedIndicator (0) with properties:

           Airspeed: 0
        ScaleColors: [4×3 double]
    ScaleColorLimits: [4×2 double]
             Limits: [40 400]
           Position: [100 100 120 120]
```

Show all properties

# Input Arguments

**parent — Parent container**
Figure object (default) | Panel object | Tab object | ButtonGroup object | GridLayout object

Parent container, specified as a Figure created using the uifigure function, or one of its child containers: Tab, Panel, ButtonGroup, or GridLayout.

## Name-Value Pair Arguments

Specify optional comma-separated pairs of Name,Value arguments. Name is the argument name and Value is the corresponding value. Name must appear inside quotes. You can specify several name and value pair arguments in any order as Name1,Value1,...,NameN,ValueN.

For a full list of airspeed indicator properties and descriptions for each type, see AirspeedIndicator Properties.

# Output Arguments

**airspeed — Airspeed indicator component**
object

Airspeed indicator component, returned as an object.

# See Also
AirspeedIndicator Properties

## Topics
“Create and Configure Flight Instrument Component and an Animation Object” on page 2-69

“Display Flight Trajectory Data Using Flight Instruments and Flight Animation” on page 2-65

**Introduced in R2018b**

# uiaeroaltimeter

**Package:** Aero.ui.control

Create altimeter component

## Syntax

```
altimeter = uiaeroaltimeter
altimeter = uiaeroaltimeter(parent)
altimeter = uiaeroaltimeter( ___ ,Name,Value)
```

## Description

`altimeter = uiaeroaltimeter` creates an altimeter in a new figure. MATLAB calls the `uifigure` function to create the figure.

**Note** Use this function only with figures created using the `uifigure` function. Apps created using GUIDE or the `figure` function do not support flight instrument components.

`altimeter = uiaeroaltimeter(parent)` specifies the object in which to create the altimeter.

`altimeter = uiaeroaltimeter( ___ ,Name,Value)` specifies altimeter properties using one or more `Name,Value` pair arguments. Use this option with any of the input argument combinations in the previous syntaxes.

## Examples

### Create Altimeter Component

Create an altimeter component named `altimeter`. By default, the function creates a `uifigure` object for the indicator object.

```
altimeter = uiaeroaltimeter
```

```
altimeter =

Altimeter (0) with properties:

    Altitude: 0
    Position: [100 100 120 120]

Show all properties
```

### Create Figure Window and Altimeter Component

Create a figure window to contain the altimeter component, then create a altimeter component named `altimeter`.

```
figure = uifigure;
altimeter = uiaeroaltimeter(figure)
```

```
altimeter =

  Altimeter (0) with properties:

    Altitude: 0
    Position: [100 100 120 120]

  Show all properties
```

## Input Arguments

### `parent` — Parent container

`Figure` object (default) | `Panel` object | `Tab` object | `ButtonGroup` object | `GridLayout` object

Parent container, specified as a `Figure` created using the `uifigure` function, or one of its child containers: `Tab`, `Panel`, `ButtonGroup`, or `GridLayout`.

### Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name,Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside quotes. You can specify several name and value pair arguments in any order as `Name1,Value1,...,NameN,ValueN`.

For a full list of Altimeter properties and descriptions for each type, see Altimeter Properties.

## Output Arguments

**`altimeter` — Altimeter component**
object

Altimeter component, returned as an object.

## See Also

Altimeter Properties

### Topics

“Create and Configure Flight Instrument Component and an Animation Object” on page 2-69
“Display Flight Trajectory Data Using Flight Instruments and Flight Animation” on page 2-65

**Introduced in R2018b**

# uiaeroclimb

**Package:** Aero.ui.control

Create climb rate indicator component

## Syntax

```
climbrate = uiaeroclimb
climbrate = uiaeroclimb(parent)
climbrate = uiaeroclimb( ___ ,Name,Value)
```

## Description

`climbrate = uiaeroclimb` creates a climb rate indicator in a new figure. MATLAB calls the `uifigure` function to create the figure.

---

**Note** Use this function only with figures created using the `uifigure` function. Apps created using GUIDE or the `figure` function do not support flight instrument components.

---

`climbrate = uiaeroclimb(parent)` specifies the object in which to create the climb rate indicator.

`climbrate = uiaeroclimb( ___ ,Name,Value)` specifies climb rate indicator properties using one or more `Name,Value` pair arguments. Use this option with any of the input argument combinations in the previous syntaxes.

## Examples

### Create Climb Rate Indicator Component

Create a climb rate indicator indicator component named `climbrate`. By default, the function creates a `uifigure` object for the indicator object.

```
climbrate = uiaeroclimb
```

```
climbrate =

  ClimbIndicator (0) with properties:

      ClimbRate: 0
    MaximumRate: 2000
       Position: [100 100 120 120]

  Show all properties
```

### Create Figure Window and Climb Rate Indicator Component

Create a figure window to contain the climb rate indicator component, then create an climb rate indicator component named `climbrate`.

```
figure = uifigure;
climbrate = uiaeroclimb(figure)
```

```
climbrate =

  ClimbIndicator (0) with properties:

      ClimbRate: 0
    MaximumRate: 2000
       Position: [100 100 120 120]

  Show all properties
```

## Input Arguments

### `parent` — Parent container

`Figure` object (default) | `Panel` object | `Tab` object | `ButtonGroup` object | `GridLayout` object

Parent container, specified as a `Figure` created using the `uifigure` function, or one of its child containers: `Tab`, `Panel`, `ButtonGroup`, or `GridLayout`.

### Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name,Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside quotes. You can specify several name and value pair arguments in any order as `Name1,Value1,...,NameN,ValueN`.

For a full list of climb rate indicator properties and descriptions for each type, see ClimbIndicator Properties.

## Output Arguments

**`climbrate` — Climb rate indicator component**
object

Climb rate indicator component, returned as an object.

## See Also

ClimbIndicator Properties

### Topics

“Create and Configure Flight Instrument Component and an Animation Object” on page 2-69
“Display Flight Trajectory Data Using Flight Instruments and Flight Animation” on page 2-65

**Introduced in R2018b**

# uiaeroegt

**Package:** Aero.ui.control

Create exhaust gas temperature (EGT) indicator component

## Syntax

```
egt = uiaeroegt
egt = uiaeroegt(parent)
egt = uiaeroegt( ___ ,Name,Value)
```

## Description

`egt = uiaeroegt` creates an EGT indicator in a new figure. MATLAB calls the `uifigure` function to create the figure.

**Note** Use this function only with figures created using the `uifigure` function. Apps created using GUIDE or the `figure` function do not support flight instrument components.

`egt = uiaeroegt(parent)` specifies the object in which to create the EGT indicator.

`egt = uiaeroegt( ___ ,Name,Value)` specifies EGT indicator properties using one or more `Name,Value` pair arguments. Use this option with any of the input argument combinations in the previous syntaxes.

## Examples

### Create EGT Indicator Component

Create an EGT indicator component named `egt`. By default, the function creates a `uifigure` object for the indicator object.

```
egt = uiaeroegt

egt =

  EGTIndicator (0) with properties:

         Temperature: 0
         ScaleColors: [3×3 double]
    ScaleColorLimits: [3×2 double]
              Limits: [0 1000]
            Position: [100 100 120 120]

  Show all properties
```

### Create Figure Window and EGT Indicator Component

Create a figure window to contain the EGT indicator component, then create an EGT indicator component named `egt`.

```
figure = uifigure;
egt = uiaeroegt(figure)

egt =

  EGTIndicator (0) with properties:

         Temperature: 0
         ScaleColors: [3×3 double]
    ScaleColorLimits: [3×2 double]
              Limits: [0 1000]
            Position: [100 100 120 120]

  Show all properties
```

## Input Arguments

### `parent` — Parent container

`Figure` object (default) | `Panel` object | `Tab` object | `ButtonGroup` object | `GridLayout` object

Parent container, specified as a `Figure` created using the `uifigure` function, or one of its child containers: `Tab`, `Panel`, `ButtonGroup`, or `GridLayout`.

### Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name,Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside quotes. You can specify several name and value pair arguments in any order as `Name1,Value1,...,NameN,ValueN`.

For a full list of EGT indicator properties and descriptions for each type, see EGTIndicator Properties.

## Output Arguments

**`egt` — EGT indicator component**
object

EGT indicator component, returned as an object.

## See Also

EGTIndicator Properties

### Topics

“Create and Configure Flight Instrument Component and an Animation Object” on page 2-69
“Display Flight Trajectory Data Using Flight Instruments and Flight Animation” on page 2-65

**Introduced in R2018b**

# uiaeroheading

**Package:** Aero.ui.control

Create heading indicator component

## Syntax

```
heading = uiaeroheading
heading = uiaeroheading(parent)
heading = uiaeroheading( ___ ,Name,Value)
```

## Description

`heading = uiaeroheading` creates a heading indicator in a new figure. MATLAB calls the `uifigure` function to create the figure.

---

**Note** Use this function only with figures created using the `uifigure` function. Apps created using GUIDE or the `figure` function do not support flight instrument components.

---

`heading = uiaeroheading(parent)` specifies the object in which to create the heading indicator.

`heading = uiaeroheading( ___ ,Name,Value)` specifies heading indicator properties using one or more `Name,Value` pair arguments. Use this option with any of the input argument combinations in the previous syntaxes.

## Examples

### Create Heading Indicator Component

Create a heading indicator component named `heading`. By default, the function creates a `uifigure` object for the indicator object.

```
heading = uiaeroheading
```

```
heading =

HeadingIndicator (0) with properties:

     Heading: 0
    Position: [100 100 120 120]
```

### Create Figure Window and Heading Indicator Component

Create a figure window to contain the heading component, then create a heading indicator component named `heading`.

```
figure = uifigure;
heading = uiaeroheading(figure)
```

```
heading =
HeadingIndicator (0) with properties:

     Heading: 0
    Position: [100 100 120 120]

Show all properties
```

## Input Arguments

### `parent` — Parent container

`Figure` object (default) | `Panel` object | `Tab` object | `ButtonGroup` object | `GridLayout` object

Parent container, specified as a `Figure` created using the `uifigure` function, or one of its child containers: `Tab`, `Panel`, `ButtonGroup`, or `GridLayout`.

### Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name,Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside quotes. You can specify several name and value pair arguments in any order as `Name1,Value1,...,NameN,ValueN`.

For a full list of heading indicator properties and descriptions for each type, see HeadingIndicator Properties.

## Output Arguments

**`heading` — Heading indicator component**
object

Heading indicator component, returned as an object.

## See Also

HeadingIndicator Properties

### Topics

“Create and Configure Flight Instrument Component and an Animation Object” on page 2-69
“Display Flight Trajectory Data Using Flight Instruments and Flight Animation” on page 2-65

**Introduced in R2018b**

# uiaerohorizon

**Package:** Aero.ui.control

Create artificial horizon component

## Syntax

```
horizon = uiaerohorizon
horizon = uiaerohorizon(parent)
horizon = uiaerohorizon( ___ ,Name,Value)
```

## Description

`horizon = uiaerohorizon` creates an artificial horizon in a new figure. MATLAB calls the `uifigure` function to create the figure.

---

**Note** Use this function only with figures created using the `uifigure` function. Apps created using GUIDE or the `figure` function do not support flight instrument components.

---

`horizon = uiaerohorizon(parent)` specifies the object in which to create the artificial horizon.

`horizon = uiaerohorizon( ___ ,Name,Value)` specifies artificial horizon properties using one or more `Name,Value` pair arguments. Use this option with any of the input argument combinations in the previous syntaxes.

## Examples

### Create Artificial Horizon Component

Create an artificial horizon component named `horizon`. By default, the function creates a `uifigure` object for the indicator object.

```
horizon = uiaerohorizon
```

```
horizon =

  ArtificialHorizon ([0  0]) with properties:

       Pitch: 0
        Roll: 0
    Position: [100 100 120 120]

  Show all properties
```

### Create Figure Window and Artificial Horizon Component

Create a figure window to contain the artificial horizon component, then create an artificial horizon component named `horizon`.

```
figure = uifigure;
egt = uiaeroegt(figure)
```

```
horizon =

  ArtificialHorizon ([0  0]) with properties:

       Pitch: 0
        Roll: 0
    Position: [100 100 120 120]

  Show all properties
```

## Input Arguments

### `parent` — Parent container

`Figure` object (default) | `Panel` object | `Tab` object | `ButtonGroup` object | `GridLayout` object

Parent container, specified as a `Figure` created using the `uifigure` function, or one of its child containers: `Tab`, `Panel`, `ButtonGroup`, or `GridLayout`.

### Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name,Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside quotes. You can specify several name and value pair arguments in any order as `Name1,Value1,...,NameN,ValueN`.

For a full list of artificial horizon properties and descriptions for each type, see ArtificialHorizon Properties.

## Output Arguments

**`horizon` — Artificial horizon component**
object

Artificial horizon component, returned as an object.

## See Also

ArtificialHorizon Properties

### Topics

“Create and Configure Flight Instrument Component and an Animation Object” on page 2-69
“Display Flight Trajectory Data Using Flight Instruments and Flight Animation” on page 2-65

**Introduced in R2018b**

# uiaerorpm

**Package:** Aero.ui.control

Create revolutions per minute (RPM) indicator component

## Syntax

```
rpm = uiaerorpm
rpm = uiaerorpm(parent)
rpm = uiaerorpm( ___ ,Name,Value)
```

## Description

`rpm = uiaerorpm` creates an RPM indicator in a new figure. MATLAB calls the `uifigure` function to create the figure.

**Note** Use this function only with figures created using the `uifigure` function. Apps created using GUIDE or the `figure` function do not support flight instrument components.

`rpm = uiaerorpm(parent)` specifies the object in which to create the RPM indicator.

`rpm = uiaerorpm( ___ ,Name,Value)` specifies RPM indicator properties using one or more `Name,Value` pair arguments. Use this option with any of the input argument combinations in the previous syntaxes.

## Examples

### Create RPM Indicator Component

Create an RPM indicator component named `rpm`. By default, the function creates a `uifigure` object for the indicator object.

```
rpm = uiaerorpm

rpm =

  RPMIndicator (0) with properties:

                 RPM: 0
          ScaleColors: [3×3 double]
    ScaleColorLimits: [3×2 double]
            Position: [100 100 120 120]

  Show all properties
```

### Create Figure Window and RPM Indicator Component

Create a figure window to contain the RPM indicator component, then create an RPM indicator component named `rpm`.

```
figure = uifigure;
rpm = uiaerorpm(figure)

rpm =

  RPMIndicator (0) with properties:

                 RPM: 0
          ScaleColors: [3×3 double]
    ScaleColorLimits: [3×2 double]
            Position: [100 100 120 120]

  Show all properties
```

## Input Arguments

### `parent` — Parent container

`Figure` object (default) | `Panel` object | `Tab` object | `ButtonGroup` object | `GridLayout` object

Parent container, specified as a `Figure` created using the `uifigure` function, or one of its child containers: `Tab`, `Panel`, `ButtonGroup`, or `GridLayout`.

### Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name,Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside quotes. You can specify several name and value pair arguments in any order as `Name1,Value1,...,NameN,ValueN`.

For a full list of RPM indicator properties and descriptions for each type, see RPMIndicator Properties.

## Output Arguments

**`rpm` — RPM indicator**
object

RPM indicator component, returned as an object.

## See Also

RPMIndicator Properties

### Topics

“Create and Configure Flight Instrument Component and an Animation Object” on page 2-69
“Display Flight Trajectory Data Using Flight Instruments and Flight Animation” on page 2-65

**Introduced in R2018b**

# uiaeroturn

**Package:** Aero.ui.control

Create turn coordinator component

## Syntax

```
turn = uiaeroturn
turn = uiaeroturn(parent)
turn = uiaeroturn( ___ ,Name,Value)
```

## Description

`turn = uiaeroturn` creates a turn coordinator in a new figure. MATLAB calls the `uifigure` function to create the figure.

---

**Note** Use this function only with figures created using the `uifigure` function. Apps created using GUIDE or the `figure` function do not support flight instrument components.

---

`turn = uiaeroturn(parent)` specifies the object in which to create the turn coordinator.

`turn = uiaeroturn( ___ ,Name,Value)` specifies turn coordinator properties using one or more `Name,Value` pair arguments. Use this option with any of the input argument combinations in the previous syntaxes.

## Examples

### Create Turn Coordinator Component

Create a turn coordinator component named `turn`.

```
turn = uiaeroturn

turn =

  TurnCoordinator ([0  0]) with properties:

        Turn: 0
        Slip: 0
    Position: [100 100 120 120]

  Show all properties
```

### Create Figure Window and Turn Coordinator Component

Create a figure window to contain the turn coordinator component, then create a turn coordinator component named `turn`.

```
figure = uifigure;
turn = uiaeroturn(figure)

turn =

  TurnCoordinator ([0  0]) with properties:

        Turn: 0
        Slip: 0
    Position: [100 100 120 120]

  Show all properties
```

## Input Arguments

### `parent` — Parent container

`Figure` object (default) | `Panel` object | `Tab` object | `ButtonGroup` object | `GridLayout` object

Parent container, specified as a `Figure` created using the `uifigure` function, or one of its child containers: `Tab`, `Panel`, `ButtonGroup`, or `GridLayout`.

### Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name,Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside quotes. You can specify several name and value pair arguments in any order as `Name1,Value1,...,NameN,ValueN`.

For a full list of turn coordinator properties and descriptions for each type, see TurnCoordinator Properties.

## Output Arguments

**`turn` — Turn coordinator component**
object

Turn coordinator component, returned as an object.

## See Also

TurnCoordinator Properties

### Topics

“Create and Configure Flight Instrument Component and an Animation Object” on page 2-69
“Display Flight Trajectory Data Using Flight Instruments and Flight Animation” on page 2-65

**Introduced in R2018b**

# update (Aero.Body)

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`

**Introduced in R2007a**

# update (Aero.Camera)

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`

**Introduced in R2007a**

# update (Aero.FlightGearAnimation)

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`

**Introduced in R2007a**

# update (Aero.Node)

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`

**Introduced in R2007b**

# updateBodies

**Class:** Aero.Animation
**Package:** Aero

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);
```

# updateCamera

**Class:** Aero.Animation
**Package:** Aero

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)

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`

**Introduced in R2007b**

# Viewpoint (Aero.Viewpoint)

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.

**Introduced in R2007b**

# VirtualRealityAnimation (Aero.VirtualRealityAnimation)

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`

**Introduced in R2007b**

# wrldmagm

Use World Magnetic Model

**Note** The `'2000'` or `'2005'` epoch year are outdated. For model years between 2000 and the start of 2010, use `igrfmagm`. For model years between 2010 and 2015, use `wrldmagm`.

## Syntax

```
[xyz, h, dec, dip, f] = wrldmagm(height, lat, lon, dyear)
[xyz, h, dec, dip, f] = wrldmagm(height, lat, lon, dyear, '2015')
[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-2015, which is valid after the epoch of the model, which is January 1, 2015.

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. |
| `WMM` | Optional World Magnetic Model, as a character vector or string. |

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, '2015')` is an alternate method for calling WMM-2015, or 2015 epoch.

`[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, 2015, using WMM-2015:

```
[XYZ, H, DEC, DIP, F] = wrldmagm(1000, 42.283, -71.35, decyear(2015,7,4),'2015')
XYZ =

   1.0e+04 *

    1.9454
   -0.5086
    4.8168

H =
```

```
   2.0108e+04

DEC =

  -14.6499

DIP =

   67.3416

F =

   5.2197e+04
```

## 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

`https://www.ngdc.noaa.gov/geomag/WMM/DoDWMM.shtml`

“NOAA Technical Report: The US/UK World Magnetic Model for 2015–2020”

## See Also

`decyear`

**Introduced in R2006b**

# Bodies property

**Class:** Aero.Animation
**Package:** Aero

Specify name of animation object

## Values

`MATLAB array`

**Default:** `[ ]`

## Description

This property specifies the bodies that the animation object contains.

# Camera property

**Class:** Aero.Animation
**Package:** Aero

Specify camera that animation object contains

## Values

`handle`

**Default:** `[ ]`

## Description

This property specifies the camera that the animation object contains.

# Figure property

**Class:** Aero.Animation
**Package:** Aero

Specify name of figure object

## Values

`MATLAB array`

**Default:** `[ ]`

## Description

This property specifies the name of the figure object.

# FigureCustomizationFcn property

**Class:** Aero.Animation
**Package:** Aero

Specify figure customization function

## Values

`MATLAB array`

**Default:** `[ ]`

## Description

This property specifies the figure customization function.

# FramesPerSecond property

**Class:** Aero.Animation
**Package:** Aero

Animation rate

## Values

`MATLAB array`

**Default:** 12

## Description

This property specifies rate in frames per second.

# Name property

**Class:** Aero.Animation
**Package:** Aero

Specify name of animation object

## Values

`Character vector | string`

**Default:** `' '`

## Description

This property specifies the name of the animation object.

# TCurrent property

**Class:** Aero.Animation
**Package:** Aero

Current time

## Values

`double`

**Default:** `0`

## Description

This property specifies the current time.

# TFinal property

**Class:** Aero.Animation
**Package:** Aero

End time

## Values

`double`

**Default:** `NaN`

## Description

This property specifies the end time.

# TimeScaling property

**Class:** Aero.Animation
**Package:** Aero

Scaling time

## Values

`double`

**Default:** 1

## Description

This property specifies the time, in seconds.

# TStart property

**Class:** Aero.Animation
**Package:** Aero

Start time

## Values

`double`

**Default:** `NaN`

## Description

This property specifies the start time.

# VideoCompression property

**Class:** Aero.Animation
**Package:** Aero

Video recording compression file type

## Values

**`'Archival'`**

Create Motion JPEG 2000 format file with lossless compression.

**`'Motion JPEG AVI'`**

Create compressed AVI format file using Motion JPEG codec.

**`'Motion JPEG 2000'`**

Create compressed Motion JPEG 2000 format file.

**`'MPEG-4'`**

Create compressed MPEG-4 format file with H.264 encoding (Windows 7 systems only).

**`'Uncompressed AVI'`**

Create uncompressed AVI format file with RGB24 video.

Data type: `Aero.VideoProfileTypeEnum`

Default: `'Archival'`

## Description

This property specifies the compression file type to create. For more information on video compression, see `VideoWriter`.

# VideoFileName property

**Class:** Aero.Animation
**Package:** Aero

Video recording file name

## Values

*filename*

Data type: character vector | string

Default: `temp`

## Description

This property specifies the file name for the video recording.

# VideoQuality property

**Class:** Aero.Animation
**Package:** Aero

Video recording quality

## Values

Value between `0` and `100`

Data type: double

Default: `75`

## Description

This property specifies the recording quality. For more information on video quality, see the `Quality` property in `VideoWriter`.

# VideoRecord property

**Class:** Aero.Animation
**Package:** Aero

Video recording

## Values

**'on'**

Enable video recording.

**'off'**

Disable video recording.

**'scheduled'**

Schedule video recording. Use this setting with the `VideoTStart` and `VideoTFinal` properties.

Data type: character vector | string

Default: `'off'`

## Description

This property enables video recording of animation objects.

If you are capturing frames of a plot that takes a long time to generate or are repeatedly capturing frames in a loop, make sure that your computer's screen saver does not activate and that your monitor does not turn off for the duration of the capture; otherwise one or more of the captured frames can contain graphics from your screen saver or nothing at all.

**Note** In situations where MATLAB software is running on a virtual desktop that is not currently visible on your monitor, it may capture a region on your monitor that

corresponds to the position occupied by the figure or axes on the hidden desktop. Therefore, make sure that the window to be captured exists on the currently active desktop.

# Examples

### Record Animation Object Simulation

Simulate and record flight data. Create an animation object.

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

Control the frame display rate.

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

Set the time-scaling (`TimeScaling`) property on the animation object to specify the data per second.

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

The combination of `FramesPerSecond` and `TimeScaling` properties determines the time step of the simulation. These settings result in a time step of approximately 0.5 s.

Create and load a body for the animation object.

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

Load simulated flight trajectory data (`simdata`), located in *`matlabroot`*`\toolbox\aero\astdemos`.

```
load simdata;
```

Set the time series data for the body.

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

Create a figure object for the animation object.

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

Set up recording properties.

```
h.VideoRecord = 'on';
h.VideoQuality = 50;
h.VideoCompression = 'Motion JPEG AVI'
```

```
h =
  Animation with properties:

                      Name: ''
                    Figure: [1×1 Figure]
    FigureCustomizationFcn: []
                    Bodies: {[1×1 Aero.Body]}
                    Camera: [1×1 Aero.Camera]
```

```
            TimeScaling: 5
                 TStart: NaN
                 TFinal: NaN
               TCurrent: 0
        FramesPerSecond: 10
            VideoRecord: 'on'
          VideoFileName: 'temp'
       VideoCompression: 'Motion JPEG AVI'
           VideoQuality: 50
            VideoTStart: NaN
            VideoTFinal: NaN
```

```
h.VideoFilename = 'astMotion_JPEG';
```

Play the animation.

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

Verify that a file named `astMotion_JPEG.avi` was created in the current folder.

Disable recording to preserve the file.

```
h.VideoRecord = 'off';
```

### Record Animation for Four Seconds

Simulate flight data for four seconds. Create an animation object.

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

Control the frame display rate.

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

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` properties determines the time step of the simulation (`TimeScaling`/|FramesPerSecond|). These settings result in a time step of approximately 0.5 s.

Create and load a body for the animation object.

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

Load simulated flight trajectory data (`simdata`), located in *`matlabroot`*`\toolbox\aero\astdemos`.

```
load simdata;
```

Set the time series data for the body.

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

Create a figure object for the animation object.

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

Set up recording properties.

```
h.VideoRecord='on';
h.VideoQuality = 50;
h.VideoCompression = 'Motion JPEG AVI';
h.VideoFilename = 'astMotion_JPEG';
```

Play the animation from `TFinal` to `TStart`.

```
h.TSTart = 1;
h.TFinal = 5;
h.play();
```

Verify that a file named `astMotion_JPEG.avi` was created in the current folder. When you rerun the recording, notice that the play time is shorter than that in the previous example when you record for the length of the simulation time.

Disable recording to preserve the file.

```
h.VideoRecord = 'off';
```

### Schedule Three Second Recording of Simulation

Schedule three second recording of animation object simulation.

Create an animation object.

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

Control the frame display rate.

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

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` properties determines the time step of the simulation (`TimeScaling`/|`FramesPerSecond`|). These settings result in a time step of approximately 0.5 s.

Create and load a body for the animation object.

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

Load simulated flight trajectory data (`simdata`), located in `matlabroot\toolbox\aero\astdemos`.

```
load simdata;
```

Set the time series data for the body.

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

Create a figure object for the animation object.

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

# VideoTFinal property

**Class:** Aero.Animation
**Package:** Aero

Video recording stop time for scheduled recording

## Values

Value between `TStart` and `TFinal`

Data type: double

Default: `NaN`, which uses the value of `TFinal`

## Description

This property specifies the stop time of scheduled recording.

Use when `VideoRecord` is set to `'scheduled'`. Use `VideoTStart` to set the start time of the recording.

# VideoTStart property

**Class:** Aero.Animation
**Package:** Aero

Video recording start time for scheduled recording

## Values

Value between `TStart` and `TFinal`

Data type: double

Default: `NaN`, which uses the value of `TStart`.

## Description

This property specifies the start time of the scheduled recording.

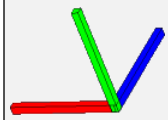
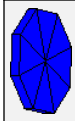
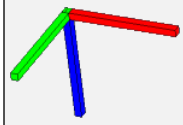
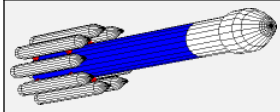
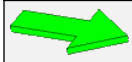
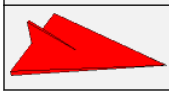
Use when `VideoRecord` is set to `'scheduled'`. Use `VideoTFinal` to set the end time of the recording.

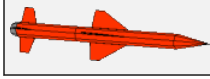
A

# AC3D Files and Thumbnails

# 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` |
|  | `redwedge.ac` |

| Thumbnail | AC3D File |
| --- | --- |
|  | `testrocket.ac` |