

Aerospace Toolbox 2

Aerospace reference standards, environmental models, and aerodynamic coefficient importing

Aerospace Toolbox provides reference standards, environmental models, and aerodynamic coefficient importing for performing advanced aerospace analysis to develop and evaluate your designs. Options for visualizing vehicle dynamics include a six-degrees-of-freedom MATLAB® animation object and interfaces to FlightGear flight simulator and Virtual Reality Toolbox. These options let you visualize flight data in a three-dimensional (3-D) environment and reconstruct behavioral anomalies in flight-test results.

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

```
% Open a FlightGearAnimation object.
fg=fganimation;

% Convert Latitude, longitude and Euler angles from
% degrees to radians using the *convang* function and
% set FlightGearAnimation object properties for timeseries.
fg.TimeseriesSource = [myflightdata(:,1) ...
convang(myflightdata(:, [3 2]), 'deg', 'rad') ...
myflightdata(:,4) ...
convang(myflightdata(:,5:7), 'deg', 'rad')];

% Play Back the Flight Trajectory
fg.play;
```



KEY FEATURES

- Includes standards-based environmental models for atmosphere, gravity, geoid height, wind, and magnetic field
- Converts units and transforms coordinate systems and spatial representations
- Implements predefined utilities for aerospace parameter calculations, time calculations, and quaternion math
- Imports aerodynamic coefficients from the U.S. Air Force Digital Data Compendium (Datcom)
- Provides options for visualizing vehicle dynamics in a 3-D environment, including an interface to FlightGear flight simulator



Visualization of Boeing 777 flight data (above) achieved by using Aerospace Toolbox interface to FlightGear flight simulator (left).

Working with Environmental Models

Aerospace Toolbox provides standards-based environmental models for atmosphere, gravity, geoid height, and magnetic field.

The atmospheric models help you calculate ambient flight conditions and normalize flight data. They incorporate the 1976 Committee on Extension to the Standard Atmosphere (COESA) and International Standard Atmosphere (ISA) models, as well as nonstandard day models from U.S. military specifications (MIL-HDBK-310 and MIL-STD-210C).

Additional atmospheric model functions implement mathematical representations from these models: 2001 United States Naval Research Laboratory Mass Spectrometer and Incoherent Scatter Radar Exosphere

(NRLMSISE) and 1986 Committee on Space Research (COSPAR) International Reference Atmosphere (CIRA). The NRLMSISE model provides atmospheric temperatures and densities at altitudes from 0 to 1,000 kilometers for a specified location and time. The CIRA model provides mean climatic data for atmospheric temperature, zonal wind, and either geopotential height or pressure for altitudes from 0 to 120 kilometers.

The gravity, geoid height, and magnetic field model functions help you analyze data and develop algorithms for navigation and geodesy

applications. The gravity model is based on the 1984 World Geodetic System (WGS84) gravitational model. The geoid height function uses the 1996 Earth Geopotential Model (EGM96) to calculate geoid height for a specified latitude and longitude. The magnetic field model incorporates the 2000 and 2005 versions of the World Magnetic Model (WMM), which both use the National Imagery and Mapping Agency (NIMA) standard to calculate total intensity, horizontal intensity, declination, inclination, and the vector of the Earth's magnetic field for a specified location and time.

```
% Load Recorded Flight Data for Analysis
load('astflight.mat');

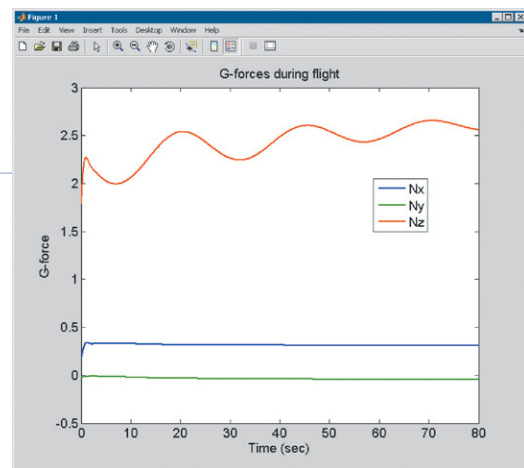
% Extract Flight Parameters from Loaded Data
alpha = fltdata(:,2);
beta  = fltdata(:,3);
alt   = fltdata(:,10);

% Convert body angular rates from
% radians per second to degrees per second
omega = convangvel( fltdata(:,5:7), 'rad/s', 'deg/s' );

% The atmospheric properties, temperature (T),
% speed of sound (a), pressure (P), and density (rho),
% are determined at altitude for standard day
% using the *atmoscoesa* function.
[T a P rho]= atmoscoesa( alt );

% Compute True Airspeed from Indicated Airspeed
flaps0IAS = 40:10:140;
flaps0CAS = [43 51 59 68 77 87 98 108 118 129 140];
CAS = interp1( flaps0IAS, flaps0CAS, fltdata(:,4) );
Vt = correctairspeed( CAS, a, P, 'CAS', 'TAS' );

% Import Digital DATCOM Data for Aircraft
data = datcomimport( 'astflight.out', true, 0 );
```



A portion of the script (left) built with Aerospace Toolbox utilities to calculate G-forces during flight (above). The chosen utilities converted units, accessed the Committee on Extension to the Standard Atmosphere (COESA) model, calculated true airspeed, and imported Digital Datcom aerodynamic coefficients.

```

% The aircraft parameters are declared as follows.
W = 2400; % weight, lbf
S = 174; % wing reference area, ft^2;
A = 7.38; % wing aspect ratio
C_D0 = 0.037; % flaps up parasite drag coefficient
e = 0.72; % airplane efficiency factor

% Set the current aircraft conditions.
% The bank angle (phi) is zero for this case.
h = 4000; % altitude, ft
phi = 0; % bank angle, deg

% Convert altitude to meters.
% The atmospheric calculations in the next step
% require values in metric units.
h_m = convlength(h, 'ft', 'm');

% Calculate atmospheric parameters based on altitude.
[T, a, P, rho] = atmoscoesa(h_m, 'Warning');

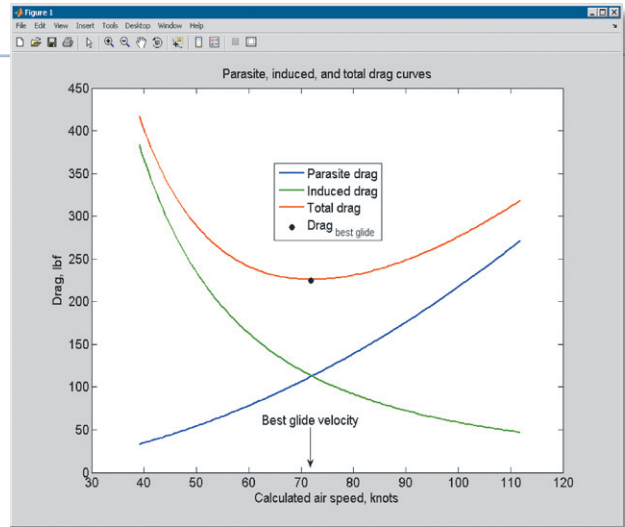
% Convert density from metric to English units.
rho = convdensity(rho, 'kg/m^3', 'slug/Ft^3');

% Calculate best glide velocity TAS
% (true airspeed in feet per second).
TAS_bg = sqrt((2*W) / (rho*S))...
    *(1./(4*C_D0.^2 + C_D0.*pi*e*A*cos(phi)^2)).^(1/4); % TAS, fps

% Convert velocity from fps to kts. KTAS is true airspeed in knots.
KTAS_bg = convvel(TAS_bg, 'ft/s', 'kts');

% Convert KTAS to KCAS.
% KCAS (calibrated airspeed in knots) is the velocity corrected
% for instrument error and position error.
% This position error comes from inaccuracies in static pressure
% measurements at different points in the flight envelope.
KCAS_bg = correctairspeed(KTAS_bg, a, P, 'TAS', 'CAS');

```



Parasite, induced, and total drag curves (above) for a Cessna 172 created by using Aerospace Toolbox unit conversion utilities, atmospheric models, and flight parameter calculations (left). The best glide velocity, indicated by an arrow, corresponds to the minimum value of drag on the total drag curve.

Converting Units and Transforming Coordinate Systems

Aerospace Toolbox lets you convert units and transform axes representations and coordinate systems. The unit conversion utilities convert physical properties, such as acceleration, density, and temperature, between metric and English units. The axes transformation utilities create direction cosine matrices and convert spatial representations between Euler angles and quaternion vectors.

The Euler angles can be in any of the twelve standard rotation sequences. The direction cosine (rotation) matrix transfers between coordinate systems, such as body and inertial; body and wind; Earth-centered, Earth-fixed (ECEF) and north-east-down (NED); and ECEF and latitude, longitude, and altitude (LLA). Other representations include geocentric and geodetic latitude.

Performing Parameter Calculations, Time Calculations, and Quaternion Math

Aerospace Toolbox implements utilities for flight parameter calculations, time calculations, and quaternion math operations, such as the conjugate, division, inverse, and modulus.

The flight parameter utilities let you calculate these common parameters: relative pressure, density, and temperature ratios; equivalent airspeed; calibrated airspeed; Mach number; dynamic pressure; and, for a given geocentric latitude, planet radius. With the time calculation utilities, you can compute Julian dates, decimal year, and leap year.

Importing Digital Datcom Aerodynamic Coefficients

The U.S. Air Force Digital Datcom is a computer program that uses flight conditions and aircraft geometry to estimate the aerodynamic stability and control characteristics of aircraft. Digital Datcom follows the methods in the U.S. Air Force Stability and Control Datcom. Aerospace Toolbox includes a function for importing output files from Digital Datcom into MATLAB. This function lets you collect aerodynamic coefficients from static and dynamic analyses and transfer them into MATLAB as a cell array of structures, with each structure containing information about a Digital Datcom output file.

Visualizing Flight Data

Aerospace Toolbox provides three options for visualizing flight data. First, the interface to FlightGear flight simulator lets you visualize vehicle dynamics in a sophisticated 3-D simulation framework. You can play back flight-test data through FlightGear and quickly reconstruct behavioral anomalies in your flight-test results. Aerospace Toolbox includes functions for controlling the position and attitude of a vehicle in FlightGear flight simulator by using double-precision values of longitude, latitude, altitude, roll, pitch, and yaw from MATLAB. Second, the interface to Virtual Reality Toolbox lets you use your flight data to control vehicle position and attitude in a virtual-reality scene. You can customize this scene, for example, by adding other vehicles. You can also visualize space flight. Third, MATLAB animation objects let you animate six-degrees-of-freedom motion within the MATLAB environment.

Required Products

MATLAB

Related Products

Aerospace Blockset. Model and simulate aircraft, spacecraft, and propulsion systems

Control System Toolbox. Design and analyze control systems

Mapping Toolbox. Analyze and visualize geographic information

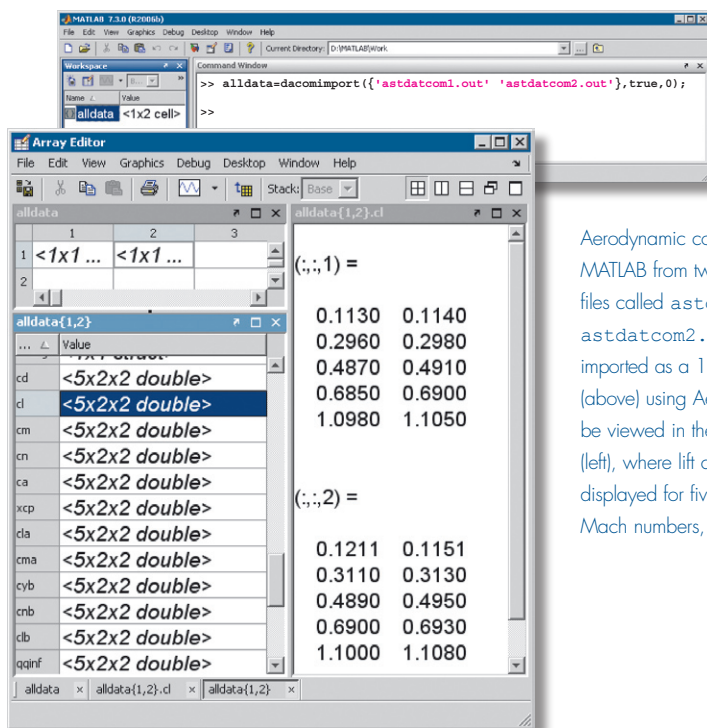
Statistics Toolbox. Apply statistical algorithms and probability models

Virtual Reality Toolbox. Animate and visualize Simulink® systems in three dimensions

For more information on related products, visit www.mathworks.com/products/aerotb

Platform and System Requirements

For platform and system requirements, visit www.mathworks.com/products/aerotb



Aerodynamic coefficients imported into MATLAB from two Digital Datcom output files called `astdatcom1.out` and `astdatcom2.out`. The coefficients are imported as a 1×2 cell array of structures (above) using Aerospace Toolbox and can be viewed in the MATLAB Array Editor (left), where lift coefficient (`cl`) values are displayed for five angles of attack, two Mach numbers, and two altitudes.

Resources

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