Chapter 1. MATLAB/Simulink as a Technical Computing Language
Outline

- 1.1 Introduction
- 1.2 History of MATLAB Creation and Development
- 1.3 Capabilities and Resources
- 1.4 Aerospace Application Tools
- 1.5 Overview of MathWorks Products
- 1.6 Installing Mathworks Products
- 1.7 MATLAB Online
Fast Facts

- Founded in 1984
- Software installations at over 80,000 business, government, and university sites
- Customers in over 180 countries
- There are more than:
  - 2 million users of MATLAB worldwide
  - 4 million files downloaded from File Exchange on MATLAB Central in 2016
  - 225,000 contributors worldwide to MATLAB Central apps
  - 500 third-party solutions that build on MATLAB and Simulink
  - Over 2,000 MATLAB based books in 28 languages
The Growth of MATLAB and The MathWorks over Two Decades

The Origins of MATLAB

Jack Little left his job at the consulting company and bought a new COMPAQ portable computer at Sears. The machine had only 256 KB of memory and no hard disc; Jack had to swap 5-1/4-inch floppies to compile programs. Jack and Steve took a year and a half to rewrite MATLAB in C, adding new features they had envisioned. Steve wrote the parser/interpreter, and Jack wrote the math libraries, including translations to C of about a dozen routines from LINPACK and MATLAB. Jack also wrote the first Control System Toolbox. Some of their original code is still used in MATLAB today.

In 1984, Jack, Steve, and I founded The MathWorks. The first mailing address was a rented A-frame cabin where Jack lived in the hills above Stanford University in Portola Valley, California.

The MathWorks released MATLAB 1.0, implemented in C for MS-DOS PCs. MATLAB made its commercial debut at the IEEE Conference on Design and Control in Las Vegas, Nevada.

Jack suggested making MATLAB a matrix-based programming language to which we could easily add new functions, organized into toolboxes. He wanted the system to be available on a wide range of machines, from PCs and workstations to mainframes. He also wanted it to take advantage of graphics where they were available. I readily agreed.

There was considerable concern about code size in the initial versions of MATLAB. On the PC, MATLAB had to share 256 KB of memory with the DOS operating system and still leave room to store a few matrices. I designed a simple, single-shift, complex QZ algorithm that was not in EISPACK. It required little memory and could be used for most of the matrix eigenvalue problems. We even used it for polynomial zeros to save code.

Video: The Origins of MATLAB

Cleve Moler describes his inspiration for authoring MATLAB.

MATLAB Product Family

Simulink Product Family

- Code Generation
- Rapid Prototyping and HIL Simulation
- Embedded Targets
- Verification, Validation, and Testing
- Physical Modeling
- Fixed-Point Modeling
- Event-Based Modeling
- Simulation Graphics
- Math and Optimization
- Statistics and Data Analysis
- Database Connectivity and Reporting
- Application Deployment

Application-Specific Products

- Control System Design and Analysis
- Signal Processing and Communications
- Image and Video Processing
- Test and Measurement
- Computational Biology
- Financial Modeling and Analysis

All rights reserved. No part of this publication may be reproduced, distributed, or transmitted, unless for course participation, in any form or by any means, or stored in a database or retrieval system, without the prior written permission of the Publisher and/or Author. Contact the American Institute of Aeronautics and Astronautics, Professional Development Programs, 12700 Sunrise Valley Drive, Suite 200, Reston, VA 20191-5807.
Latest Release Highlights

- **R2012b** – new Desktop features (Toolstrip interface that replaced menus and toolbars, Apps gallery presenting apps from the MATLAB product family, redesigned Help system), command line suggestions; new Simulink Editor, smart signal routing and simulation tools
- **R2013b** – new types of data (*table* data container, *categorical* array)
- **R2014a** – new way to display Command History window (pop-up window rather than static window)
- **R2014b** – new graphics system, new types of data (*datetime*, *duration*, and *calendarDuration*), suggested corrections for syntax errors in the Command Window, packaging a sharing tool, big data analysis tools (*datastore* and others)
- **R2016a** – Live Editor to create and run live scripts with embedded output), suggested corrections for syntax errors in the Command Window, App Designer
- **R2016b** – new types of data (*timetable* data container, *timeseries* objects, *string* array), working with missing data (*fillmissing*) and big data (*tall*)
- **R2017a** – MATLAB Online to use MATLAB through the web browser, working with outliers (*filloutliers* and others)
- **R2017b** – MATLAB Drive providing a common free cloud-based storage of 250Mb), plotting in geographic coordinates, *wordcloud* function
- **R2018a** – improved graphic (*axes*, *legend*)
- **R2018b** – new plotting functions (*xline*, *yline*, *geoaxes*, *stackedplot*, *scatterhistogram* and others), axes toolbar, Deep Learning Toolbox
- **R2019a** – new tabular data reading functions (*readmatrix* and others), *parallelplot*, graphics export, Reinforcement Learning Toolbox
Toolboxes and Blocksets

MathWorks - Products and Services - Windows Internet Explorer

MATLAB Products
Simulink Products
Poly-space Products
Services

Signal Processing and Communications
- Signal Processing Toolbox
- DSP System Toolbox
- Communications System Toolbox
- Wavelet Toolbox
- Fixed-Point Toolbox
- RF Toolbox
- Phased Array System Toolbox

Image Processing and Computer Vision
- Image Processing Toolbox
- Computer Vision System Toolbox
- Image Acquisition Toolbox
- Mapping Toolbox

Test and Measurement
- Data Acquisition Toolbox
- Instrument Control Toolbox
- Image Acquisition Toolbox
- OPC Toolbox
- Vehicle Network Toolbox

Computational Finance
- Financial Toolbox
- Econometrics Toolbox
- Datafeed Toolbox
- Fixed-Income Toolbox
- Financial Derivatives Toolbox

Computational Biology
- Bioinformatics Toolbox
- Simbiology

Code Generation
- MATLAB Coder
- MATLAB Compiler
- Embedded Coder
- DSP System Toolbox
- Image Processing Toolbox
- Simulink Coder

Application Deployment
- MATLAB Compiler
- MATLAB Builder NE (for Microsoft.NET Framework)
- MATLAB Builder JA (Java language)
- MATLAB Builder EX (Microsoft Excel)
- Spreadsheet Link EX (for Microsoft Excel)

Database Connectivity and Reporting
- Database Toolbox
- MATLAB Report Generator

Control System Design and Analysis
- Control System Toolbox
- System Identification Toolbox
- Fuzzy Logic Toolbox
- Robust Control Toolbox
- Model Predictive Control Toolbox
- Aerospace Toolbox

Parallel Computing
- Parallel Computing Toolbox
- MATLAB Distributed Computing Server

Math, Statistics, and Optimization
- Symbolic Math Toolbox
- Partial Differential Equation Toolbox
- Statistics Toolbox
- Curve Fitting Toolbox
- Optimization Toolbox
- Global Optimization Toolbox
- Neural Network Toolbox
- Model-Based Calibration Toolbox

Control System Design and Analysis
- Control System Toolbox
- System Identification Toolbox
- Fuzzy Logic Toolbox
- Robust Control Toolbox
- Model Predictive Control Toolbox
- Aerospace Toolbox

All rights reserved. No part of this publication may be reproduced, distributed, or transmitted, unless for course participation, in any form or by any means, or stored in a database or retrieval system, without the prior written permission of the Publisher and/or Author. Contact the American Institute of Aeronautics and Astronautics, Professional Development Programs, 12700 Sunrise Valley Drive, Suite 200, Reston, VA 20191-5807.
<table>
<thead>
<tr>
<th>Subgroup</th>
<th>Brief Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axes Transformations</td>
<td>Transforms axes of coordinate systems to different types</td>
</tr>
<tr>
<td>Flight Parameters</td>
<td>Computes various flight parameters, including ideal airspeed correction, Mach number, and dynamic pressure</td>
</tr>
<tr>
<td>Quaternion Math</td>
<td>Assures common mathematical and matrix operations on a quaternion</td>
</tr>
<tr>
<td>Unit Conversion</td>
<td>Converts common measurement units from one system to another, and enables time calculations, including Julian dates, decimal year, and leap year</td>
</tr>
<tr>
<td>Environment</td>
<td>Simulates various aspects of aircraft environment, such as atmosphere conditions, gravity, magnetic fields, and wind</td>
</tr>
<tr>
<td>Gas Dynamics</td>
<td>Provides various gas dynamics tables</td>
</tr>
<tr>
<td>Trajectory and Attitude Visualization</td>
<td>Allows constructing FlightGear animation objects to be used in virtual reality animations</td>
</tr>
</tbody>
</table>
Aerospace Blockset

Pressure Altitude

ISA Atmosphere Model

Celestial Phenomena

Atmosphere

Gravity

Wind

MATLAB-Based Animation

Flight Simulator Interfaces

Animation Support Utilities

6DOF

3DOF

Point Mass

Pilot Models

Environment

Actuators

Animation

Aerodynamics

Equations of Motion

GNC

Flight Parameters

Mass Properties

Propulsion

Utilities

3DoF (Body Axes)

F_x (N)

F_z (N)

M (N-m)

8 (rad)

\( \omega \) (rad/s)

\( \dot{\omega} \) (rad/s^2)

\( \mathbf{H}(s) \)

Control

Guidance

Navigation

Body Fixed

Mass

Flight Instruments

3DoF (Wind Axes)

F_x (N)

F_z (N)

M (N-m)

\( \gamma \) (rad)

\( \dot{\gamma} \) (rad/s)

\( \ddot{\gamma} \) (rad/s^2)

Simple Mass 3DoF (Wind Axes)

Custom Variable Mass 3DoF (Wind Axes)

Simple Variable

Wind

\( \mathbf{M} \)

\( \mathbf{V} \)

\( \mathbf{r} \)

\( \mathbf{a} \)

\( \mathbf{f} \)

\( \mathbf{m} \)

\( \mathbf{d} \)

\( \mathbf{t} \)

\( \mathbf{g} \)

\( \mathbf{x} \)

\( \mathbf{y} \)

\( \mathbf{z} \)

\( \mathbf{x} \)

\( \mathbf{y} \)

\( \mathbf{z} \)

\( \mathbf{x} \)

\( \mathbf{y} \)

\( \mathbf{z} \)

Direction Cosine Matrix to Wind Angles

Direction Cosine Matrix to Body to Wind to Alpha and Beta

LLA to ECEF Position

Flat Earth to LLA

Geocentric to Geodetic Latitude

Geocentric to Geodetic Latitude
Mathworks for Academia

Teach and Learn with MATLAB and Simulink
The tools used at more than 5000 universities worldwide.

Research with MATLAB and Simulink
Researchers in engineering and science rely on platforms that let them explore and express new ideas, solve difficult problems, and create tools leveraging a robust and flexible computational foundation. MATLAB and Simulink are widely used across industries for research and product development, so you can apply your research to interesting and challenging real-world examples.

All rights reserved. No part of this publication may be reproduced, distributed, or transmitted, unless for course participation, in any form or by any means, or stored in a database or retrieval system, without the prior written permission of the Publisher and/or Author. Contact the American Institute of Aeronautics and Astronautics, Professional Development Programs, 12700 Sunrise Valley Drive, Suite 200, Reston, VA 20191-5807.
1. **MATLAB Student** version includes MATLAB only, with the option to purchase add-on products for a variety of courses and applications.

2. **MATLAB and Simulink Student Suite** includes full-featured versions of MATLAB and Simulink (the student version of Simulink enables you to create models that include over 300 blocks) along with the key functions from:
   - Control System Toolbox
   - Curve Fitting Toolbox
   - DSP System Toolbox
   - Image Processing Toolbox
   - Instrument Control Toolbox
   - Optimization Toolbox
   - Parallel Computing Toolbox
   - Signal Processing Toolbox
   - Statistics and Machine Learning Toolbox
   - Symbolic Math Toolbox

Runs on Windows, Mac and Linux
Explore the wide range of product capabilities, and find the solution that is right for your application or industry.

Data Analytics
Develop data-driven insights that lead to improved designs and decisions.
Learn more

Internet of Things
Connect embedded devices to the Internet and gain insight from your data.
Learn more

Medical Devices
Model and simulate algorithms, and prototype your diagnostic and therapeutic designs.
Learn more
Support

Get Started
- Download Products
- Installation Help
- Tutorials

Get Help
- Documentation
- Examples
- Answers

Community
- File Exchange: Find and Share Code
- Blogs: Learn from Experts
- Cody: Play Coding Game
- ThingSpeak: Collect and Analyze IoT data

Contact support
Download products
An open exchange for the MATLAB and Simulink user community

A place where you can get answers, challenge yourself and others, and share your knowledge.
Tap into the knowledge and experience of over 100,000 community members and MathWorks employees.

Ask and Answer  Get & Share Code  Read and Learn  Play  Explore IoT Data

CONTRIBUTORS  ANSWERS PER DAY  DOWNLOADS PER DAY  SOLVERS PER DAY
Mathworks Training

MATLAB and Simulink Events

MATLAB EXPO 2018
United States
November 6 | San Jose, California

Register
From GPS measurements to ENU measurements: sample code

This code was written in MATLAB

Step 1: Convert GPS to ECEF

```
function [X,Y,Z] = llh2xyzTest(lat,long,h)
    % Convert lat, long, height in WGS84 to ECEF X,Y,Z
    % lat and long given in decimal degrees.
    lat = lat/180*pi; % converting to radians
    long = long/180*pi; % converting to radians
    a = 6378137.0; % earth semimajor axis in meters
    f = 1/298.257223563; % reciprocal flattening
    e2 = 2*f - f^2; % eccentricity squared
    chi = sqrt(1-e2*(sin(lat).^2));
    X = (a/chi + h).*cos(lat).*cos(long);
    Y = (a/chi + h).*cos(lat).*sin(long);
    Z = (a*(1-e2))/chi + h).*sin(lat);
```

Step 2: Convert ECEF to ENU

```
function [e,n,u] = xyz2enuTest(Xr,Yr,Zr,X,Y,Z)
    % convert ECEF coordinates to local east, north, up
    phiP = atan2(Zr,sqrt(Xr^2 + Yr^2));
    lambda = atan2(Yr,Xr);
    e = -sin(lambda).*((X-Xr) + cos(lambda).*((Y-Yr));
    n = -sin(phiP).*cos(lambda).*((X-Xr) - sin(phiP).*sin(lambda).*((Y-Yr) + cos(phiP).*((Z-Zr);
    u = cos(phiP).*cos(lambda).*((X-Xr) + cos(phiP).*sin(lambda).*((Y-Yr) + sin(phiP).*((Z-Zr);
```
MATLAB/Simulink: What’s Next?

Event-Based Modeling

- Real-Time Simulation and Testing
- Verification, Validation, and Test

Physical Modeling

- Simulation Graphics and Reporting

Applications

- Control Systems
- Signal Processing and Communications
- Image Processing and Computer Vision
- Test and Measurement
- Computational Finance
- Computational Biology

MATLAB

- The Language of Technical Computing

SIMULINK

- Simulation and Model-Based Design
- Parallel Computing
- Code Generation

Math, Statistics, and Optimization

- Application Deployment
- Database Access and Reporting
MATLAB Code Generation Tools

Integrate
algorithms with custom software

Prototype
algorithms on PCs

Accelerate
algorithm execution

Implement
algorithms on embedded processor

Prepare → Test → Generate

C/C++
MEX

MATLAB Code Generation Report

Radar Tracking Using MATLAB Function Block

All rights reserved. No part of this publication may be reproduced, distributed, or transmitted, unless for course participation, in any form or by any means, or stored in a database or retrieval system, without the prior written permission of the Publisher and/or Author. Contact the American Institute of Aeronautics and Astronautics, Professional Development Programs, 12700 Sunrise Valley Drive, Suite 200, Reston, VA 20191-5807.
Application Deployment Tools

MATLAB

MATLAB Compiler
MATLAB Compiler SDK

Standalone Application
Excel Add-in
Hadoop
C/C++
Java
.NET
MATLAB Production Server

Develop algorithms in MATLAB
Package them as Excel add-ins

All rights reserved. No part of this publication may be reproduced, distributed, or transmitted, unless for course participation, in any form or by any means, or stored in a database or retrieval system, without the prior written permission of the Publisher and/or Author. Contact the American Institute of Aeronautics and Astronautics, Professional Development Programs, 12700 Sunrise Valley Drive, Suite 200, Reston, VA 20191-5807.
Simulink Coder & Simulink Real-Time

Development computer

Target computer

Physical system

Ethernet

I/O interface

All rights reserved. No part of this publication may be reproduced, distributed, or transmitted, unless for course participation, in any form or by any means, or stored in a database or retrieval system, without the prior written permission of the Publisher and/or Author. Contact the American Institute of Aeronautics and Astronautics, Professional Development Programs, 12700 Sunrise Valley Drive, Suite 200, Reston, VA 20191-5807.
Simulink Model V&V Tools

- Collaboration: modeling standards checks
- Track design changes: traceability analysis
- Structural verification: model coverage
- Formal verification:
  - test generation
  - static error detection
  - requirements proving

Simulink Verification and Validation

1. Design Component
   - Generate Harness and Import Tests
   - Harness Model
     - Simulate
     - Model Coverage Results

Simulink Design Verifier

- Increase Model Coverage
- Detect Potential Design Errors
- Validate Requirements

Word, IBM DOORS, etc.

Designs

Tests

Code
Access **MATLAB Online** with your Mathwork’s account at [www.matlab.mathworks.com](http://www.matlab.mathworks.com)

**Enjoy Cloud Storage and Synchronization**

- **MATLAB Drive** gives you up to 5Gb (250Gb free) to store, access, and manage your files from anywhere with MATLAB Online
- **MATLAB Drive Connector** enables synchronizing your files between your computers and MATLAB Online, eliminating the need for manual upload or download then
Installing MathWorks Products


Between-release updates

The End of Chapter 1

Questions?