**Astrodynamics Tools for MATLAB/Octave**

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1. **Info and Setup Instructions**

This document contains instructions for how to setup the astrodynamics tools in MATLAB or Octave, as well as a list of project scripts and the functions used in them. All the functions were created by the author, with the exception of “subtightplot.m” which was downloaded from the MathWorks File Exchange website. It is included in the repository to save the user the trouble of downloading it separately, and its inclusion is not meant to imply authorship. The subtightplot function is cited wherever it is used, and can also be found here: <https://www.mathworks.com/matlabcentral/fileexchange/39664-subtightplot>

Some of the functions in this code repository contain routines that are very computationally intense, requiring complex tasks to be repeated thousands of times to generate the desired set of outputs. For some of these functions, the computationally intense routines proved to be prohibitively slow when implemented in the MATLAB language, which is optimized for operating on matrices or performing vectorized operations, but is very slow when dealing with element by element operations in nested loops. To improve performance, some routines were translated from MATLAB to C in order to speed up operation. These functions can be compiled as MATLAB executables (MEX), which can then be called within MATLAB functions or scripts as if they were MATLAB files, but run with the performance of compiled C code. In order to run the code in this repository, the MEX files must first be built on your machine. The “setup.m” script performs this task automatically when run, and only needs to be run once after downloading the code to build the MEX files from the corresponding C source files.

**Setup Instructions**

1. Download all code from the Astrodynamics-Code repository on Github.
2. Take the Functions and Scripts (.m / .c) Data files (.txt) and Images (.jpg / .png) out of their individual folders and place all into one single directory folder
3. Verify all C source files and are present in the directory:

C Source Files

asc\_legendre\_c.c

lambert\_c.c

planet\_ephemerides\_c.c

planet\_ephemerides\_full\_c.c

propagator\_c.c

series\_B\_c.c

1. Install MinGW-w64 Compiler if not already installed on your machine <https://www.mathworks.com/help/matlab/matlab_external/install-mingw-support-package.html>
2. Run “setup.m” script from the command window or editor
3. Verify MEX functions created in the directory:

MEX Functions

asc\_legendre\_c.mex

lambert\_c.mex

planet\_ephemerides\_c.mex

planet\_ephemerides\_full\_c.mex

propagator\_c.mex

series\_B\_c.mex

1. **Data Files**

Many functions require external data files, these files are listed below along with the online source each can be downloaded from. Some of these files are trimmed to remove header text or shorten to a more manageable length for various applications, so the data files are also included in the download with the code already in the correct format so the user will not need to download and modify them.

|  |  |
| --- | --- |
| Local Filename | Source |
| IERS\_EOP1.txt  IERS\_EOP2.txt | <https://www.iers.org/IERS/EN/DataProducts/EarthOrientationData/eop.html> |
| IAU2006\_X\_coef.txt  IAU2006\_Y\_coef.txt  IAU2006\_s\_coef.txt  IAU2006\_X\_coef\_short.txt  IAU2006\_Y\_coef\_short.txt  IAU2006\_s\_coef\_short.txt | <http://webtai.bipm.org/iers/convupdt/convupdt_c5.html#Listupdt> |
| EGM2008\_Norm\_Coefficients\_ 1000x1000.txt | <https://earth-info.nga.mil/GandG/update/index.php?action=home#tab_wgs84-data> |
| DE430t\_1550\_E.txt  DE430t\_1650\_E.txt  DE430t\_1750\_E.txt  DE430t\_1850\_E.txt  DE430t\_1950\_E.txt  DE430t\_2050\_E.txt  DE430t\_2150\_E.txt  DE430t\_2250\_E.txt  DE430t\_2350\_E.txt  DE430t\_2450\_E.txt  DE430t\_2550\_E.txt | <https://ssd.jpl.nasa.gov/?planet_eph_export> |

Only the Earth Orientation Parameters (EOP) and time system conversion values in the following two data files should need to be updated in the future. This data comes from the International Earth Rotation Service (IERS) website and is constantly being updated as detailed predictions for the values in the data are only extended about a year ahead of the current date. If updated versions of the files are required (i.e. you are trying to call data that is outside the range of dates in the current version of the data files) these can be downloaded from the IERS website listed in the above table.

The table below gives the website filename for each, and what to save it as in the directory to make it visible to the “getdata\_EOP.m” function.

|  |  |
| --- | --- |
| Local Filename | Website Filename |
| IERS\_EOP1.txt | finals.all(IAU2000) |
| IERS\_EOP2.txt | EOP C01 IAU2000(1900-now) |

The data files “IERS\_EOP1.txt”, “IERS\_EOP2.txt” contain two different sets of data which are necessary inputs for many functions. The two data files can be read by the “getdata\_EOP.m” function, however this process is too slow for many of the applications in this repository. Running the script “combine\_EOP.m” generates a single file “IERS\_EOP\_combined.txt” which contains all the necessary information and can be read by the much quicker “getdata\_EOP\_fast.m” function. “getdata\_EOP.m” and “getdata\_EOP\_fast.m” can be used interchangeably, however if updated versions of these two data files are downloaded, “combine\_EOP.m” will need to be run again to generate an updated combined file for the faster function. The header text in each of the getdata functions provides more detailed information on the format of each data file and the format of the variable created for MATLAB from each data file.

Along with the text files containing data for the functions, there are two images of the Earth. These images used by the visualization functions below and are either mapped onto the globe for 3D visualizations of geocentric orbits or set as the plot background for groundtracks. Any image of an equirectangular map projection will work with these functions and can be used in place of the two images included with the code, as long as the file names match the names below. The table below lists the functions that directly use map images and the images used by each.

|  |  |
| --- | --- |
| Visualization Function/Script | Images Used |
| orbit\_vis\_1 | equirectangular\_1.jpg |
| orbit\_vis\_2 | equirectangular\_1.jpg  equirectangular\_2.png |
| orbit\_vis\_TLE1 | equirectangular\_1.jpg  equirectangular\_2.png |
| orbit\_vis\_TLE2 | equirectangular\_1.jpg |
| trajectory\_multi\_plot | equirectangular\_1.jpg  equirectangular\_2.png |

1. **Summary of Scripts and Functions**

The following is a list of all the scripts and functions contained in the repository. Not all the functions listed here are used in the scripts, however they are included as they may be useful tools for future projects.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Scripts (.m) | Functions (.m/.mex) | | | |
| Time/Coordinate Conversion Utilities | 2-Body Keplerian Utilities | Data Reading and Management | Other |
| special\_perturbations  interplanetary\_trajectory  porkchop  orbit\_vis\_TLE1  orbit\_vis\_TLE2  look\_angles | julian\_date  gregorian\_date  local\_sidereal  convert\_time  s2hms  si\_canonical  IAU2006  IAU2006\_rotations  AZEL\_RADEC  ECI\_ground  ground\_ECI  DOY\_modhms  YMDHMS2sec  terrestrial\_MJD  RAZEL  TZ2UTC  UTC2TZ | true\_anomaly  eccentric\_anomaly  mean\_anomaly  kepler\_equation  lambert\_UV  lambert\_c  orbital\_elements  position\_velocity  propagation\_OE  propagation\_UV  propagator\_G  propagator\_c | getdata\_EOP  getdata\_EOP\_fast  getdata\_EGM2008  getdata\_IAU2006  getdata\_DE430  combine\_EOP  EOP | site  site\_track  IOD\_angles  orbit\_vis\_1  orbit\_vis\_2  trajectory\_multi\_plot  chebyshev\_first  asc\_legendre  asc\_legendre\_c  EGM2008  groundtrack  intercept  intercept\_HC  perturbed\_eom  planet\_ephemerides  planet\_ephemerides\_c  planet\_ephemerides\_full\_c  propagator\_SP  RK4  RKF45  series\_B\_c  third\_body  TLE2state  subtightplot  setup |

The documentation and references for each script/function can be viewed by opening it in MATLAB and reading the header text. The header at the top of each script/function contains a list of other functions it uses, the input and output variables and their nomenclature, and a description of the function’s purpose and the theory employed. References for equations, data, and general theory are found in the last lines of the header. For MEX functions, the header can be viewed in the C source file.