Ada Ephemeris Library

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This manual is for the Ada Ephemeris Library (version 1.01, 20 June, 2006).

Table of Contents

1 Introduction

1.1 Purpose

This manual contains instructions for installing and using the Ada Ephemeris Library (AEL), a collection of Ada 2005 packages that provide access to the Solar System Ephemerides developed by the Jet Propulsion Laboratory (JPL)[1].

The AEL distribution consists of a set of packages defining constants and library functions that can be used in other Ada programs to read ephemeris data, and some utility programs which are needed to install and test the ephemeris data files. The data files themselves are not part of the AEL distribution, and should be downloaded by the user directly from the JPL site[2].

Previous knowledge of the Ada 2005 programming language is assumed. The reader should also be familiar with GNAT[3] or some other programming environment for Ada 2005.

1.2 Installation requisites

The AEL software is highly portable and can be used on any platform for which an Ada 2005 compilation system is available. The distributed version has been compiled with GNAT Pro 5.04 and GNAT GPL 2005 on PC workstations running GNU/Linux and Windows® XP operating systems. Compiling the software with other Ada 2005 compilers should no give any problems as only Ada 2005 standard language features have been used.

1.3 Acknowledgments

The information on the JPL ephemerides that has been used to develop the Ada Ephemeris Library comes from the following sources:

- The JPL ephemerides package user's guide[4].
- David Hoffman's user's guide for the C utility programs for processing JPL Ephemeris Data[5].
- The *Explanatory Supplement to the Astronomical Almanac*, edited by P. Kenneth Seidelmann, University Science Books, 1992, especially chapter 5.

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[1] The JPL has developed several kinds of ephemerides (e.g. DE200, DE405, and DE406). The current version of AEL has been designed to work with different ephemeris formats, but has only been tested with the DE200 series.

[2] ftp://ssd.jpl.nasa.gov/pub/eph/export/

[3] GNAT (GNU-NYU Ada Translator) is a free programming environment for Ada. See http://www.gnat.com for more details.

[4] ftp://ssd.jpl.nasa.gov/pub/eph/export/usrguide

[5] ftp://ssd.jpl.nasa.gov/pub/eph/export/C-versions/hoffman

2 Overview

2.1 Fundamental ephemerides

The fundamental ephemerides of the solar system bodies are the computations of the body states of the bodies, i.e their positions and velocities with respect to some reference coordinate frame. The motion of the solar system bodies is governed by Newton's laws corrected for general and special relativity effects. Integration of these equations fitting observational data is the basis for the computation of modern ephemerides data. The resulting values are stored in computer files in order to make them available for astronomical computations.

The computation of position and velocity values at every instant of time is clearly not feasible. The solution is to use an interpolation method in order to get a compact representation of the state values. The JPL ephemerides use Chebyshev polynomial interpolation in such a way that the state of a body at any time within the ephemeris range can be efficiently computed from a small number of coefficients. The number of coefficients and the precision of the data are adjusted so that the interpolation error is less than 0.5 mm. See Section 4.1 [Interpolation coefficients], page 5, for the details.

The position and velocity components are computed in barycentric rectangular equatorial coordinates, referred to the mean equator and equinox of J2000.0. In this reference system the origin of coordinates is the center of mass of the solar system, the X-Y plane is parallel to the celestial equator plane, i.e. the plane that is normal to the axis of rotation of the Earth, and the X axis has the direction of the equinox, i.e. the intersection of the equator and the ecliptic planes. The units are km and km/day for the position and velocity, respectively. The time independent variable is TDB (barycentric dynamical time) in Julian days. See the *Explanatory Supplement to the Astronomical Almanac* for the details.

Since the orientation of the Earth's equator and the direction of the equinox are changing, the reference system is defined with respect to a particular epoch. The reference epoch for the DE200 ephemeris is J2000.0, which is defined as Julian date 2451545.0 (January 1st, 2000, at 12:00).

2.2 The JPL ephemeris files

The JPL ephemeris files contain the Chebyshev coefficients for the position and velocity of the main solar system bodies across a given time span. The coefficients are grouped into records, each of them containing data for a 32-day long *interval*. Intervals are further subdivided into *granules*, with a length that depends on the body under consideration. The coefficients enable the position and velocity components to be computed for each major solar system body. Appendix A [Ephemeris file formats], page 6, contains a detailed description of the JPL source files and the binary files used by AEL.

2.3 The Ada Ephemeris Library

The Ada Ephemeris Library is a set of Ada packages that provide high-level access to the state of the main solar system bodies: Mercury, Venus, the Earth, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto, the Moon, and the Sun[1]. The position and velocity values are given in AU[2] and AU/day[3]. Notice that the coefficients in the ephemeris files give the state components in

[1] The ephemeris files contain data for a slightly different set of bodies: Mercury, Venus, the Earth/Moon barycenter, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto, the Moon (in geocentric coordinates), and the Sun, plus nutation angles and, in some cases, libration angles. The transformations for the Earth and the Moon are carried out internally in the AEL operations, and the nutation angles are not being used in this version of AEL.

[2] An AU (Astronomical Unit) is a unit of distance which equals $1.4959787066 \times 10^{11}$ m.

[3] The astronomical day is defined as 86400 s.

km and km/day, respectively. The unit transformations are carried out internally in the AEL operations.

The main packages in the AEL are `Ephemeris` and `Ephemeris.Data`. The former is the root package of the library, in which the supported ephemeris sets (DE200, DE405, and DE406)[4] are defined. The `Ephemeris.Data` package contains all the necessary definitions to get the state of a body at a given time. The next chapter (see Chapter 3 [User's Guide], page 4) contains a detailed description of these two packages.

[4] Notice that the current version has only been tested with DE200

3 User's Guide

3.1 Installing the Ada Ephemeris Library

3.1.1 Downloading and compiling the AEL distribution

The AEL can be dowloaded from http://www.dit.upm.es/jpuente/AEL as a set of Ada source and other auxiliary files packed in a `.tgz` (for UNIX or GNU/Linux systems) or `.zip` (for Windows® systems) archive.

An Ada 2005 compilation system must be installed in order to compile the library. GNAT GPL 2006 is assumed in the following, but any other Ada compilation system can be used as well. In this case, refer to the appropriate manuals for compilation instructions.

To compile the library on a UNIX or GNU/Linux system, unzip the archive into any directory (<*build-dir*>) and then type:

```
$ cd <build-dir>
$ make
```

Instructions for building the library on Windows® systems are included in appendix

3.1.2 Retrieving and installing the ephemeris files

3.1.3 Testing the library

3.2 Using the Ada Ephemeris Library

3.2.1 Main packages

3.2.2 The package `Ephemeris`

3.2.3 The package `Ephemeris.Data`

3.2.4 Compiling with AEL packages

4 Detailed design

4.1 Interpolation coefficients

Since computing the values of the state components (position and velocity) for every point in time is not possible, the ephemeris files provide instead a set of interpolation coefficients that can be used to calculate the state at any given point of time. To this purpose, time is divided into continous adjacent intervals of fixed length called *granules*. The state components as functions of time are then expressed as a sum of Chebyshev polynomials.

The expression of the position and velocity components of a body in terms of Chebyshev polinomials is:

$$p_i(\tau) \doteq \sum_{n=0}^{N} a_n T_n(\tau) \tag{1}$$

$$v_i(\tau) = \dot{p}_i(\tau) \doteq \sum_{n=0}^{N} a_n \dot{T}_n(\tau) \tag{2}$$

The independent variable t is the normalized time (-1.0..+1.0) in a granule span:

$$\tau = \frac{t - t_0}{t_1 - t_0} \tag{3}$$

where t is the time for which the calculation is to be made, and t_0 and $t - 1$ are, respectively, the beginning and end times of the granule in which t lies.

The Chebyshev polynomial of

The length of a granule is not the same for all solar system bodies. Table 4.1 shows the granule lenght and the number of Chebyshev polynomials used for the development of the state of the main solar system bodies.

No.	**Name**	**Granule (days)**	**No. of polynomials**
1	Mercury	8	13

Table 4.1: Granule length and number of polynomials for the main solar system bodies.

Appendix A Ephemeris file formats

Appendix B Building the library on Windows systems

Appendix C Copying this manual

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Version 1.2, November 2002

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