PLANETARY EPHEMERIDES

Interplanetary Mission Design

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INTRODUCTION

The positions and velocities of the planets must be known on desired dates to compute interplanetary trajectories. There are various methods to determine the location of a planet for a given date. Currently, the most accurate method is to use the planetary ephemerides provided by JPL's Horizons system or from the Navigation and Ancillary Information Facility (NAIF) website (http://naif.jpl.nasa.gov/naif/). The NAIF website also provides several software packages for reading ephemerides. For the purposes of this class, the position of the planets in a heliocentric frame will be computed as a function of time using an algorithm given by Meeus.[1] Although not as accurate as ephemerides such as the DE421, it is a good approximation.

In Meeus' algorithm, the orbital elements of the planets are expressed as polynomials of the form:

$$\text{Element} = a_0 + a_1 T + a_2 T^2 + a_3 T^3$$

where T is time measured in Julian centuries of 36525 ephemeris days from the epoch J2000.0 = JDE 2451545. T may be computed as:

$$T = \frac{\text{JDE} - 2451545.0}{36525}$$

Meeus provides coefficients for the following elements:

$L =$ Mean longitude of the Planet
$a =$ Semimajor axis of the orbit
$e =$ Eccentricity of the orbit
$i =$ Inclination of the orbit
$\Omega =$ Longitude of the Ascending Node
$\Pi =$ Longitude of the Perihelion

The longitude of perihelion, Π should not be confused with the argument of perihelion, ω. Π is related to Ω and ω as follows:

$$\Pi = \Omega + \omega$$

The planet's mean anomaly, M, is given by:

$$M = L - \Pi$$

The true anomaly can be found as:

$$\nu = M + C_{cen}$$

where

$$C_{cen} = \left(2e - \frac{e^3}{4} + \frac{5}{96}e^5\right)\sin M + \left(\frac{5}{4}e^2 - \frac{11}{24}e^4\right)\sin(2M) + \left(\frac{13}{12}e^3 - \frac{43}{64}e^5\right)\sin(3M) + \frac{103}{96}e^4\sin(4M) + \frac{1097}{960}e^5\sin(5M)$$

The traditional orbital elements (a, e, i, Ω, ω, ν) are now known, and the position and velocity of the planet can be calculated. Table 1 shows the coefficients for the orbits of Earth and Mars for the standard J2000.0 equinox. The coefficients for the elements of the other planets may be found on the IMD class webpage.

Table 1. Coefficients for the Orbital Elements of Earth

Orbital Elements	a_0	a_1	a_2	a_3
L (deg)	100.466449	35999.3728519	-0.00000568	0.0
a (AU)	1.000001018			
e	0.01670862	-0.000042037	-0.0000001236	0.00000000004
i (deg)	0	0.0130546	-0.00000931	-0.000000034
Ω (deg)	174.873174	-0.2410908	0.00004067	-0.000001327
Π (deg)	102.937348	0.3225557	0.00015026	0.000000478

REFERENCES

[1] J. Meeus, *Astronomical Algorithms*. Richmond, VA: William-Bell, Inc., First English ed., 1991.