Report of the IAU Commission 4 Working Group on Standardizing Access to Ephemerides and File Format Specification

James L. Hilton, Charles Acton, Jean-Eudes Arlot, Steven A. Bell, Nicole Capitaine, Agnès Fienga, William M. Folkner, Mickaël Gastineau, Dmitry Pavlov, Elena V. Pitjeva, Vladimir I. Skripnichenko, & Patrick Wallace

james.hilton@usno.navy.mil

Abstract

The IAU Commission 4 Working Group on Standardizing Access to Ephemerides recommends the use of the Spacecraft and Planet Kernel (SPK) file format to provide a uniform format for the position ephemerides of planets and other natural solar system bodies and the use of the binary Planetary Constants Kernel (PCK) format ephemeris file for the orientation of a body. It further recommends supporting data be stored in a text PCK. These formats are used by the SPICE system developed by the Navigation and Ancillary Information Facility of NASA's Jet Propulsion Laboratory. The bulk of this report is a description of the portion of PCK and SPK kernel formats required for these ephemerides. A new data type, Type 20: Chebyshev (Velocity Only) has been added to the specification to accommodate the Ephemeris Planets Moon developed by the Institute for Applies Astronomy in St. Petersburg, Russia. Other changes to the specification are a new object identification number for coordinate time ephemerides and a set of three new data types that uses the TCB rather than the TDB timescale for the ephemerides, but are otherwise identical to their TDB versions.

Introduction

To provide a uniform format for the position ephemerides of planets and other natural solar system bodies the International Astronomical Union (IAU) Commission 4: Ephemerides Working Group on Standardizing Access to Ephemerides recommends:

1. The use of the Spacecraft and Planet Kernel (SPK) file format.
2. The use of the binary Planetary Constants Kernel (PCK) format ephemeris file for the orientation of a body.
3. Supporting data on the ephemerides, such as values of parameters, whether they are fixed or adjusted, and their uncertainties, are stored in a text PCK kernel.

These file formats were developed for and are used by the SPICE system, developed by the Navigation and Ancillary Information Facility (NAIF) of NASA's Jet Propulsion Laboratory (JPL).

Most users will want to use either the SPICE libraries or CALCEPH, developed by the Institut de mécanique céleste de calcul des éphémérides (IMCCE), to access ephemerides stored in these formats.

SPICE is an information system to assist scientists in planning and interpreting scientific observations from space-based instruments. SPICE data and software may be used within many different computing environments. The software is available in FORTRAN 77, C, IDL and MATLAB from the NAIF web site.

CALCEPH is an ephemeris file reader developed by the IMCCE primarily to read its Intégrateur Numérique Planétaire de l'Observatoire de Paris (INPOP) planetary ephemerides. Starting with version 2.0, CALCEPH has the ability to read text PCK, binary PCK, and SPK kernels. It may be linked to programs written in C, FORTRAN 77, and Fortran 90/95/2003. It is available at the INPOP web site and will be made available the IAU Commission 4: Ephemerides web site.

Some users, such as ephemeris developers, may want to access the ephemeris files directly or construct ephemeris files in these formats using their own software. For those readers that require a detailed specification of the file formats, it is available in the full version of this report online at the IAU Commission 4: Ephemerides web site.

Changes Made to the binary SPK and PCK Formats

To meet the requirements of the wider community NAIF has agreed to make some additions to the SPK format and adjustments to SPICE and its documentation.

1. A new data type, named Type 20: Chebyshev (Velocity Only).
2. The data types beginning with 101 have been reserved for ephemerides where the time argument is TCB rather than TDB.
3. Data types 901 through 910 have been reserved for the development of new ephemeris types by other groups.
4. The ephemeris object number 1,000,000,000 has been reserved for Coordinate Time ephemerides.

The SPK Kernel

The SPK kernel was developed specifically to store positional ephemerides of objects. Each kernel is capable of holding a large number of segments. Each of these segments holds and ephemeris for a single object. The summary at the beginning of each segment contains data on

- the ephemeris object,
- the ephemeris center (*i.e.* the coordinate system origin),
- the reference frame,
- the data type (*i.e.* the format for the ephemeris data), and
- the ephemeris time span.

Each object in the solar system is assigned a unique identification number. Table 1 gives some of the identification numbers recognized by SPICE of interest for those working with ephemerides of the Moon and planets.

NAIF ID	Name
10	Sun
0	Solar System Barycenter
199	Mercury
299	Venus
399	Earth
301	Moon
3	Earth-Moon Barycenter
499	Mars
1,000,000,000	Coordinate Time

Table 1: NAIF identification numbers for the Sun, Moon, and planets.

Reference Frames

An ephemeris also requires a reference frame. The only reference frame of interest to planetary ephemerides is the International Celestial Reference System (ICRS). The NAIF identification code for the ICRS is 1 and the name used for it is "J2000".

Time Scales

The independent argument for the ephemerides is time. Time is given in ephemeris seconds from Terrestrial Julian Day 245 1545.0. The time scale for the ephemeris may be either Barycentric Dynamical Time (TDB) or Barycentric Coordinate Time (TCB) depending on the data type.

Chebyshev Kernel Data Types

The six data types that use Chebyshev polynomials of the first kind are of interest for solar system ephemerides are:

- Type 2. Chebyshev polynomials (position only).
- Type 3. Chebyshev polynomials (position and velocity).
- Type 20. Chebyshev polynomials (velocity only).
- Type 102. Chebyshev polynomials (TCB: position only): This type is identical to Type 2 except the time argument is TCB rather than TDB.
- Type 103. Chebyshev polynomials (TCB: position and velocity): This type is identical to Type 3 except that the time argument is TCB rather than TDB.
- Type 120. Chebyshev polynomials (velocity only): This type is identical to Type 20 except the time argument is TCB rather than TDB.

PCK Kernels

PCK kernels are designed to provide a mechanism for supplying planetary physical constants. These data may include almost any form of supporting data. PCK kernels store both text and binary data. Text and binary kernels have different formats, so text and binary data may not both be stored in the same file.

Most of these data consist of a limited number of single values or small vectors and matrices that are easily stored as text. Other supporting data is not easily stored as text. In particular, the Moon's orientation as a function of time is complex and is required to high accuracy. Thus, its orientation ephemeris is represented with Chebyshev polynomials. These polynomials may be stored in a binary PCK kernel to both save storage and speed up evaluation.

Text PCK Kernels

Text PCK kernels are ASCII files so they may be modified by text editors and can also be ported between computer systems, even when the systems have different file systems and file formats.

Parameter values are associated with name strings using a "keyword = value" format. These name strings, together with their associated values, are called "kernel variables". Kernel variables may consist of arrays of values such as

```
NAME = ( VALUE1, VALUE2, ... )
```

where `NAME` is a case sensitive string, no longer than 32 characters. The values on the right hand side may be integer or floating point numeric values or strings.

A text kernel consists of blocks of comments, alternating with blocks of data. Comment blocks begin with the control sequence (a string alone on a line)

```
\begintext
```

Data blocks consist of one or more kernel variables and begin with the control sequence

```
\begindata
```

The lines preceding the first `\begindata` control sequence constitutes a comment block. The text of comment blocks is arbitrary.

The Binary PCK Kernel

The binary PCK kernel format is similar to that of the SPK kernel. The rotation of a body is the equivalent of the change in orientation of one reference system with respect to a second as a function of time. SPICE currently has recognizes for four data types in the binary PCK kernels. These are types 2, 3, 102, and 103.

Discussion

The IAU Commission 4 Working Group on Standardizing Access to Ephemerides and File Format Specification recommends the use of the SPICE Toolkit's SPK kernel format for the positional ephemerides of solar system bodies, the SPICE Toolkit's binary PCK for the orientation ephemeris of the Moon, and the text PCK format for the storage of other data useful for the application of these ephemerides.

The SPK format can store these ephemerides using several different data types. The formats for each of the types of interest will be described in detail in on line documentation available at the IAU Commission 4 web site.

NAIF has also reserved the data types 901 through 910 for development of additional data types by other developers. These experimental data types will not be recognized by SPICE. NAIF has sole discretion on the acceptance and incorporation of new data types into SPICE.

In addition to SPICE, binary PCK and SPK kernels can be read using the CALCEPH library available from the IMCCE and the IAU Commmssion 4 website.

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