Report of the IAU Commission 4 Working Group on Standardizing Access to Ephemerides and File Format Specification: Update September 2014

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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. Since the previous report:

- Some minor changes have been made to the formats for:
  - the coordinate time ephemeris
  - data types 20: Chebyshev Polynomials (Velocity Only) and 120: Chebyshev Polynomials (TCB:Velocity Only)
- the working group's final report is currently undergoing review by the Navigation and Ancillary Information Facility (NAIF) of NASA's Jet Propulsion Laboratory (JPL) to assure it correctly describes these file formats.

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 toolkit or CALCEPH, developed by the Institut de mécanique céleste de calcul des éphémérides (IMCCE), to access ephemerides stored in these formats. The SPICE toolkit is available at

`http://naif.jpl.nasa.gov/naif/toolkit.html`,

and CALCEPH is available at

`http://www.imcce.fr/inpop/calceph/index.php`.

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.

The SPK and Binary PCK Kernel Formats

The binary kernel formats are designed to contain ephemerides of multiple objects. These ephemerides may be stored using multiple data types. Only a few of these formats are used for the storage of the position ephemerides of natural solar system bodies. The SPK kernel and binary PCK kernel formats are similar (Bachman, 2014). The SPK kernel was developed specifically to store positional ephemerides of objects, while PCK kernels are designed to provide a mechanism for supplying planetary physical constants. The binary PCK format may, among other things, be used to store ephemerides of the orientation of bodies such as the lunar orientation portion of the DE, EPM, and INPOP ephemerides.

Chebyshev Kernel Data Types

The six data types that use Chebyshev polynomials of the first kind that 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 (TCB: velocity only): This type is identical to Type 20 except the time argument is TCB rather than TDB.

Text PCK Kernels

Most of the supporting data consist of a limited number of single values or small vectors and matrices that are easily stored as text. 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.

Recent Changes Made to the SPK and binary PCK Formats

Coordinate Time Ephemerides

Coordinate time scales are now designated by three NAIF identification numbers.

- 1 000 000 001: TT – TDB data are stored in the X-coordinate,
- 1 000 000 002: TCG – TCB data are stored in the Y-coordinate,
- 1 000 000 003: TT – TDB data are stored in the X-coordinate *and* TCG – TCB data are stored in the Y-coordinate.

The second integer code, normally used to indicate the reference frame, is set to 1 000 000 000 to indicate the data is being stored is a coordinate time ephemeris.

Data Types 2 Chebyshev Polynomials (Position Only) and 102 Chebyshev Polynomials (TCB: Position Only)

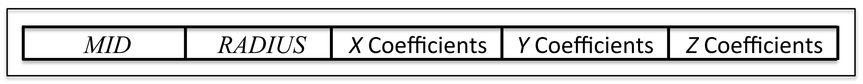

Figure 1: The structure of the record for Type 2: Chebyshev polynomials (position only) and Type 102: Chebyshev Polynomials (TCB: position only), SPK and binary PCK data segment.

These two data types contain:

- MID: The position of the center of the time span of the Chebyshev polynomials in seconds from J2000.0.
- $RADIUS$: The time in seconds from the extrema of the times span to MID.
- The Chebyshev polynomial coefficients for the object's position.

Data Types 3 Chebyshev Polynomials (Position and Velocity) and 103 Chebyshev Polynomials (TCB: Position and Velocity)

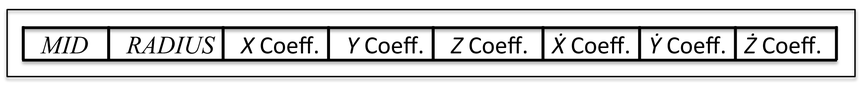

Figure 2: The structure of the record for Type 3: Chebyshev polynomials (position and velocity) and Type 103: Chebyshev Polynomials (TCB: position and velocity), SPK and binary PCK data segment.

In addition to the data for types 2 and 102, these two data types include a set of Chebyshev polynomials for the object's velocity.

Data Types 20 Chebyshev Polynomials (Velocity Only) and 120 Chebyshev Polynomials (TCB: Velocity Only)

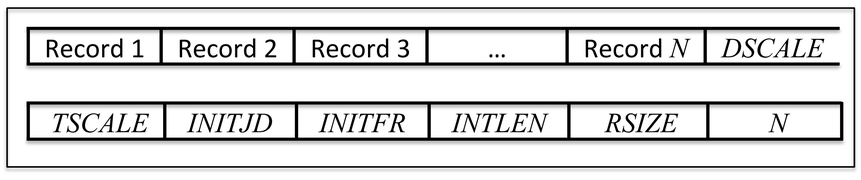

Figure 3: The structure of the record for Type 20: Chebyshev Polynomials (velocity only) and Type 120: Chebyshev Polynomials (TCB: velocity only), SPK and binary PCK data segment.

These two data types use a different set of segment data parameters to allow for additional flexibility. They include:

- $DSCALE$: A scaling parameter for the distance. If $DSCALE = 1$, then distances are in km.
- $TSCALE$: A scaling parameter for the time. If $TSCALE = 1$, then time is in s.
- $INITJD$ and $INITFR$ are respectively the integer and fractional parts if the initial Julian date on the coordinate time scale of the ephemeris.

For the other data types of interest distances are always in km, time is always in s, and the initial time of the ephemeris is given in seconds from J2000.0.

Current Status

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.

To assure that the specification of the portions of these kernels of interest to users comply with the SPICE Toolkit, the detailed final report is currently being reviewed by NAIF. Once the detailed report is approved, it will be made available at the IAU Commission 4 or comparable web site and a summary report will be submitted for publication.

Acknowledgements

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References

Bachman, N.J.: SPK Required Reading. NAIF SPICE Toolkit Hypertext Documentation http://naif.jpl.nasa.gov/pub/naif/toolkit_docs/FORTRAN/req/spk.html (2014). Accessed: 4 August 2014.