INPOP binary ephemeris file format - version 2.0

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January 19, 2012

The INPOP binary file format for the INPOP ephemeris is based on the JPL binary ephemeris file format, described in [1], with some extensions. The mandatory part of the INPOP binary file format is fully compatible with the JPL binary ephemeris file format.

1 Description of the file format for the version 1.0

The overview of the file structure for the version 1.0 of the INPOP binary ephemeris file format is described in the table 1.

header information	record 1
constant values	record 2
coefficients of the Chebyshev polynomials for the planets ...	records 3 to $\left(\frac{timeData[2]-timeData[1]}{timeData[3]}\right)+2$

Table 1: Overview of the file structure for the version 1.0

The information records is split between two binary records : the "header information" record and the "constant values" record. The remaining records contain the coefficients of the Chebyshev polynomials for the planets. The planets fill $\left(\frac{timeData[2]-timeData[1]}{timeData[3]}\right)$ records.

The version 1.0 extends the JPL file format with the following informations:

- adds the fields *recordsize* and *TTmTDBPtr* in the header information record (first record).
- requires the presence of the prefined constants (*KSIZER, VERSIO, FVERSI, FORMAT, UNITE*) in the constant values record (second record).

The ephemeris INPOP06, INPOP08, INPOP10a have been published using the version 1.0 of this format.

2 Description of the file format for the version 2.0

The previous versions of the file format assume that the ephemerids are expressed in the TDB time scale. The version 2.0 of the file format allow to store the ephemerids expressed in the TDB or TCB time scale. Optionally, this file format could store the Chebyshev polynomials for the asteroids.

So, the version 2.0 of this file format extends the version 1.0 with the following informations :

- requires the presence of the prefined constant (*TIMESC*) in the "constant values" record (second record). It allows to detect the time scale of the planetary ephemerids.

- not mandatory information : Chebyshev polynomials for the asteroids and all records about asteroids. The presence of the asteroids is decteted by the constant *FORMAT*.

The records for the asteroids contains the asteroid number, GM and coefficients of the Chebyshev polynomials for the asteroids. The overview of the file structure for the version 2.0 is described in the table 2. All asteroids records are not mandatory. So, if none of the asteroids are present, then the data file structure is identical to the version 1.0.

header information	record 1
constant values	record 2
coefficients of the Chebyshev polynomials for the planets ...	records 3 to $\left(\frac{timeData[2]-timeData[1]}{timeData[3]}\right)+2$
Information Asteroid	record $\left(\frac{timeData[2]-timeData[1]}{timeData[3]}\right)+3$
... ID Asteroid	records *locIDAstRecord* to *locIDAstRecord +numIDAstRecord-1*
GM Asteroid ...	records *locGMAstRecord* to *locGMAstRecord +numGMAstRecord-1*
... Coefficient Pointer Asteroid ...	records *locCoeffPtrAstRecord* to *locCoeffPtrAstRecord +numCoeffPtrAstRecord-1*
coefficients of the Chebyshev polynomials for the asteroids ...	records *locCoeffAstRecord* to *locCoeffAstRecord +numCoeffAstRecord-1*

Table 2: Overview of the file structure for the version 2.0

The ephemeris INPOP10b have been published using the version 2.0 of this format (without asteroids).

3 Description of the records

3.1 First record

The first record contains the data of the table 3. The fields of these structure are unaligned and packed. As these data use less space than the record size, the remaining space is padded with 0-byte.

Name	Type	Size (bytes)	Offset (byte)	Description
label	char [3][84]	252	0	label description of the ephemeris file
constName	char [400][6]	2400	252	name of constants in 2nd record
timeData	double[3]	24	2652	start and stop times, and time interval (Julian dates)
numConst	int	4	2676	number of constants in 2nd record
AU	double	8	2680	astronomical unit
EMRAT	double	8	2688	mass of the Earth divided by the mass of the Moon
coeffPtr	int[12][3]	132	2696	location, number of coefficients and number of granules for the position of the bodies
DENUM	int	4	2840	ephemeris id
libratPtr	int[3]	12	2844	location, number of coefficients and number of granules for the libration angles of the Moon
recordsize	int	4	2856	size of the record in bytes
TTmTDBPtr	int[3]	12	2860	location, number of coefficients and number of granules for the time TT-TDB or TCG-TCB

Table 3: Content of the first record. This data structure is unaligned and packed.

The value for the field *DENUM* is 100 for the INPOP ephemeris. Due to the problem of the endianess in the computer (order in which integers are stored as bytes in computer memory), the value of the field *DENUM* must be less than 2^{15}. That allow to detect at run-time if the binary file is encoded using big-endian or little-endian format.

The addition of the INPOP file format to the JPL binary ephemeris file consists of the two fields *recordsize* and *TTmTDBPtr*. Where as libration angles of the moon or position-velocity for the planets use 3 components, *TTmTDBPtr* requires and uses only one component. The content of *TTmTDBPtr* depends on the value of *TIMESC* (see its description in second record).

3.2 Second record

The second record contains the values of the constants. INPOP file format uses predefined constants to store additional properties of the ephemeris file. The name of these predefined constant are stored in the field *constName* of the first record. The table 4 contains the name and description of these predefined constants.

The value *((FORMAT/10) mod 10) = 1* and *TIMESC* is introduced in the version 2.0 of the INPOP format in order to specify if the ephemeris is expressed in TDB or TCB time scale. The value *((FORMAT/100) mod 10) = 1* is introduced in the version 2.0 of the INPOP format in order to specify if the asteroids records are stored in the file.

The field *VERSIO* identifies a unique ephemeris release. The field *FVERSI* is used to identify two ephemeris file of the same release. This field is used only if a broken file was distributed previously for the same ephemeris release.

3.3 Information Asteroid record

This specific record is introduced in the version 2.0 of the INPOP format and is only present if *((FORMAT/100) mod 10) = 1*, i.e. the Chebychev coefficients for asteroids are stored in the file. This record is located after the planets' coefficients. It starts at the record $\left(2 + \frac{timeData[2]-timeData[1]}{timeData[3]}\right)$.

The content of the record is described in the table 5. As these data use less space than the record size, the remaining space is padded with 0-byte. The location of the records assumes that the numbering of the records starts with 1. So *locIDAstRecord* indicates a location after the planets' coefficients.

The fields *locCoeffPtrAstRecord, numCoeffPtrAstRecord, locCoeffAstRecord* and *numCoeffAstRecord* are valids only if *typeAstRecord*=1.

3.4 ID Asteroid records

The location and number of these records are specified in the Information Asteroid record by the fields *locIDAstRecord* and *numIDAstRecord*. These records contain the asteroid numbers. Each asteroid number is stored on a 32-bit integer. If these data use less space than the record size, the remaining space is padded with 0-byte.

3.5 GM Asteroid records

The location and number of these records are specified in the Information Asteroid record by the fields *locGMAstRecord* and *numGMAstRecord*. These records contain the GM value of the asteroid. Each GM is stored on a double precision floating-point number. If these data use less space than the record size, the remaining space is padded with 0-byte. The asteroid GM are stored in the same order as the asteroid number.

For example, an asteroid, which has its number located at the 32-bit integer j (byte $4 \times j$ up to $4 \times j + 3$), has its GM located at the 64-bit floating-point number (byte $8 \times j$ up to $8 \times j + 7$).

Name	Description
KSIZER	number of floating-point numbers by record.
VERSIO	version number of the ephemeris. This number usually consists of the YYYY.MMDD
FVERSI	file version number for this ephemeris. This number is usually 0.
FORMAT	description of the file format. This number satisfies the following rules **(FORMAT mod 10) = 0** The file contains the positions and velocities for the bodies and the libration angles for the Moon. **(FORMAT mod 10) = 1** The file contains the positions for the bodies and the libration angles for the Moon. **((FORMAT/10) mod 10) = 0** The file doesn't contain the time TT-TDB or TCG-TCB. **((FORMAT/10) mod 10) = 1** The file contains the time TT-TDB or TCG-TCB. **((FORMAT/100) mod 10) = 0** The file doesn't contain asteroids. **((FORMAT/100) mod 10) = 1** The file contains asteroids.
UNITE	units of the coefficients **=0.** positions and velocities in AU and AU/day. angles in radians. time TT-TDB or TCG-TCB in seconds **=1.** positions and velocities in km and km/day. angles in radians. time TT-TDB or TCG-TCB in seconds
TIMESC	time scale **=0.** ephemeris in TDB time scale. The file may contain the time TT-TDB (but not TCG-TCB). **=1.** ephemeris in TCB time scale. The file may contain the time TCG-TCB (but not TT-TDB).

Table 4: List of the predefined constants in the second record to describe the INPOP ephemeris file.

3.6 Coefficient Pointer Asteroid records

The location and number of these records are specified in the Information Asteroid record by the fields *locCoeffPtrAstRecord* and *numCoeffPtrAstRecord*. These records contain the location, number of coefficients and number of granules for each asteroid. The location, number of coefficients and number of granules are stored on three packed 32-bit integers. If these data use less space than the record size, the remaining space is padded with 0-byte. These Coefficient pointers are stored in the same order as the asteroid number. These Coefficient pointers for asteroids use the same rules as the Coefficient pointers for planets.

For example, an asteroid, which has its number located at the 32-bit integer j (byte $4 \times j$ up to $4 \times j + 3$), has its coefficient pointer table located at the byte $4 \times 3 \times j$ up to $4 \times 3 \times j + 11$.

3.7 Coefficient Asteroid records

This section applies only if typeAstRecord equals to 1.

The Chebychev coefficients for the asteroids starts at the record *locCoeffAstRecord*. To cover a time-slice *timeData*[3], *numCoeffAstRecord* records are used. These Coefficients for asteroids use the same rules as the Coefficient for planets.

4 Compatibility with JPL file format

The INPOP file format is fully compatible with the JPL file format if *FORMAT*=1, *UNITE*=1 and *TIMESC*=0. That allow to produce binary ephemeris file which could be read with software that only accept JPL file format.

5 Summary of the addition of the INPOP file format

INPOP file format 1.0	=	JPL file format
	+	fields *recordsize* and *TTmTDBPtr* in the first record
	+	prefined constants (*KSIZER, VERSIO, FVERSI, FORMAT, UNITE*) in the second record.
INPOP file format 2.0	=	INPOP file format 1.0
	+	prefined constants (*TIMESC*) in the second record.
	+	Asteroid information record (optional)
	+	ID Asteroid records (optional)
	+	GM Asteroid records (optional)
	+	Coefficient Pointer Asteroid records (optional)
	+	Coefficient Asteroid records (optional)

References

[1] David Hoffman : 1998, A Set of C Utility Programs for Processing JPL Ephemeris Data,
ftp://ssd.jpl.nasa.gov/pub/eph/export/C-versions/hoffman/EphemUtilVer0.1.tar

Name	Type	Size (bytes)	Offset (byte)	Description
locNextRecord	int	4	0	location of the next information record. **=0.** no other information record (reserved for future extension).
numAstRecord	int	4	4	number of records used for asteroids in the file
numAst	int	4	8	number of asteroids in the file
typeAstRecord	int	4	12	type of the tchebychev record **=1.** the intervals have a fixed length time and the asteroid time-slice is the same as the planet time-slice.
locIDAstRecord	int	4	16	location of the first record used for the asteroid numbers.
numIDAstRecord	int	4	20	number of records used for the asteroid numbers
locGMAstRecord	int	4	24	location of the first record used for the value of the GM of the asteroids .
numGMAstRecord	int	4	28	number of records used for the value of the GM of the asteroids
locCoeffPtrAstRecord	int	4	32	location of the first record used for the location, number of coefficients and number of granules for the asteroids
numCoeffPtrAstRecord	int	4	36	number of records used for location, number of coefficients and number of granules for the asteroids
locCoeffAstRecord	int	4	40	location of the first record used for the asteroids' coefficients.
numCoeffAstRecord	int	4	44	number of records used for the asteroids' coefficients over one time-slice.

Table 5: description of the asteroid record information if *((FORMAT/100) mod 10) = 1.* This data structure is aligned on the size of the fields.