

Specifications for the Solar System ephemeris delivery from IMCCE to DPAC

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Abstract

Detailed specifications related to the content and format for the delivery of the Solar System ephemeris from IMCCE to DPAC.

Document History

Issue	Revision	Date	Author	Comment
3	0	2012-04-12	FM	Final editing after discussions during REMAT 10 held on 30/03/2012. Document issued
3	D	2012-02-22	FM	Change for the Moon (BCRS origin). Further comments from S. Klioner and U. Lammers
2	0	2011-10-25	FM	Comments from S. Klioner and U. Lammers included. Document issued
2	D	2011-09-26	FM	Preparation of a New issue for the final delivery
1	0	2006-10-12	FM	First release
1	D	2006-10-03	FM	Initial version

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1 Object of the note

The processing of the Gaia observations requires *a priori* knowledge of the position and velocity vectors of the spacecraft with respect to the barycentre of the solar system, in order to correct the sources (stars or planets) apparent positions for the aberration, but also to determine the stellar parallax with the proper scale-length. Likewise, the computation of the deflection of light by the Sun, the major planets and possibly few satellites cannot be done without a rather accurate knowledge of the distance and angular position of the planets. Finally the observations of solar system objects place severe constraints on the knowledge of the positions of Gaia to determine the orbital elements and also to supply observed positions referred to the centre of the Earth without accuracy loss. The dynamical modelling requires also accurate solar system ephemeris to compute the gravitational forces acting on the asteroids.

The data processing baseline assumes that these elements will be available as auxiliary data and accessible in a unique and very uniform way by all the CUs through the CU1-provided GaiaTools library.

The accuracy requirements have been discussed in [1], [2] and recently updated in [3, 4] taking into account the target astrometric accuracy of the latest instrument design. The latter document is the reference version as far accuracy requirements are concerned. The requirements have been established so that the remaining uncertainty coming from the computation of the position and velocity of the spacecraft or of the planets has a negligible impact on the accuracy budget. A safety margin of one order of magnitude has been applied in the requirement assessment.

Regarding the solar system ephemeris the requirements are :

1. Velocity of the Earth in the BCRS to 2.5 $\mathrm{mm\,s^{-1}}$ for each component (1-σ error) and no systematic error over the mission length larger than 1 $\mathrm{mm\,s^{-1}}$,
2. Position of the Earth in the BCRS to 0.15 km over each component(1-σ error).

and it is highly desirable to have the position of the other planets in the $\sim 2-5$ km range. With the exclusion of the Earth the velocity of the planets is not critical and could be taken in the 0.1 - 1 $\mathrm{m\,s^{-1}}$ range. A good ephemeris of the Moon is also required for dynamical modelling.

It is known that not every planet (e.g. Jupiter) can be provided to that accuracy and in this case the delivery must include the state of the art accuracy. More generally, since it is in practice quite difficult to assess the external accuracy of an ephemeris, the delivery must come with an

estimation of its accuracy based on the post-fit residuals and the error propagation during Gaia operation. This will be up to the DP groups to take the necessary actions during the processing to deal with the observations affected by a planet in the most appropriate way.

The aim of this note is to set the final specifications regarding the reference frame, the timescale, the data format exchange with the provider (IMCCE), the test files and the schedule for the different deliveries.

The Ephemeris referred to in this note are meant for the DPAC use in the data processing of the Gaia observations. There are totally independent of another on-going action aiming at providing ephemeris of European origin for the research and operational activities at ESOC. Preliminary tests have been made (successfully with IMCCE) to use this alternative primary source with a set of data specially prepared and sharing the same format as JPL's. A wider and joint action is under way and involves representatives from Belgium, France and Italy. Obviously for the purpose of having a full consistency in the Gaia data it would be better if IMCCE planetary theories and ephemeris could be used to process the Gaia tracking data at ESOC when Gaia flies and this remains an objective, not covered by the Ephemeris delivery to DPAC.

2 Specifications and interfaces

2.1 General specifications

SE-SPEC 1 The ephemeris will be provided in the form of interpolating Chebyshev coefficients to allow the computation of the position and velocity of a set of solar system bodies over a specified interval of time.

SE-SPEC 2 The Chebyshev polynomials shall be continuous at each boundary of the selected time intervals, in which the interpolation is carried out.

SE-SPEC 3 The bodies to be included in the ephemeris delivery are the Sun, Mercury, Venus, Earth, the Moon, EMB, Mars, Jupiter, Saturn, Uranus and Neptune.
Mercury will never be in the Gaia field of view, but these ephemeris are needed for the numerical integration of the motion of minor planets or investigations on relativistic timescales. In fact all the major planets and the Moon are required for this purpose.

SE-SPEC 4 Target External accuracy: DPAC expects to receive the state-of-the-art ephemeris from the INPOP group, but at least one should have

1. Velocity of the Earth in the BCRS to 2.5 $\mathrm{mm\,s^{-1}}$ for each component (1-σ error) and no systematic error over the mission length larger than 1 $\mathrm{mm\,s^{-1}}$,
2. Position of the Earth in the BCRS to 0.15 km over each component(1-σ error).

The documentation shall include an accuracy assessment for each body over the period of validity requested by the DPAC.

2.2 Units and frames

SE-SPEC 5 The ephemeris will be built with the TCB (Barycentric Coordinate time) as independent time variable.

SE-SPEC 6 The unit of time to access the ephemeris shall be julian days in TCB.

SE-SPEC 7 An ephemeris for the transformation between TDB and TT shall be given also with a Chebyshev representation for DT = TT - TDB. The accuracy shall correspond to the state of the art.

SE-SPEC 8 The position and velocity vectors of the planets and the EMB shall be given in the BCRS as defined by the IAU resolutions (Resolution A4, IAU 1991 and Resolution B1, IAU 2000) and with the current realisation (as of 2011) of the ICRS by the ICRF-2. Same orientation and origin from all the bodies.

SE-SPEC 9 The position and velocity vectors of the Moon shall be geocentric with axies aligned to BCRS.

SE-SPEC 10 The boundaries of the Chebyshev sub-intervals for the barycentric Earth and geocentric Moon shall be identical.

SE-SPEC 11 The unit of length shall be SI m everywhere and the velocities will be given in SI $\mathrm{m\,s^{-1}}$.

SE-SPEC 12 The astronomical (e.g. planetary masses) and physical constants used to construct the ephemeris should be given in the documentation.

2.3 Period of validity

SE-SPEC 13 The ephemeris should be valid for a period covering the preparation of the mission, the operational period including the one year extension, with a margin to allow for a possible launch slip. This period is called hereafter validity timespan.

First date of validity: JD 2452500 (13/08/2002 12h TCB)

Last date of validity: JD 2459500 (12/10/2021 12h TCB)

This can be adapted around the lower or/and upper boundaries to fit an integral number of Chebyshev sub-intervals with the provision that the final range overlaps this reference on both side. The starting date has been selected so as to maintain backward compatibility with the existing version of DPAC software that may have access to the ephemeris as early as 2003.

SE-SPEC 14 The period of validity of each Chebyshev sub-interval of a given body will be constant over the validity timespan. It may vary from body to body or for a given body between position and velocity.

2.4 Arrangement and format

SE-SPEC 15 The ephemeris of each body is provided as a set of Chebyshev coefficients with a common layout.

SE-SPEC 16 The format should be the current INPOP exchange format in ASCII as described in the INPOP webpages. Size of the sub-intervals and degrees are not constrained (see however Sect. 2.3), provided the required accuracy is achieved by the selected parameters.

2.5 Delivery

SE-SPEC 17 The delivery will consist of :

1. the data files in ASCII (two per body : position, velocity), 11 bodies.
2. the data files in ASCII with similar organisation for the TT-TDB transformation.
3. A documentation summarising the modelling and main assumptions and describing the content, expected accuracy and format.
4. Samples of test results for every file (time, x, y, z or v_x, v_y, v_z for the planets, the Moon and one for the TT-TDB transformation) with at least 500 epochs selected in the validity timespan.

SE-SPEC 18 The delivery is expected by **15th October 2012**, so that it can be received, tested and implemented before launch and the start of the commissioning without rush. This delivery date leaves also the possibility of an iteration in case of problems.

The current baseline is to keep this version all the way through the data processing, but without excluding that the very last iterations could take advantage of running with the best version of the ephemeris available at that time. Should this plan materialise, contacts will be done in due time. At the moment there is no scheduled further release of INPOP for the DPAC.

References

[1] F. Mignard. Ephemeris requirements for Gaia. Technical report, Observatoire de la Côte D'Azur, June 1998. SAG_FM_004.

[2] S. Klioner. Requirements on the accuracy of Gaia orbit determination from the relativistic light deflection effects. Technical report, Lohrmann Observatory, Dresden, April 2003. Technical note on Livelink.

[3] F. Mignard. Ephemeris requirements for Gaia. Technical report, Observatoire de la Côte D'Azur, September 2005. GAIA_FM_023.

[4] M. Perryman. Specifications for absolute time and orbital ephemeris for ESOC. Technical report, ESA/ESTEC, December 2005. GAIA-CA-TN-ESA-MP-012-2.